Rainfall Recovery in North-East Arid Zone of Nigeria: Comparative Analysis of Drought and Post Drought Decades

Ahmed Abubakar Jajere[1*], Adam Modu Abbas[1] and Ali Abdu[1]

[1]Department of Geography, Federal University of Kashere, Gombe State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

This study used annual rainfall records from three stations within the North East Arid Zone of Nigeria for the period (1957-2017) to measure the extent of the rainfall recovery by comparing the drought decades and post drought decades rainfall patterns. Monthly rainfall records from Potiskum, Maiduguri and Nguru Stations were used. Descriptive and inferential statistical tools were employed in analysing the data. The findings of the study revealed a significant year-to-year variability in rainfall characteristics around 61 years (1957-2017) averages. The variability was large in 1970s up till 1990s, and lower in 1960s and from 2000 to 2018. Decreasing trend in annual rainfall amount was observed during the study period while a stability in onset and cessation dates were observed. The differences between 1957-1986 and 1987-2017 climatic season were found to be statistically insignificant. The study concluded that the reported rainfall recovery from drought is statistically insignificant and the observed long term mean trend revealed a decreasing trend. Therefore, the theory of Sahel rainfall recovery can be better termed as a ''break of the series of drought or decline in frequency and magnitude of occurrence of drought'' The research recommended the continuations with the drought adaptation and mitigation strategies adopted by local population, decisions makers and organizations following the series Sahelian droughts of 1970s and 1980s.

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Corresponding author: E-mail: ahmedabubakarjajere@yahoo.com;

1. INTRODUCTION

West African Sahel is one the most ecologically vulnerable regions of the world. Since 17th century paleoclimatic evidence reveals that West African Sahel has been experiencing series of historical drought, the 20th century series of Sahelian drought started in the 1910s, the 1940s, 1960s and reached its peak in 1970s, especially in the 1971,1972,1973 and 1974, followed by 1980s with most recent in 2012. Partial recoveries were report between 1975-80 and 1990s. Sahelian droughts occur without leaving its imprint on environment and livelihood. This ecological zone is characterized by strong climatic variations and irregular rainfalls, which pose a serious threat to ecosystem and livelihood (Sahel and West African Club 2006).

Meteorological history of Sahel reveals that 20 years of severe drought was recorded within period of only 23 years (1970 to 1993). Similarly, rainfall decline of almost 20% was recorded in 1970s and 80s, with a resultant ecological degradation of over 80% of regional land [1]. IFAD [2] reported that, the long term decline in West African rainfall of almost 20-40%, between1931-1990 caused a southward shift of savannah ecological zones boundary of almost 25-35km. The climatic condition of West African Sahel has attracted the attention of scientific research, inspired by series of drought since 1950s. The decadal drought reached its peak in 1970s and 80s. The series of droughts left its foot prints on ecosystem components and people's livelihoods. Rainfall recovery was reported in several empirical studies, suggesting the Sahel rainfall pattern shift to wetter conditions, while other studies on African dry land ecosystem reported recovering from drought of 1970s and 1980s as against the mainstream paradigm of irreversible land degradation in Sahel. The greening scenario is reported in number of studies [3, 4], Husai et-al 2014; [5, 6; 7, 8, 9; 10,11, 23]. They reported a surprising increase in Normalize Differentials Vegetation Index (NDVI) result in West African Sahel between 1982 and 2008 as against the orthodox view of progressive degradation, most of the studies attributed the greening to increase rainfall after 1980s drought, using almost similar methodology. This study used annual rainfall records from three stations within the Sahel for the period (1957-2017) to measure the extent of the rainfall recovery by comparing the drought decades and post drought decades rainfall pattern.

2. STUDY AREA AND METHODOLOGY

2.1 Study Area

2.1.1 Location

The North-east arid zone of Nigeria occupies limited area west of Lake Chad and covers North-eastern parts of Borno and Yobe States. It lies between latitudes 12º00" and 14º00' north of the Equator and longitudes 10º00' and 14º00" east of the Greenwich Meridian. (Fig. 1). The region supports some 11 million people (FAO, 2004). The area is bounded by Jigawa state to the west, Bauchi state to the south west, Borno state and Niger republic to the north.

2.1.2 Climate

The climate of North East Arid Zone of Nigeria is a Sahelo-sudanian, with definite wet and dry seasons, with an average annual rainfall of between 300 to 600 mm. The rainfall pattern within the ecological zone follows the ITCZ (inter-tropical convergent zone) movement pattern, as rainfall decrease in amount and durations northeast ward. The ecological zone records three (3) distinct temperature seasons namely; cold dry, hot-dry and warm moist season [12].

2.2 Methodology

2.2.1 Data used and sources

Six (6) decades' rainfall records of Nguru, Potiskum and Maiduguri weather stations were obtained from Maiduguri International Airport and North East Arid Zone Development Programme (NEAZDP) office, Gashua. Data containing monthly rainfall records of the three selected stations were used in calculating the mean monthly and annual rainfalls for the stations.

2.2.2 Method of data analysis

Descriptive statistical tools such as mean, maximum, minimum, skewedness, coefficients of variance, standard deviation and Kurtosis were employed in analyzing temporal trend distribution pattern of the stations' rainfalls during the study period. Linear regression, inferential statistics
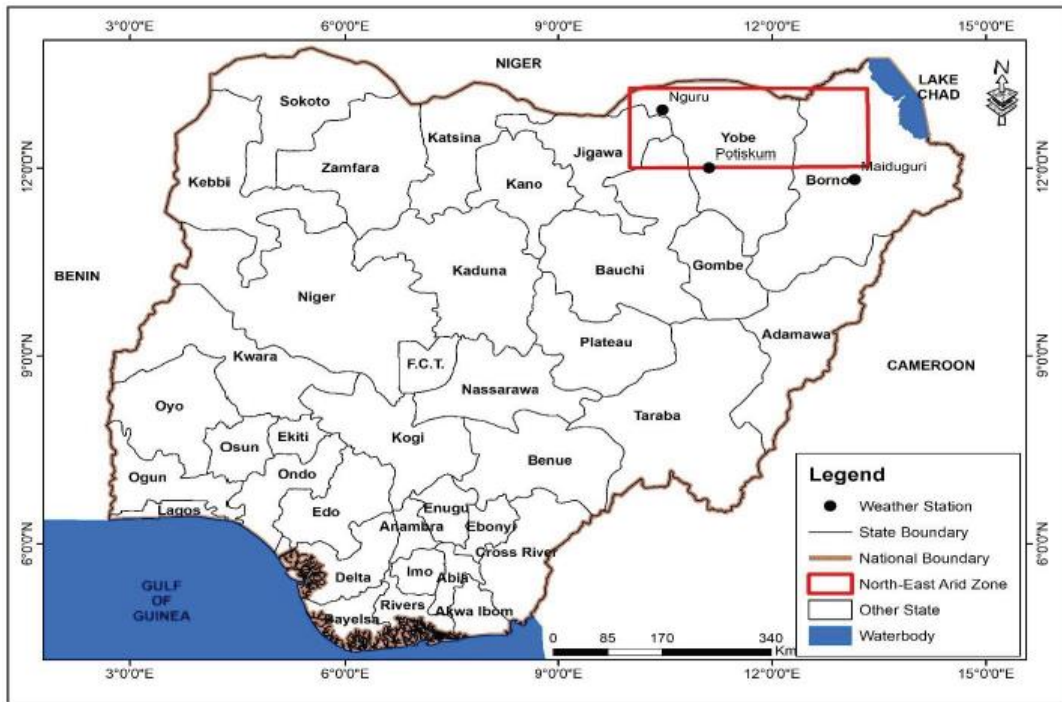
Fig. 1. Map of the Study area
Source: Adapted and Modified from North East Arid Zone Development Programme (NEAZDP 1990).

were also used in analyzing temporal variability trend patterns of rainfall attributes.

