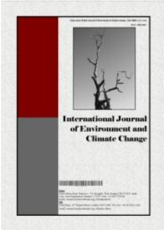

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Rainfall Variability and Trend Analysis Over Nguru Yobe State, Nigeria

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: This study aimed to analyze rainfall variation in a semi-arid environment by examining the annual precipitation over Nguru in Yobe, Nigeria for a period of 31 years (1975-2005).

Place and Duration of Study: The study was conducted in Nguru town, an arid environment in Yobe State of Nigeria using rainfall data from Nguru meteorological station from 1975-2005.

Methods: Coefficient of variability (CV) was used to evaluate rainfall variability over time in the area, and non-parametric Mann-Kendall and Sen's slope estimator were used to determine rainfall trend and its magnitude in the study area. The investigation was based on data collected over a 31-year period at a single site.

Results: The result indicates that the coefficient of variation CV for the annual rainfall in Nguru revealed a moderate inter annual variability (25%), whereas the CV for seasonal rainfall demonstrates that rainfall in the May June July monsoon period is highly variable between seasons (more than 40%). The CV for the August September October monsoon period, on the other hand, was 31.6%, indicating a considerable and high variability in total rainfall received.

Conclusion: The main conclusion of this study is that rainfall is highly variable over the years, posing a threat to climate change-induced drought and, as a result, affecting the socio-economic well-being of the people in the area, who are mostly peasant farmers who rely solely on agricultural activities for their livelihood.

Keywords: Rainfall trend; mann kendall test; sen's slope; coefficient of variability.

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1. INTRODUCTION

Climate is a long-term average of a location's meteorological conditions. It is the statistical description of key parameters' average and variability over timescales ranging from months to thousands or millions of years [1]. Rainfall, atmospheric pressure, temperature, and humidity are all factors that influence weather and climate. Extreme weather and climatic events have become more common in recent decades, raising serious worries about climate change. It has a negative impact on human activities, the economy, and the environment [2]. Climate variability is a difficult process that comprises the shift between variability and climate change [3]. Various regions are experiencing climate variability differently across the world, and Nigeria is not exceptional. The intergovernmental panel on climate change 5th assessment report stated that global temperature will rise continuously due to anthropogenic activities [1]. Therefore, this changing trend may likely increase hydrological extremes such as drought and flood.

Rainfall is a meteorological variable that has an impact on almost all human activities. For example, rainfall is a key determinant in calculating or quantifying the amount of water available to meet diverse demands such as agricultural, industrial, home water supply, and power generation. Rainfall availability or non-availability is typically used to assess the level of wetness or dryness during the growing season, making rainfall the single most important element of the climate system affecting any region's agricultural and water resource management [1,3].

The degree to which rainfall amount vary across an area or through time is an important characteristic of the climate of an area. This subject area in meteorology/climatology is called “rainfall variability”. There are two types of rainfall variability, areal and temporal. The study of the latter is important in understanding climate change. Temporal variability is the variation of rainfall amount at a given location across a time interval (area does not vary). Temporal variability of rainfall may be used both to characterize a climate and to deduce evidence of climate change [4]. Both temporal and areal variability of rainfall may be measured in various ways. The resulting numerical value can be used to characterize the climate of a region in various ways [4]. Therefore, coefficient of variation (CV) can be used to analyse annual rainfall variations of Nguru station. The CV of annual climate is an index of climatic risk, indicating a likelihood of fluctuations in reservoir storage or crop yield from year to year. Agriculturally it is, perhaps a more crucial statistics in marginal areas [5].