2.2.2.1 Rainfall Characteristics Variability Trend

Linear regression

$$Y_t = f(T)$$

Where Y_t = annual rainfall and SPI of the station

T = time

Explicit for

$$Y_t = \lambda_o + \lambda_1 T$$

2.2.2.2 The extend of rainfall recovery

The extent of rainfall recovery was estimated by comparing the mean of the drought decades and post drought decades rainfall characteristics. Drought decades = 1957-1986

Post drought decades = 1987-2017

PDD-DC= RC Where
PDD = Post drought decades
DD = Drought decades

RC= Rainfall recovery

3. RESULTS/FINDINGS

3.1 Rainfall Variability Pattern of Potiskum (1957-2017)

The results of descriptive statistics of Potiskum monthly rainfall (1957-2017) are presented in Table 1, while results of decadal standardized precipitation index and annual rainfall variability trend is presented in Table 2 and Fig. 2.

The results of analysis presented on Table 1 revealed that there is significant year-to-year variability in rainfall characteristics around these 61 years (1957-2017) averages. The variability in rainfall attributes was large in 1970s up till 1990s and lower in 1960s and between 2000 and 2018, as in Fig. 2. The total annual rainfall and length of growing session has large variability with a standard deviation of 163.4 mm from the average of 674.8mm and 23 days from the average 99 days respectively. The coefficient of variance results reveals that the variability of 24.2%, 0.1%, 23% and 0.2% in annual rainfall, Onset date, Cession date and Length of the growing session respectively.

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Table 1. Potiskum Monthly Rainfall Descriptive Statistics (1957-2017)

Mean		Max	Min	Stdv	C.V	Kurt	Skwn	Count >51mm/ X̧	Count %
APR (mm)	8.4	53.1	0	13.11	156	2.4	1.8	1	1.6
MAY(mm)	36.6	155.9	0	35.1	95.9	2.4	1.5	16	26.2
JUN(mm)	84.4	223.5	2.8	48.8	57.8	0.3	0.8	44	72.1
JUL (mm)	189.8	383.3	30.1	67.7	35.7	0.9	0.7	60	98.4
AUG(mm)	233.9	535	29	93.6	40.02	1.5	0.7	59	96.7
SEP (mm)	109.3	209.5	3.3	53.9	49.3	-0.6	-0.2	51	83.6
OCT (mm)	22.4	91.6	0	5.3	507.3	28.1	-	0	0
ARF (mm)	674.8	1020.5	336.9	163.4	24.2	-0.2	0.24	27	44.3
Onset date)	13-Jun	11-Jul	1-May	18.4	0.04	-	-	-	-
Cess (date)	19-Sep	22Oct	20Aug	-	-	-	-	-	-
LGS (days)	98.8	143	47	22.6	22.9	-	-	-	-

On monthly basis, the onset and cessation months of June and September show large variability with a standard deviation of 59mm from the average of 49.3mm and standard deviation of 49 mm from the average of 54mm respectively. The total annual rainfall and length of the growing session, fluctuate between the maximum of 1020.5mm to minimum of 336.9mm and maximum of 99 days to minimum of 47 days respectively.

On monthly basis the station records precipitation from March to November thus the threshold of 51mm was recorded from April to October within the study period. None of the rainy month records 100% 51mm monthly rainfall threshold account during the study period. The Month of August which records the peak of season shows a dramatic variability trend with maximum of 535mm and minimum of 29mm which is below 51mm threshold with a variance coefficient of 40.02%.

Therefore, July rainfall shows high level of stability with a variance coefficient of 35.7%. As it can be seen in Fig. 2 the station records, nine rainy months with only six months with rainfall threshold of 51mm.
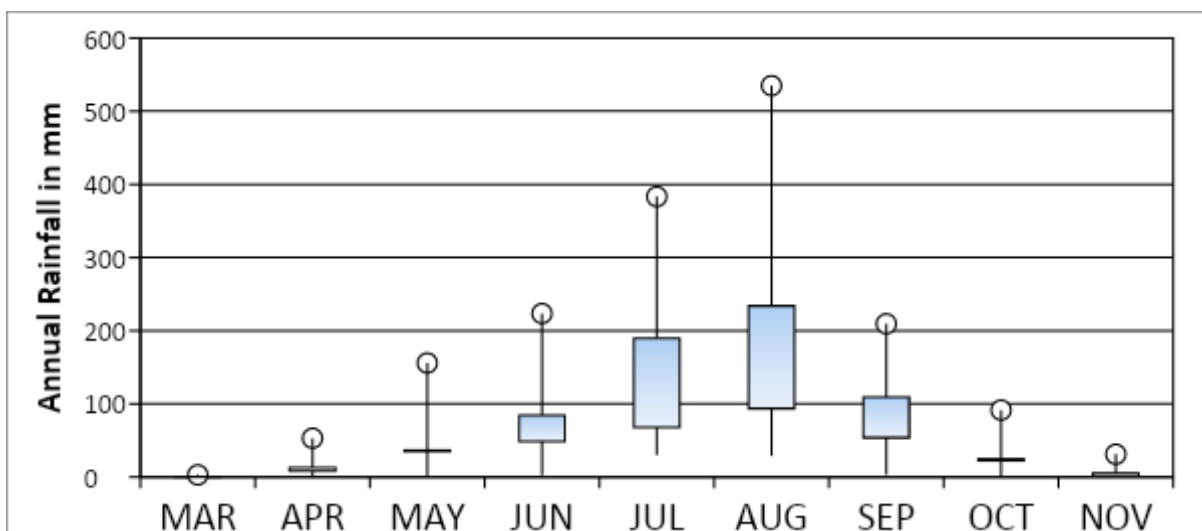

Fig. 2. Potiskum station monthly rainfall statistics (1957-2017)
Source: Authors Analysis

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Table 2. Descriptive Summary of Potiskum Station SPI (1957-2017)

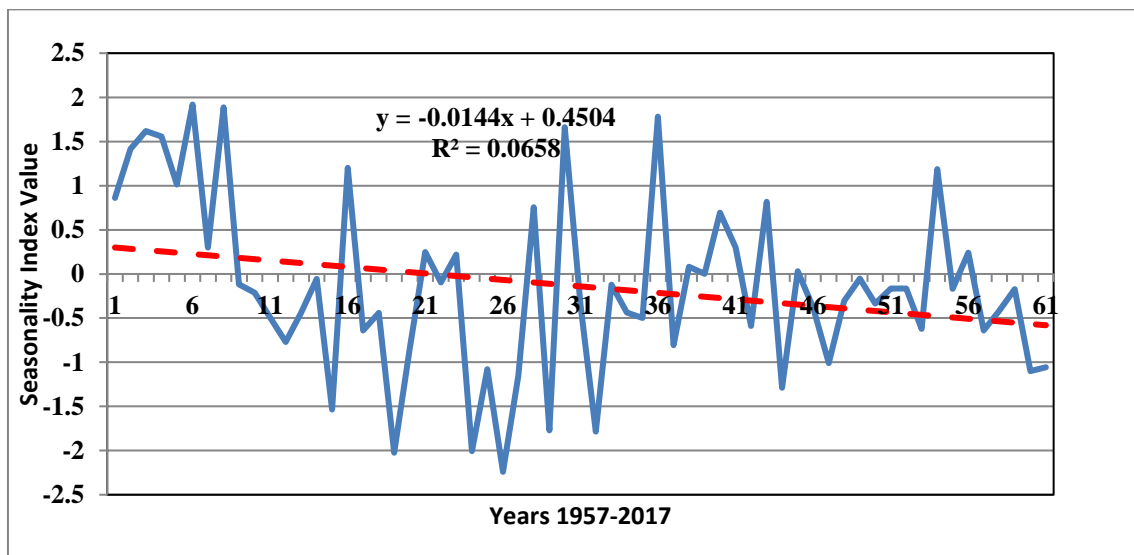| Drought Intensity	Categories	SPI Values	Number of Years	Percentage
Extremely wet		>2	2	3.3
Very wet		1.5 to 1.99	5	8.2
Moderately wet		1 to 1.50	3	5.0
Near normal		-0.99 to 0.99	43	70.5
Moderately drought		-1 to -1.49	2	3.3
Severally drought		-1.5 to -1.99	4	6.6
Extremely drought		-2<	2	3.3
TOTAL			**61**	**100**

$$y = -0.0144x + 0.4504$$
$$R^2 = 0.0658$$

Fig. 3. Potiskum station seasonality index variability trend (1957-2017)
Source: Authors Analysis

Table 3. Potiskum station climatic season rainfall shift

	1957-1986	1987-2016	Change
Annual Rainfall (mm)	737.4	664.4	-72.9
Onset date	13-June	11-June	2
Cessation date	22-September	18-September	-6
LGS	108.23	98.3	-9.93

The results of seasonality index trend analysis presented in Fig. 3, revealed a general decreasing trend during two climatic study periods despite rainfall recovery in 2000s. Thus, the variability is statistically insignificant at 0.1 R2 value. The trend line cross negative in 1970s (Sahelian drought of 1972-1974).

The results of the Potiskum station climatic sessions mean rainfall attributes changes in Table 6 revealed a negative shift trend in annual rainfall, and length of the growing session by 73mm and 10 days respectively. While, onset date and cessation dates recorded positive change by 2 and 6 days respectively. The significant decrease in annual rainfall was observed despite the severe droughts records 1972 to1974 and 1982 to 1983, the 1957-1986 climatic session recorded wetter session on average. The annual rainfall linear trend revealed a general decreasing trend of 2.3mm annually, with variability coefficient of 10% despite the reported rainfall recovery of the Sahel region. Generally shift to drier climate is observed, thus the rate is not statistically significant, a gradual manifestation of climate change is an evidence, from linear regression model result.
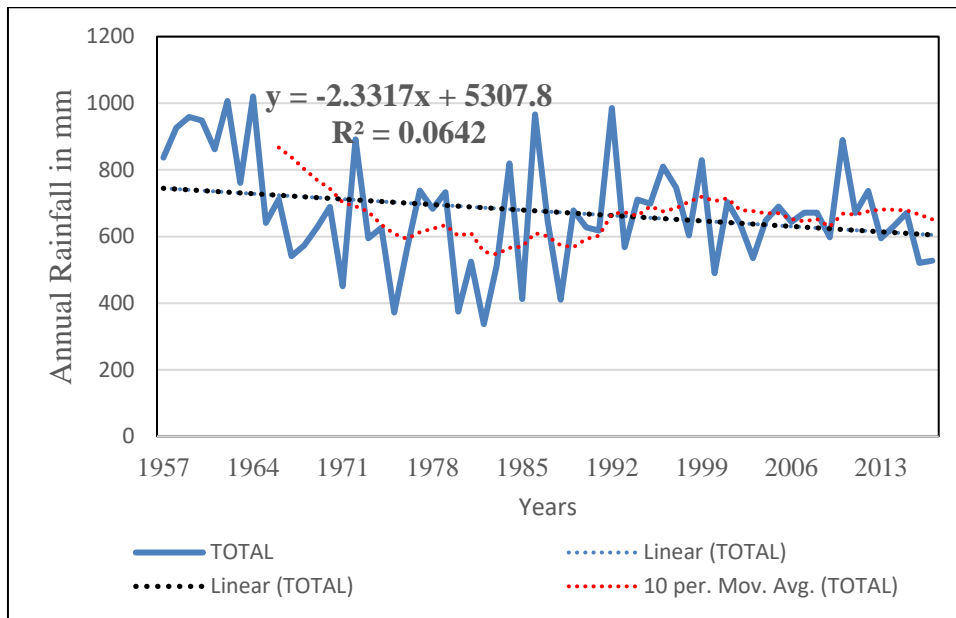
$y = -2.3317x + 5307.8$
$R^2 = 0.0642$

Fig. 4. Potiskum Station Annual Rainfall Variability Trend (1957-2017)
Source: Authors Analysis

$y = -0.0806x + 44096$
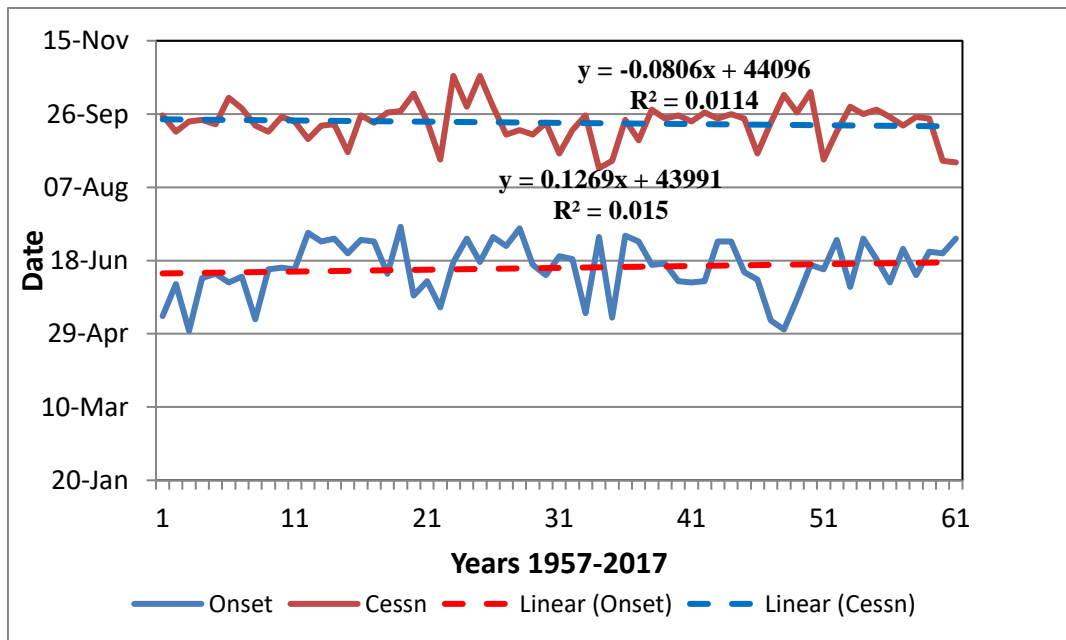$R^2 = 0.0114$

$y = 0.1269x + 43991$
$R^2 = 0.015$

Fig. 4. Potiskum Station Onset and Cession date Variability Trend (1957-2017)
Source: Authors Analysis