On a temporal and spatial basis, rainfall in Nigeria is very dynamic and changeable [6]. However, the recent occurrences of a dry spell in Northern Nigeria have heightened public worry that the region is experiencing a climate transition toward aridity [7]. In Nigeria, rainfall is seasonal, with a double maximum in the south and a single maximum in the north. The northern part has a savannah-like environment with wet and dry seasons. The annual rainfall in this region ranges from 1500 mm in the south to 400 mm in the north [8]. The rainy season in the southern part lasts around 7 months (April to October), but in the northern part it lasts only 3 to 4 months (Jun to September). Between July and August, the rainfall intensity is extremely high. As a result, even though the region is normally dry, crops are regularly lost due to excessive rainfall [9]. Therefore, studies of rainfall variation at the local and regional level give the antidote in battling the harmful impacts of droughts and crop failure, allowing the huge agricultural potentials and productivity in the Northern region to be completely harnessed and optimized [10].

Long-term trends of environmental climatic parameters must be assessed to understand the impact of climate variability on the environment [11]. Different methodologies were used to examine trends in time series data for a variety of societal issues, including socioeconomic, medical, and environmental issues. Hydro-climatic time series data are frequently characterized by data that is not normally distributed; in such time series, a non-parametric method of determining trend is typically used [11]. The non-parametric Mann-Kendall test, which is based on rank, is often used to evaluate the significance of trends in hydro-climatic time series. In addition to the original Mann-Kendall trend significance test, Sen provided a non-parametric estimator for determining trend magnitude [11].

In addition to the rainfall trend, it is critical to assess the inter-annual variability of rainfall, which has received little attention so far [12]. Inter-annual rainfall variability, in fact, is a measure of year-to-year fluctuation in cumulative rainfall occurrences that allows us to distinguish between years with abundant rainfall and years with little rainfall. The relative variability index was first introduced to quantify inter-annual rainfall variability, although the coefficient of variation (CV) has recently gained popularity [13].

The purpose of this work was to analyze rainfall variation in a semi-arid environment by examining the annual precipitation over Nguru in Yobe, Nigeria using rainfall data from 1975 to 2005. Coefficient of variability (CV) was used to evaluate rainfall variation over time in the area, and trend investigation on the rainfall data was carried out using non-parametric (Mann Kendalls and Sen's slope) tests.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area (Fig. 1) is a low-agricultural-potential marginal setting where smallholder rain-fed agriculture and livestock husbandry are the two main sources of income. For the years 1940 to 2005, the average annual rainfall and temperature in the area were 552mm and 30.5°C, respectively. The Intertropical Convergence Zone, which annually reaches its maximum northerly location above Nigeria in July or August and whose influence generates the distinct wet and dry seasons characteristic of Sub-Saharan West Africa, influences the climate of the region [14]. Nguru town is located in the north-eastern section of Nigeria, on latitude 12°5245N and longitude 10°2709E, on a floodplain of the Hadejia-Nguru marshes [11].

The rainy season begins in late May or early June, peaks in August, and ends in late September or early October. Low and irregular rainfall is common in the area, and drought-related harvest failure is common. Millet (*Pennisetum typhoides*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), cowpea, beniseed, and groundnuts are the main crops farmed (*Arachis hypogea*) [15]. The value and amount of labour invested in crop cultivation is usually larger than the volume and value of the harvest in most seasons. Furthermore, as a drought-prone region, the past 40 years have seen droughts of varying magnitude and intensity [15]. Smallholder farmers diversify their livelihoods to maintain food security and overall well-being under the tough conditions of farming in these drought-prone areas. Men and women both play important roles in the process of diversifying livelihoods to contribute to household food security [15].

2.2 Data

The study used monthly rainfall data collected from the Nigerian Meteorological Agency (NIMET) Nguru station for a period of thirty (31) years, from 1975 to 2005. The data were quality controlled and were examined for missing values and typing errors. For the rainfall variability and trend analysis, annual rainfall data were obtained from the monthly rainfall data.