5.1.1 Rainfall variability pattern of Maiduguri (1957-2017)

The results of descriptive statistics of Maiduguri monthly rainfall (1957-2017) are presented in Table 4 and Fig. 4. While results of decadal standardize precipitation index and annual rainfall variability trend is presented in Table 5 and Fig. 5.The results of analysis presented on Table 3 revealed that there is significant year-to-year variability in rainfall characteristics around these 61 years (1957-2017) averages. The variability in rainfall attributes was large in 1970s up till 1990s and lower in 1960s and between 2000 and 2018, as in Fig. 2. The total annual rainfall and length of growing session has large

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variability with a standard deviation of 146.3 mm from the average of 600.4mm and 21 days from the average 95 days respectively. The coefficient of variance results reveals that the variability of 24.4%, 0.1%, 22.4% and 0.04% in annual rainfall, Onset date, Cession date and Length of the growing session respectively.

On monthly basis, the onset and cessation months of June and September show large variability with a standard deviation of 54.1 mm from the average of 77.5mm and standard deviation of 54.2 mm from the average of 102.1mm respectively. The total annual rainfall and length of the growing session fluctuate between the maximum of 925.7mm to minimum of 263.5mm and maximum of 94.8 days to minimum of 51 days respectively. On monthly basis the station records precipitation from March to November thus the threshold of 51mm was recorded from April to October within the study period. 100% monthly threshold was recorded in the month of August during the two climatic calendars. The Month of August which records the peak of season shows a dramatic variability trend with maximum of 462.8mm and minimum of 67.3mm which is below 51mm threshold with a variance coefficient of 36.8%. As it can be seen in Fig. 2 the station records, nine rainy months with only four months with rainfall threshold of 51mm.

Table 4. Maiduguri Monthly Rainfall Descriptive Statistics (1957-2017)

|	Mea n	Max	Min	Stdv	C.V	Kurt	Skwn	Count	Count %
APR (mm)	8.7	60.9	0	15.8	180.2	4.9	2.4	4	6.6
MAY (mm)	28.5	85.5	0	23.2	81.6	-0.2	0.7	11	18.0
JUN (mm)	77.5	371.6	8.5	54.1	69.8	13.6	2.7	41	67.2
JUL (mm)	166.9	342.7	39.3	69.12	41.42	-0.17	0.52	60	98.36
AUG (mm)	203.4	462.8	67.3	74.9	36.8	1.42	0.74	61	100
SEP (mm)	102.1	231.8	0.3	54.2	53.1	-0.11	0.58	52	85.2
OCT (mm)	13.1	81.7	0	20.7	158.4	3.05	1.86	5	8.2
An RF (mm)	600.4	925.7	263.5	146.3	24.4	-0.23	-0.02	35	57.38
Onset (date)	6-Jun	16-Jul	20Apr	21.1	0.05	-	-	-	-
Cess (date)	3-Sep	11Oct	1-Aug	17.3	0.04	-	-	-	-
LGS (days)	94.8	147	51	21.2	22.4	-	-	-	-
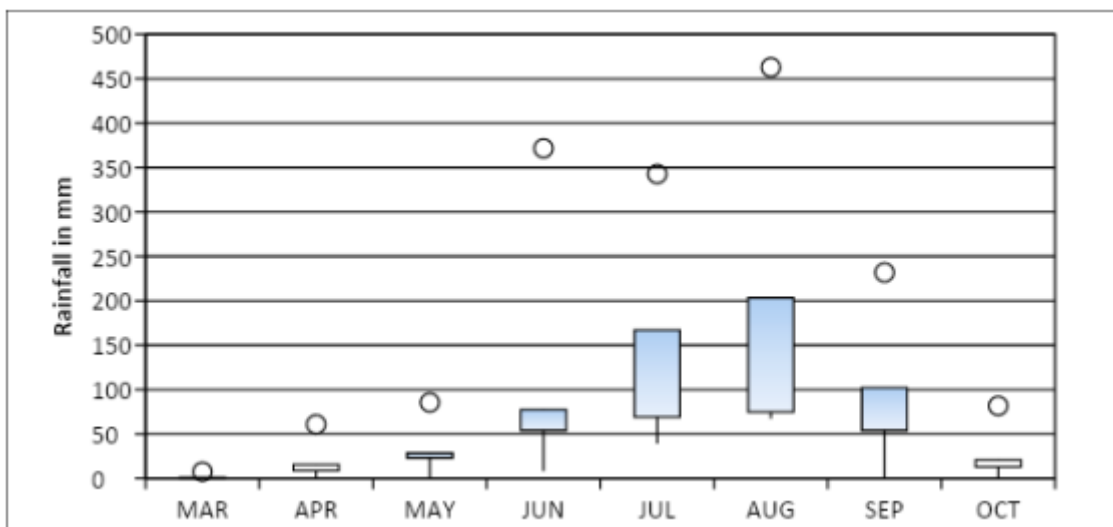
Fig. 5. Maiduguri Station Monthly rainfall statistics (1957-2017)
Source: Authors Analysis.

Table 5. Maiduguri Station climatic season rainfall shift

MEAN	1957-1986	1987-2017	Change
Annual Rainfall (mm)	597.2667	605.01667	7.75
Onset date	5-Jun	6-Jun	1
Cession date	5-Sep-20	31-Aug-20	-5
LGS (days)	96.3	93.5	-3

Table 6. Descriptive summary of Maiduguri station SPI (1957-2017)

Drought Intensity	Categories	SPI Values	Number of Years	Percentage
Extremely wet		>2	2	3.3
Very wet		1.5 to 1.99	3	4.9
Moderately wet		1 to 1.50	2	3.3
Near normal		-0.99 to 0.99	42	68.9
Moderately drought		-1 to -1.49	7	11.5
Severally drought		-1.5 to -1.99	4	6.6
Extremely drought		-2<	1	1.6
TOTAL			61	100

The results of the Maiduguri station climatic sessions mean rainfall attributes changes in Table 2 revealed an increase in annual rainfall and onset date by 7.75mm and 1day respectively and decrease in Cession date and length of the growing session by 5 and 3 days respectively changes between 1957-1986 and 1987-2017 climatic session.

Maiduguri station records 42 years of near normal wetness during the 61 years study period, with only seven (7) years of wetness and 12 years of dryness. Extreme wetness was recorded in 2005 and 2007. Very wet season recorded in 1959, 1967 and 1999, while moderate wetness were recorded in 1958 and 2004. Moderate drought was recorded in 1964, 1972, 1973, 1985, 1990, 1994 and 2003, while severe drought was recorded in 1971, 1982, 1984 and 1987. Extreme, drought during the 61 years period was only recorded in 1983. The findings of this study confirmed the findings of Usman, Abdulhamid, and Sawa [13] that reports shift toward wetter condition. Also similar study by Stephen and Tobi [14] in their study of 90 years rainfall distribution cross all climatic zones of Nigeria reported common change points and transitions from dry to wet (upward shift) in all climatic zones.

The results of seasonality index trend analysis presented in Fig. 5, revealed a statistically insignificant decreasing trend during two climatic period study period despite rainfall recovery in 2000s.

The annual rainfall variability trend shows an annual decreasing trend of 0.84mm which is statistically insignificant at 0.01 R2. The findings of the study contradict the projection of Peter (2012) who projects a rainfall declines until 2019 and from 2020, rainfall begins to increase until 2030.

During the study period the onset and cession dates are largely stable as revealed linear trend coefficient of 0.003 and 0.01, for cession and onset respectively. Statistically insignificant negative shift 0.1 day cession date was observed, this implies that within the 61 years study 6 days shift was observed. Similarly onset date also records a negative shift by 0.01 day was observed, i.e less than 1 day negative change in onset date.
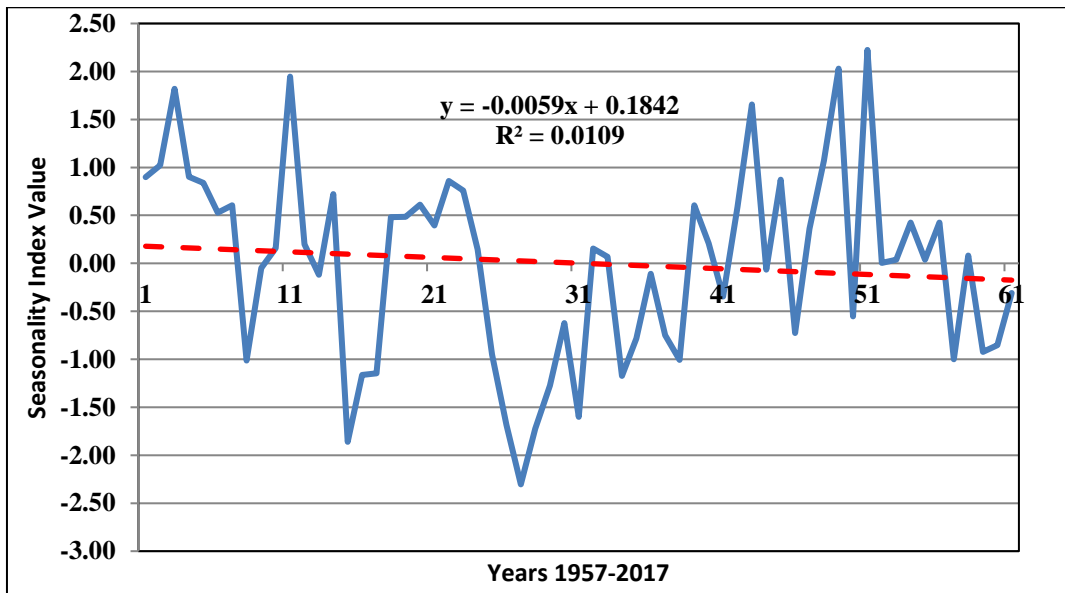
Fig. 6. Maiduguri Station Seasonality index Trend (1957-2017)
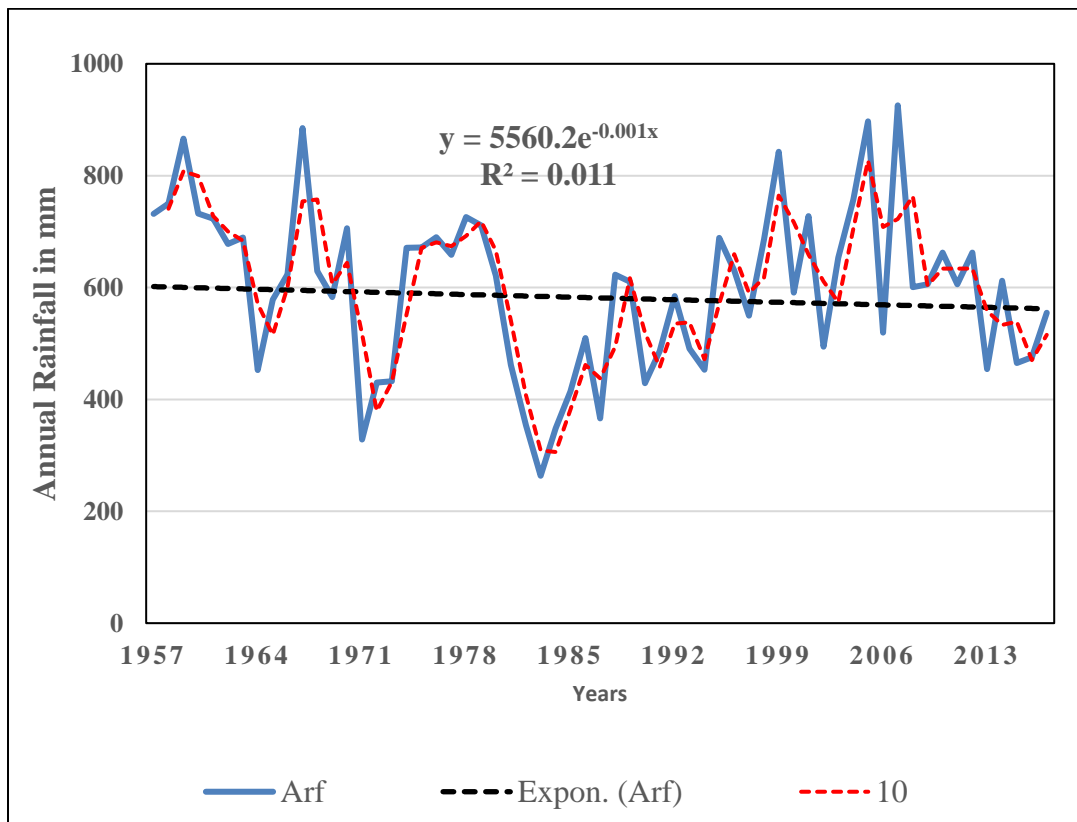*Source: Authors Analysis*

Fig. 7. Maiduguri Station Annual Rainfall Variability Trend (1957-2017)
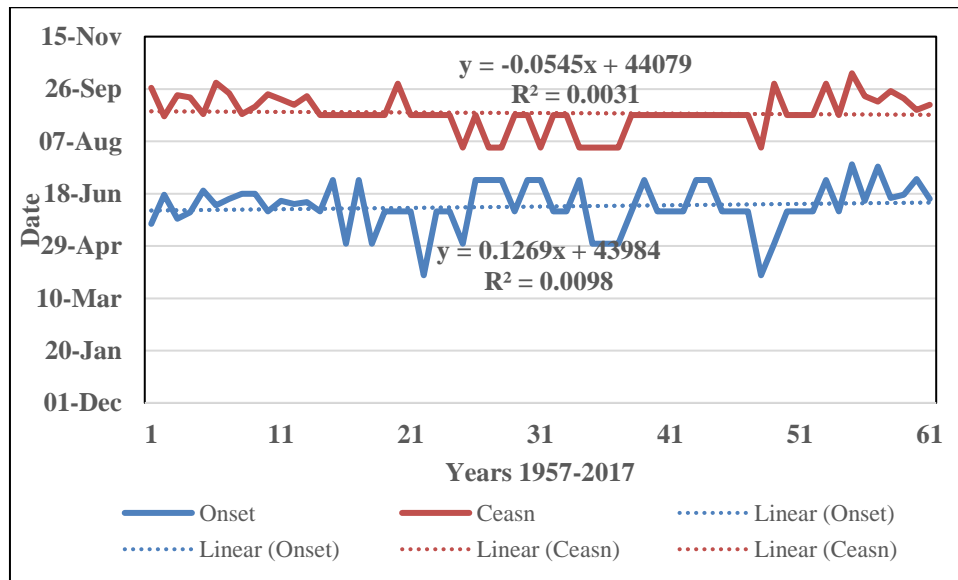*Source: Authors Analysis.*