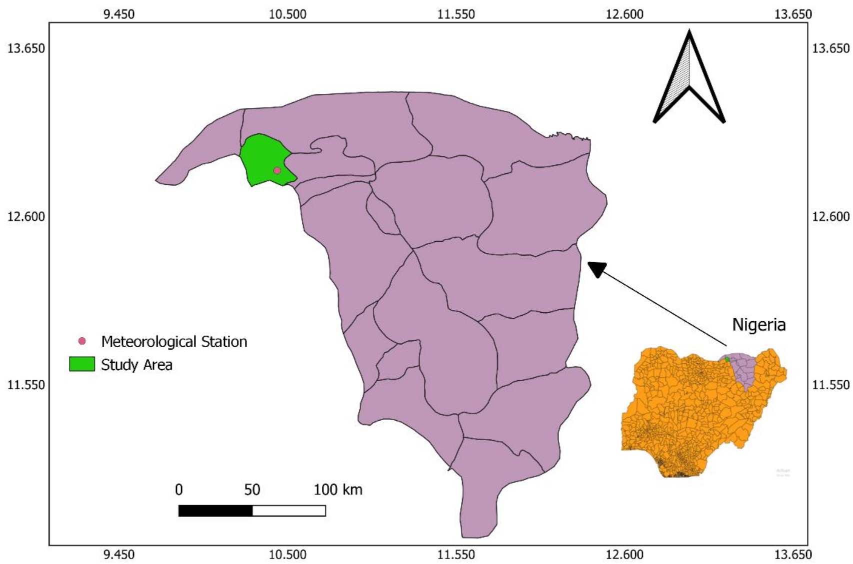

Fig. 1. Study area map

2.3 Analysis of Rainfall Variation

2.3.1 Coefficient of Variation (CV)

The coefficient of variation (CV), defined as the ratio of the standard deviation to the mean rainfall in each period, was used to determine the variability in rainfall for representative meteorological station. It computes or measures the deviation of individual data points from the mean value. A higher CV value indicates increased geographical variability, and vice versa. CV is used to classify the degree of variability as less (CV < 20%), moderate (20 < CV < 30%), high (CV >30%), very high (CV > 40%) and CV > 70% indicate extremely high inter-annual and seasonal variability of rainfall.

Coefficient of Variation Formula: CV= $\frac{\sigma}{\mu}$

Where: σ = standard deviation μ = mean

2.4 Rainfall Trend Analysis (Significance of Trend)

2.4.1 Mann-kendall test

The Mann Kendall trend test was performed using the XLSTAT programme in this investigation. This test was performed to determine whether the data sets had any trends. The non-parametric Mann Kendall Trend Test (equation 1) was used to investigate the temporal variation trend of rainfall in the research area from 1975 to 2005. The M–K test is a nonparametric statistical test commonly used for trend analysis in hydrological and climatological data. This method is used to determine if the variable has a monotonic trend over time (i.e., a trend that is continuously falling and never increasing or consistently growing and never declining) [16].

An upward trend, according to this test, means that the variable consistently climbs over time, whereas a downward trend suggests that the variable consistently decreases over time, however the trend may or may not be linear. Positive trend suggests an upward trend, whereas negative trend value indicates a downward trend. "*The value of Z is used to assess the presence of a statistically significant trend*" [17].

Mann–Kendall statistic (*S*) for a time series *x*1, *x*2, *x*3…, and *xn* is calculated as,

$$S = \sum_{k=1}^{n-1} \sum_{i=k+1}^{n-1} sign\,(xi - xk) \quad \text{……. (1)}$$

Where S denotes the Mann-Kendal test statistics; $x_í$ and x_k (denote the time series sequential data values in the years í and k (í > k); and n denotes the time series' length. A negative S value implies a falling trend in the data series, while a positive value suggests an increasing trend.

2.4.2 Sen's slope estimator test

Sen's estimate is a nonparametric method for determining the magnitude of a trend in a time series. Sen's nonparametric approach (equation 2) is used to establish the true slope of an existing trend, such as the amount of change every year. A positive Sen's slope indicates an upward tendency in the time series, while a negative value indicates a downward trend [18].

The Sen's slope estimator predicts the magnitude of the trend using the slope (Tí) of all data pairs, which is calculated as follows:

$$Tí = \frac{xj - xk}{j - k} \text{ For í = 1, 2, …... N ……} \quad (2)$$

Where, xj and xk (are data values at time *j* and *k* (*j* > *k*), respectively.