Fig. 8. Maiduguri Station Onset and Cessation dates Variability Trend (1957-2017)
Source: Authors Analysis

Table 7. Nguru Station Monthly Rainfall Descriptive Statistics (1957-2017)

	Mean	Max	Min	Stdv	C.V	Kurt	Skwn	Count	Count %
APR (mm)	1.8	40	0	6.82	384.5	20.3	4.2	0	0
MAY(mm)	15.9	137	0	21.8	136.7	15.5	3.3	3	4.9
JUN (mm)	57.8	207	4	44.3	76.6	2.15	1.4	28	45.9
JUL (mm)	136.2	312.9	12.5	64.3	47.2	0.43	0.7	56	91.8
AUG (mm)	181.6	335	58	65.7	36.2	-0.17	0.5	61	100
SEP (mm)	67.6	185.4	4	36.7	54.3	0.94	0.7	40	65.6
OCT (mm)	8.1	86	0	13.4	165.3	19.4	3.74	1	1.64
An RF (mm)	469.1	755.1	235	121.8	25.95	-0.33	0.23	29	47.55
Onset (date)	16-Jun	5-Aug	11-May	14.9	0.03	-	-	-	-
Cession (date)	31Aug	12Oct	14-Aug	11.4	0.03	-	-	-	-
LGS (days)	75.6	137	23	20.6	27.2	-	-	-	-

The results of analysis presented on Table 7 revealed that there is significant year-to-year variability in rainfall characteristics around these 61 years (1957-2017) averages. The variability in rainfall attributes was large in 1970s up till 1990s and lower in 1960s and between 2000 and 2018, as in Fig. 8. The onset and cession months, monthly has large variability with a standard deviation of 43.3 mm and 64.3 from the average of 57.8mm and 136.2 mm for the month of June and July respectively. Also, the cession month of September also revealed a larger coefficient of variability of 54.3%. The coefficient of variance results reveals that the variability of 26%, 0.03%, 0.03% and 27.2% in annual rainfall, Onset date, Cession date and Length of the growing session respectively. This revealed that during the 61 years study period the onset date and cession dates are largely stable. The climatic variability and changes is more pronounce on monthly rainfall distribution and total annual rainfall.

The total annual rainfall and length of the growing session fluctuate between the maximum of 755.1mm to minimum of 235mm and maximum of 75.6 days to minimum of 23 days respectively. On monthly basis the station records precipitation from April to October thus the threshold of 51mm was recorded from May to October within the study period. 100% monthly threshold was recorded in the month of August during the two climatic calendars. The Month of August which records the peak of season shows a dramatic variability trend with maximum of 335mm and minimum of 58mm which is slightly 51mm threshold with a variance coefficient of

36.2%. As it can be seen in Fig. 2 the station records, seven rainy months with only five months with rainfall threshold of 51mm.

The results of the Nguru station climatic sessions mean rainfall attributes changes in Table 8 revealed an decreasing trend in annual rainfall, onset date, Cession date and Length of the growing session by 36, 5 days, 2 days and 6 days respectively and increase in Cession date and length of the growing session by 5 and 3 days respectively changes between 1957-1986 and 1987-2017 climatic session.
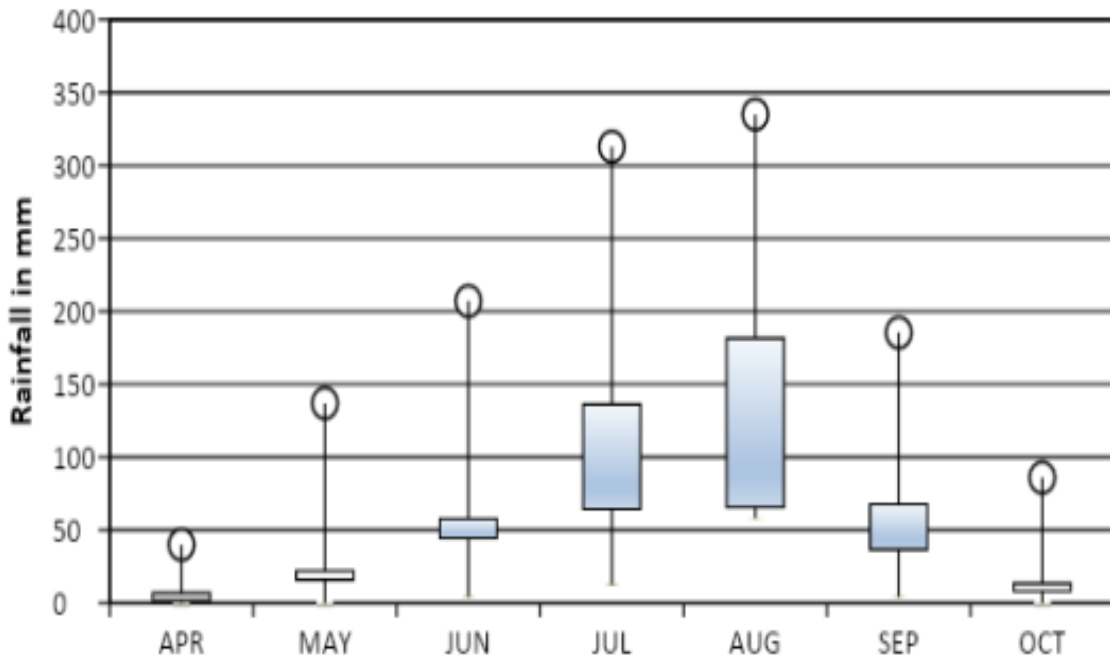

Fig. 9. Nguru Station monthly rainfall statistics (1957-2017)
Source: Authors Analysis

Table 8. Nguru Station rainfall climatic season shift

	1957-1986	1987-2016	Change
Annual Rain Fall	470.6	434.4767	-36.12333
Onset date	23-Jun	28-Jun	-5
Cession date	8-Sep	6-Sep	-2
Length Growing Session	77.03333	70.7	-6

Table 9. Descriptive Summary of Nguru Station SPI (1957-2017)