3. RESULT S AND DISCUSSION

Rainfall variation analysis for Nguru met stations in Yobe state was conducted using coefficient of variability and Mann-Kendall trend test along with the Sen’s slope estimator of time series data from 1975 to 2005 based on mean annual and seasonal basis. In Nigeria, rainfall is seasonal [8] usually from May to October in the northern region. The six months rainy season was separated into two May-June-July (MJJ) and August-September-October (ASO) Figs 4 and 5. The result of the analysis is presented below:

Fig. 2 depict the variations in annual rainfall during a 31-year period. Rainfall is the source of all water on the earth's surface, so the more rain that falls in each location, the more water is available for home, agricultural, and industrial use. The coefficient of variation was used to see if the region's mean monthly rainfall levels were the same in 1975, 1976, 1973..., and 2005, or if they differed significantly.

3.1 Coefficient of variation (CV)

The coefficient of variation CV for the annual rainfall in Nguru revealed a moderate inter annual variability (25%), whereas the CV for seasonal rainfall demonstrates that rainfall in the MJJ monsoon period is highly variable between seasons (more than 40%). The CV for the ASO monsoon period, on the other hand, was 31.6%, indicating a considerable and high variability in total rainfall received (Table 2). The result is similar with the findings of [19] which reported low and moderate inter seasonal rainfall variability in north-eastern Nigeria, with over 70% of rainfall occurring between June and September (Fig. 3). These findings indicate that inter annual variability in rainfall distribution affects agricultural operations in the study area, which is completely reliant on rainfall. As a result, even minor changes in the quantity and distribution pattern of main season (summer) rainfall may have a severe impact on crop productivity. Table 1 shows the results of the inter-annual rainfall variability analysis performed through the CV.

3.2 Annual and Seasonal Rainfall Analysis and Trend

Mann-trend Kendall's test was used to conduct a statistical study of annual rainfall trend at 95% confidence level. An increasing trend was suggested by a positive value of Mann-Kendal's test statistics (S) and Sen's slope at (P = < 0.05) significance level. The analysis from Mann-Kendall Trend test have indicated the trend of rainfall from 1975 to 2005 over Nguru station. From Table 4, 5 and 6 the Kendall's tau values were 0.011, -0.049, and 0.071 and the computed P-value were 0.946, 0.708 and 0.587 respectively. These P-values were higher than the significant level alpha equal to 0.05 thus, indicating that there is no significant trend in both annual and seasonal rainfall during the study period (1975-2005) in the area. The result corroborates the findings of [11] which revealed that there is no significant trend of rainfall over Nguru over the period of his study from 1976 to 2015.

3.3 Confidence Interval

The confidence interval value is usually used to determine the slope value. As shown in Table 7 below, when the minimum interval value is greater than maximum interval value, the slope will be negative value and when the maximum interval value is greater than the minimum value the resulting slope will be positive value [20]. Thus, for the annual rainfall trend (Fig. 6) the slope value is 0.300 (Table 7) indicating an increasing trend. However, negative slope value -0.550 (Table 8) was found during May-June-July (MJJ) period (Fig. 7) over the station revealing a decreasing trend, whereas the results for August-September-October (ASO) period (Fig. 8) is 0.773 (Table 9) at 95% confidence level which indicate an increasing trend.

Table 1. Coefficient of variation of annual rainfall

Coefficient of Variation Annual Rainfall					
Station	Mean Value	CV%	Standard Deviation	Min Value	Max Value
Nguru	409.2761	25.2%	103.088	204.000	605.800

Table 2. Coefficient of Variation of seasonal rainfall (MJJ)

Station	**Period**	**CV%**	**Standard Dev.**	**Mean Value**	**Min Value**	**Max value**
Nguru	MJJ	41.1%	74.08756	180.368	53.200	393.800

Table 3. Coefficient of Variation of seasonal rainfall (ASO)