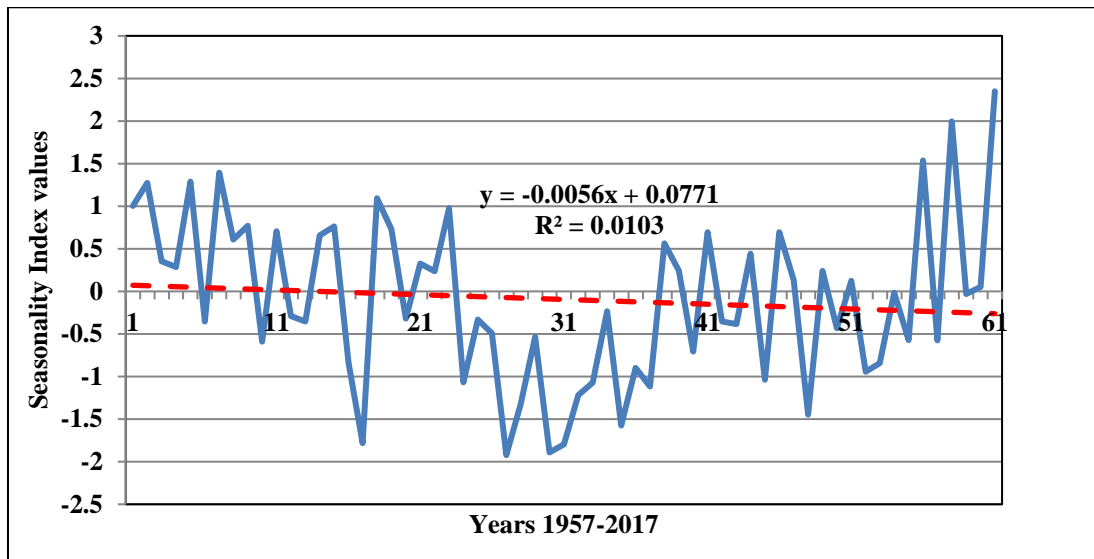| Drought Intensity	Categories	SPI Values	Number of Years	Percentage
Extremely wet		>2	1	1.6
Very wet		1.5 to 1.99	2	3.3
Moderately wet		1 to 1.50	5	8.2
Near normal		-0.99 to 0.99	41	67.2
Moderately drought		-1 to -1.49	7	11.5
Severally drought		-1.5 to -1.99	5	8.2
Extremely drought		-2<	0	0
TOTAL			**61**	**100**

Fig. 10. Nguru Station seasonality Index Variability Trend (1957-2017)
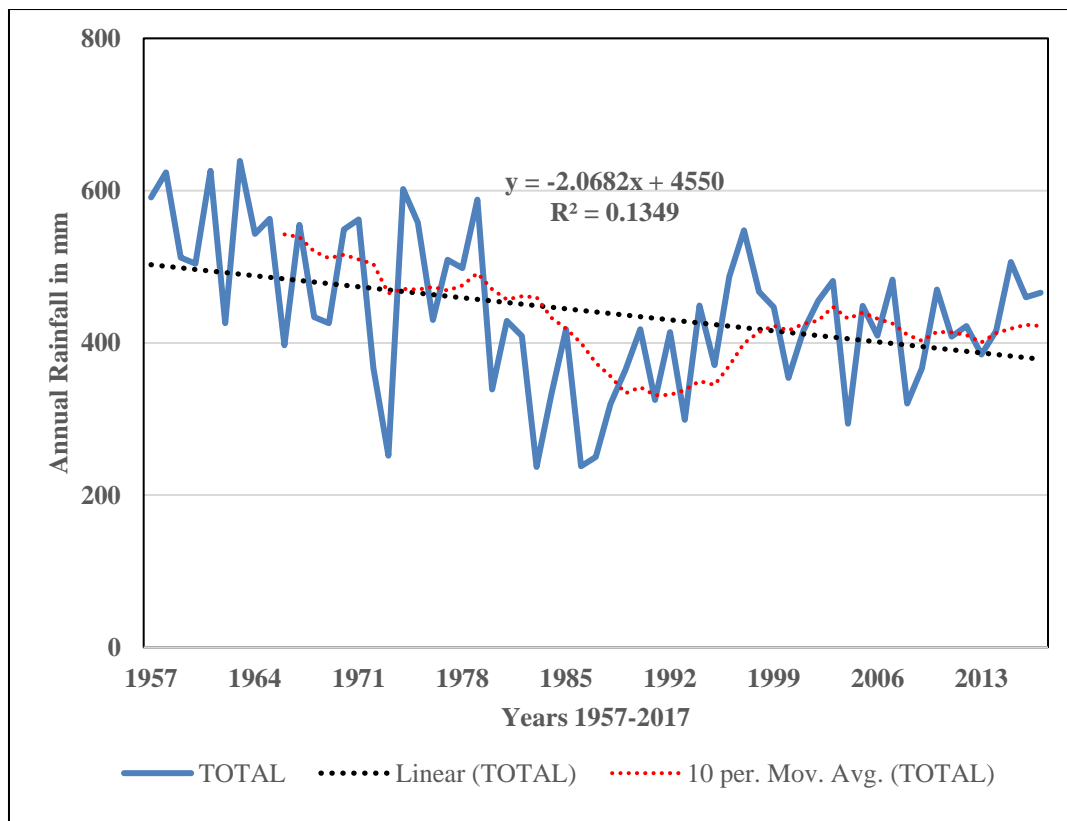*Source: Authors Analysis*

Fig. 11. Nguru Station Annual Rainfall Variability Trend (1957-2017)
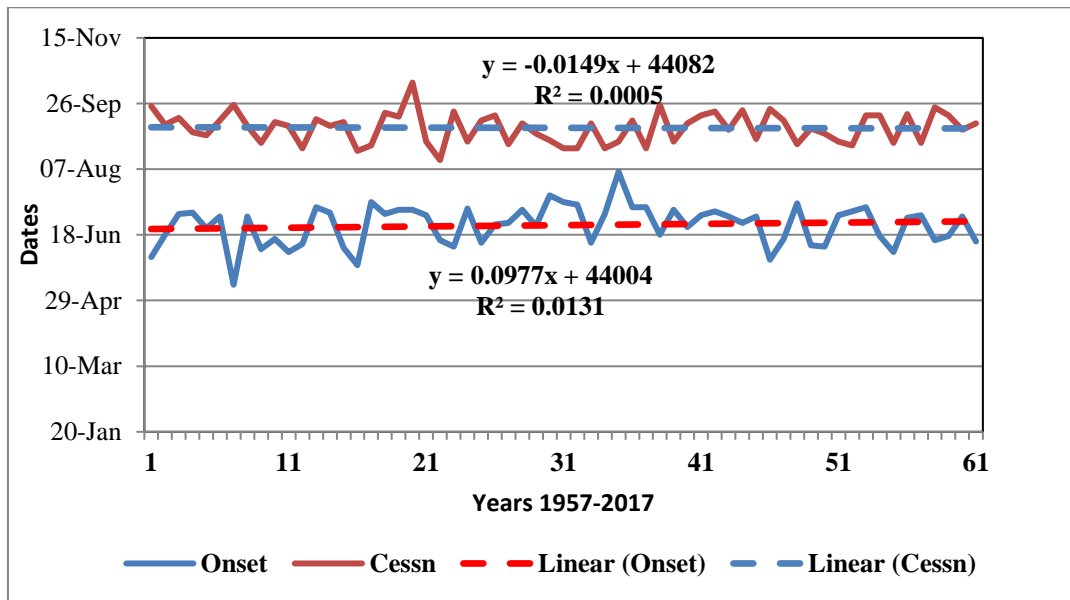*Source: Authors Analysis*

Fig. 12. Nguru Station Onset and Cession date Variability Trend (1957-2017)
Source: Authors Analysis.