Station	**Period**	**CV%**	**Standard Dev.**	**Mean Value**	**Min Value**	**Max value**
Nguru	ASO	31.6%	71.49772			

Table 4. Annual rainfall variability and trend over Nguru

Station	**Parameter**	**P-value**	**Min**	**Max**	**Mean**	**SD**	**CV**	**S**	**Kendall Tau**
Nguru	Rainfall	0.946	204.00	605.80	409.27	103.08	0.25	5.00	0.011

Table 5. Seasonal rainfall variability and trend over Nguru (MJJ)

Station	Parameter	P-value	Min	Max	Mean	SD	CV	S	Kendall Tau
Nguru	Rainfall	0.708	53.20	393.80	180.36	74.08	0.41	-23.00	-0.049

Table 6. Seasonal rainfall variability and trend over Nguru (ASO)

Station	Parameter	P-value	Min	Max	Mean	SD	CV	S	Kendall Tau
Nguru	Rainfall	0.587	86.90	373.60	225.97	71.49	0.31	33.000	0.071

Table 7. Slope and confidence interval of mann kendalls trend test for annual rainfall

Station	Parameter	Slope	Confidence Level (95)	
Nguru	Rainfall	0.300	Minimum	Maximum
			-4.275	5.792

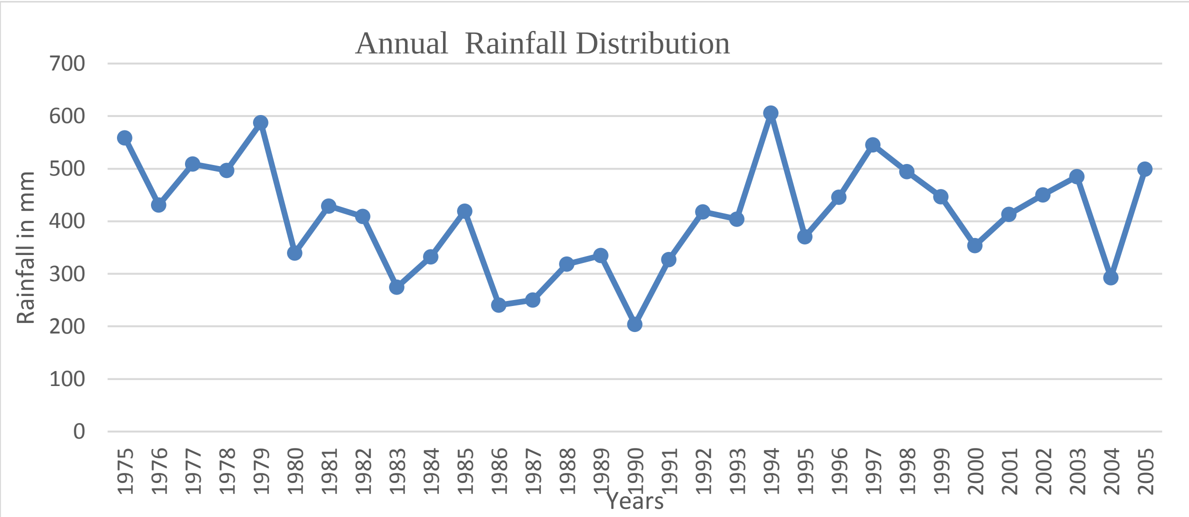

Fig. 2. Annual rainfall distribution over Nguru

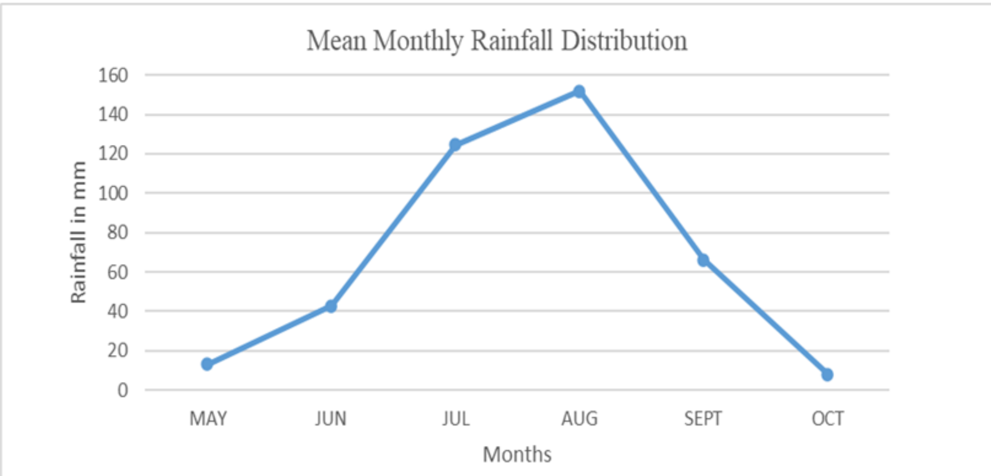

Fig. 3. Mean monthly rainfall distribution

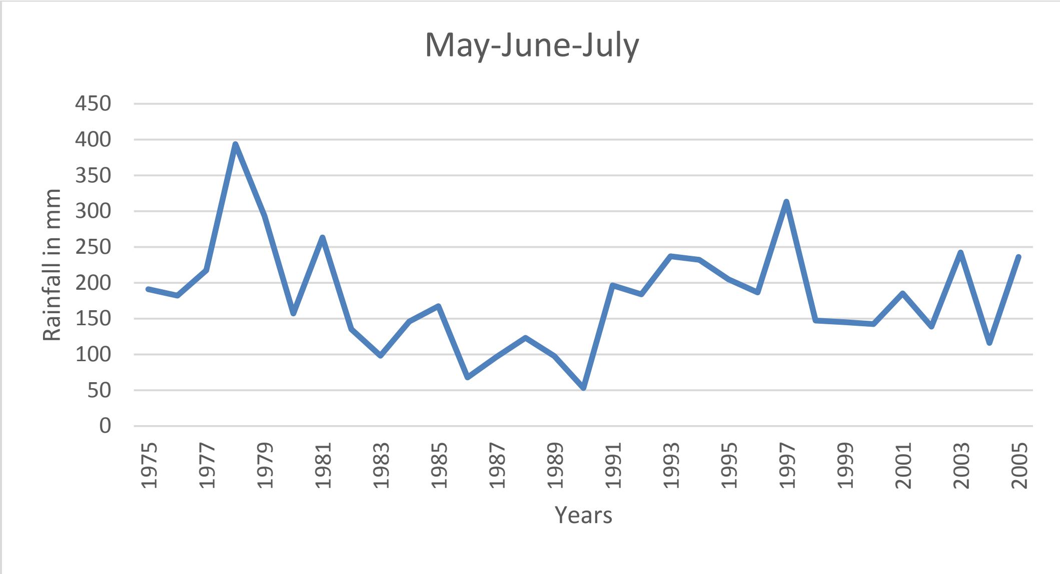

Fig. 4. May-june-july rainfall distribution over the years