Table 10. Paired Samples Test

	Paired differences					t	Df	Sig. (2-tailed)
	Mean	Std. Devn	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pot_ARF (57-86) - Pot_ARF(87-16)	25.7	249.9	45.6	-67.6	119.0	.56	29	.577
Pot_Onst(57-86) - Pot_Onst(87-16)	1.7	26.8	4.9	-8.34	11.7	.34	29	.736
Pot_Ces (57-86) - Pot_Ces(87-16)	4.0	16.2	2.95	-2.1	10.01	1.34	29	.190
Pot_LGS (57-86) - Pot_LGS(87-16)	2.6	33.2	6.1	-9.8	15.0	.429	29	.671
Pot_SI (57-86) – Pot_SI(87-16)	0.16	1.5	.28	-.41	.73	.582	29	.565
Md_ARF (57-86) - Md_ARF(87-16)	-7.8	207.02	37.8	-85.1	69.6	-.21	29	.839
Md_Onst (57-86) - Md_Onst(87-16)	-1.1	28.9	5.3	-11.9	9.7	-.21	29	.836
Md_Ces (57-86) - Md_Ces(87-16)	4.5	31.2	5.7	-7.2	16.1	.79	29	.439
Md_SI (57-86) – Md_SI(87-16)	-.05	1.4	.26	-.58	.48	-.19	29	.849
Ng_ARF (57-86)- Ng_ARF(87-16)	36.1	191.44	34.95	-35.4	107.6	1.03	29	.310
Ng_Onst (57-86) - Ng_Onst(87-16)	-5.17	23.34	4.3	-13.9	3.5	-1.2	29	.235
Ng_Cess (57-86) - Ng_Cess(87-16)	1.17	17.5	3.2	-5.4	7.7	.37	29	.717
Ng_LGS (57-86) - Ng_LGS(87-16)	6.3	32.7	5.97	-5.9	18.5	1.06	29	.298
Ng_SI (57-86) – Ng_SI(87-16)	.297	1.57	.29	-.29	.9	1.03	29	.310

The results of seasonality index trend analysis presented in Fig. 10, revealed a general decreasing trend during two climatic period study period despite rainfall recovery in 2000s. Thus, the variability is statistically insignificant at 0.01 R2 value. The trend line cross negative in 1970s (Sahelian drought of 1972-1974).

During the study period the onset and cessation dates are largely stable as revealed by linear trend coefficient of 0.001 and 0.01, for cessation and onset respectively. Statistically insignificant negative shift 0.01 day cessation date was observed. This implies that within the 61 years study, less than one day shift was observed. Similarly onset date also records a negative shift by 0.1 day was observed, i.e. a 6 days negative change in onset date.

The result of the T-test statistics presented in Table 10, revealed a statistically insignificant differences between the two climatic season rainfall attributes. The difference between 1957-1986 and 1987-2017 climatic seasons is statistically insignificant. Therefore, it can be concluded that the impact on global climate change pattern and on rainfall attributes in the study area is manifesting slowly as the impact is not significant.

4. DISCUSSION

The available scientific studies on West African Sahel rainfall reported a common shift towards wetter condition [15, 14, 13, 16, 12]. Alhough, Souleymane, Jerome, Abdramane and Ermert [17] in their study on Spatio-temporal characteristics of the recent rainfall recovery in West Africa, reported that the recovery is reflected in more rainy days associated with longer wet spell duration and more extreme rainfall events. Therefore, the rainfall recovery is largely the annual rainfall amount than other rainfall attributes that are important to agriculture, as confirmed by this study a negative shift in length of the growing season and negative shift in onset and cessation dates. While rainfall studies on the other dry land regions of the world reported a decline in rainfall amount during the same period. For instance, Hosny and Mansour (2015) reported a great inter-annual change in the rainfall over the Saudi Arabia for the period (1978–2009) and Timothy (2019) reported a decline in growing season in east of Western Australia. Also, Alka, John and Ali [18] reported that drought continues even with the above-

normal precipitation in dry land region of U.S.A. The studies that reported a rainfall recovery in West African Sahel ecological zone did not quantified the extent of the recovery. The results of this study however, revealed that the difference between the drought decades and post drought decades is statistically insignificant, as confirmed by mean trend results that showed a general decreasing trend. A similar study by Rashid, Shaofeng and Wenbin [19], reported a statistically significant rainfall decreasing trend of 1.5mm per annum. This may not be unconnected with the fact that their study period covered (1951-2015), which included two pre-drought decades. Nicholson, Andreas and Chris [20], in their study on West African rainfall recovery using 161 years rainfall records confirmed that the West African rainfall did not return to normal as against what was reported in studies that used mostly 30 years records. Therefore, using 31 years rainfall records (1980-2010) is not enough to establish the West African Sahel rainfall recovery. Therefore, what can be explored from the results of this study is that, the observed rainfall recovery by this study and several related studies are not up to pre-drought period rainfall pattern, as confirmed by Dong and Sutton [21] that although there has been some recovery of Sahel rainfall amounts since the 1980s, but not to the pre-drought levels of the 1940s and 1950s. Therefore, West African rainfall recovery theory, can better be termed as a ''break of the series of drought or decline in frequency and magnitude of occurrence of drought''.

5. IMPLICATION ON RESEARCH AND PRACTICE

The result of this study provides a blue print on rainfall recovery in North East Arid Zone of Nigeria. The series of droughts recorded in the study area between 1960s and 1980s altered the livelihoods options tied to climate, especially crop farming calendar. Therefore, the results of the study is a guide to agricultural planning, project and hydrological planning and research, instead of climatic seasons. Further research should focus on adaptation and mitigation strategies.

6. RECOMMENDATIONS

i. The drought mitigation and adaptation strategies adopted by local population, decision makers and organizations following the Sahelian drought of 1970s and 1980s, should be continued and

straightened, as reported rainfall recovery from the drought is insignificant.

ii. The findings of this study revealed a negative shift in length of the growing season. The agricultural extension workers and crop farmers in the study area should therefore adjust their crop farming calendar.

iii. Based on findings of this study, it is recommended that the agricultural planning, project and programs should be formulated on decadal basis, instead of climatic seasons.

iv. Water resources management planning should be more effective, as the manifestations of climate change is taking place slowly in the study area, since a decreasing trend in long term mean annual rainfall was observed.

7. CONCLUSSION

The findings of the study revealed a significant year-to-year variability in rainfall characteristics around 61 years (1957-2017) averages. The variability was large in 1970s up till 1990s, and lower in 1960s and from 2000 to 2018. Decreasing in trend in annual rainfall amount was observed during the study period while a stability in onset and cessation dates were observed. The difference in rainfall attributes between1957-1986 and 1987-2017 climatic season was statistically insignificant. Negative shift in mean annual rainfall by 36mm and 73mm and length of the growing season by 6 and 10 day was observed at Nguru and Potiskum stations respectively. This study concludes that the study area rainfall did not recover from the drought as reported by studies that examined 31 years rainfall records. The research recommended the continuations with the drought adaptation and mitigation strategies adopted by local population, decisions makers and organization following Sahelian drought of 1970s and 1980s.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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