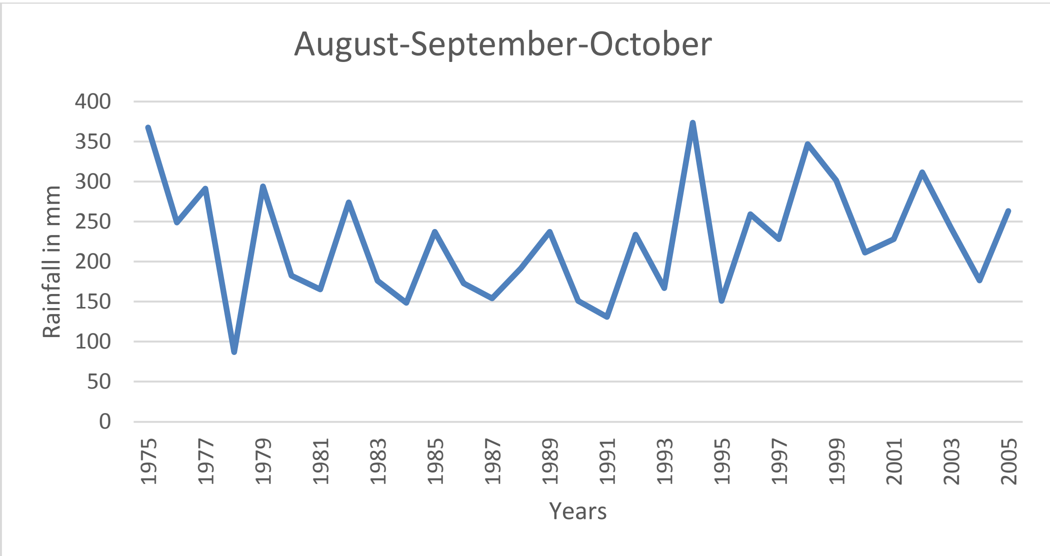

Fig. 5. August-september-october rainfall distribution over the years

Table 8. Slope and Confidence Interval of Mann Kendalls Trend Test for MJJ Rainfall

Station	Parameter	Slope	Confidence Level (95)	
Nguru	Rainfall	-0.550	Minimum	Maximum
			-4.225	2.594

Table 9. Slope and Confidence Interval of Mann Kendalls Trend Test for ASO Rainfall

Station	Parameter	Slope	Confidence Level (95)	
Nguru	Rainfall	0.773	Minimum	Maximum
			-2.113	4.350

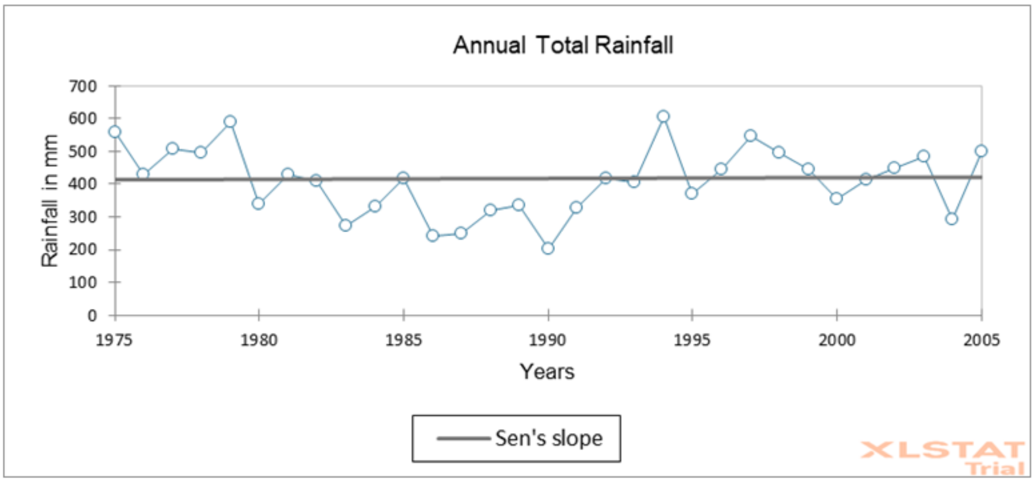

Fig. 6. Annual rainfall trend (1975-2005)

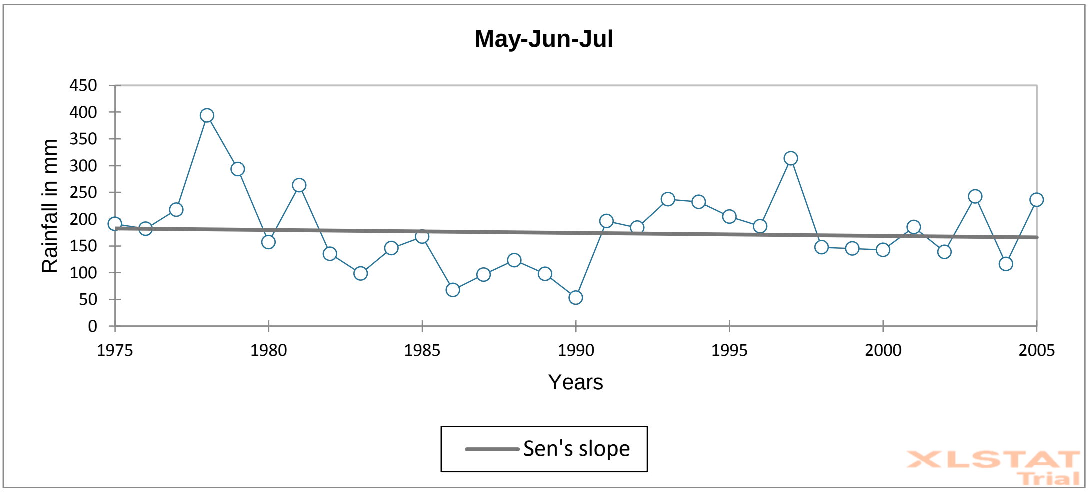

Fig. 7. Seasonal (May-June-July) rainfall trend over the years

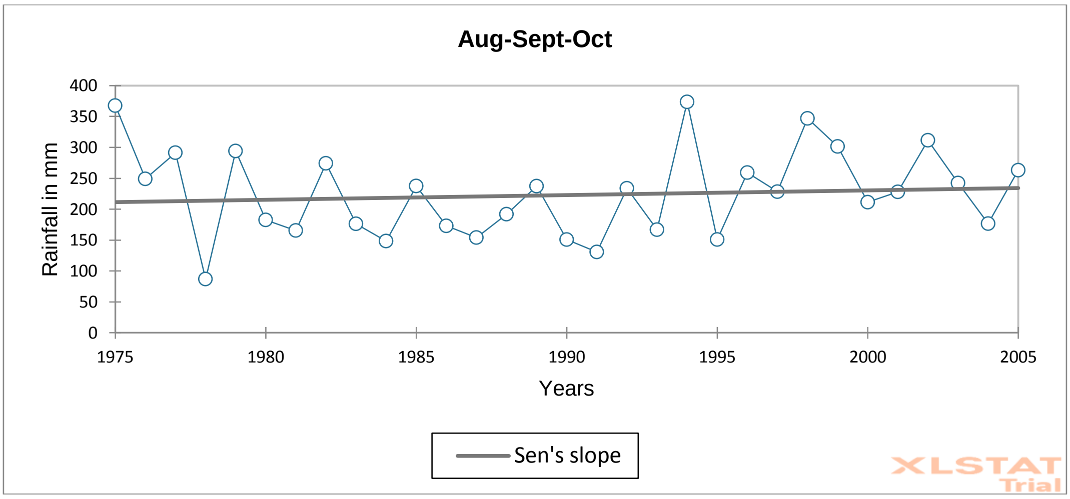

Fig. 8. Seasonal (august-september-october) rainfall trend over the years

4. CONCLUSION

Climate change is widely regarded as one of the most constraining elements for human activities. As a result, it is vital to initiate and conduct dynamic adaptation and mitigation efforts in response to the effects of current and anticipated climate change events as soon as possible. The primary purpose of this research is to look at rainfall variability over Nguru, a dry region in northern Nigeria.

Rainfall patterns have changed, not only in terms of annual amount but also in terms of other characteristics. The findings revealed a drop in rainfall, which will have a significant impact on the ecosystem and a variety of human activities. The interannual variability values in both annual and seasonal rainfall were quite high, indicating a growing scale of climate change in recent years. The rainfall index showed that during the study period, the good years, which received more rainfall than the average, were less than the bad years. Because the intensity of the rainfall was relatively high, there was a reduced efficiency of rainfall.

The main conclusion of this study is that rainfall is highly variable over the years, posing a threat to climate change-induced drought and, as a result, affecting the socio-economic well-being of the people in the area, who are mostly peasant farmers who rely solely on agricultural activities for their livelihood.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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