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TREND ANALYSIS IN RAINFALL VARIABILITY IN PARTS OF NORTH CENTRAL STATES, NIGERIA: A NON PARAMETRIC APPROACH

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ABSTRACT

Rainfall variability and change, its impacts and the associated vulnerabilities is a growing concern across the globe. It is believed to be one of the greatest impediments for achieving food security and sustainable crop production globally. The study utilized 30 years Climate Prediction Center, Merged Analysis of Precipitation (CMAP) data. Non-parametric test, Mann-Kendall test and Theil-Sen slope estimator (β) to investigate the spatio-temporal trend and rate of change in rainfall over the study area. The monthly rainfall charactristics shows signficant downward trend at the onset period in May at 0.05 and 0.1 alpha values in Lokoja and Abuja while at the cessation period in October, signficant upward trend at 0.5 alpha value was detected in Lafia stations. The rate of the significant upward trend in the seasonal rainfall were 4.56 mm

Introduction:

Rainfall is one of the most key climate elements which regulate and determine agricultural activities and production throughout the world (Adams, Hurd and Lenhart, 1998). Accurate estimation of the spatial and temporal distribution of rainfall including its trend are vital input parameters in order to secure sustainable agricultural activities in Nigeria. Rainfall is highly variable both in amount and distribution across regions and seasons (Worde-Georgis, 1997; Mersha, 1999). The seasonal and annual rainfall variations are results of the macro-scale pressure systems and moisture flows which are related to the changes in the

yr^{-1} at Lafia in the month of September, 3.72 mm yr^{-1} at Lokoja in the month of October and 6.06 mm yr^{-1} at Lafia in the month of October, respectively. The study revealed that the lowest coefficient of variation in seasonal rainfall occurred in Ilorin at 20.36% while the highest occurred in Lafia station at 37.79%. The result of annual Coefficient of variation also shows that Ilorin station has the lowest variation at 17.82% and the highest was found in Lafia at 37.7%. It is established that changes in rainfall pattern have impact on crop production. The study therefore recommend mainstreaming of farming calendar into the changing climate regime to ensure improved crop yield.

***Keywords**: Rainfall, Trend, Variability, Non-parametric Approach, North Central States, Nigeria*

Pressure systems (Hagos *et al*, 2009). One major concern of climate change is to study and identify documented changes in the climatic system (Cannarozzo, Noto, and Viola). Rainfall serve as the basis of fluids for living organisms which any alteration in amount, frequency, and intensity of fluid availability may have important consequences for the dynamics of human and natural systems (Ceballos-Barbancho *et al*. 2008). Modification in rainfall has direct effect on water resource management, agriculture, hydrology (Itiowe, Hassan and Agidi, 2019)

The impact of climate change is commonly evidenced by rainfall attributes (intensity, amount, duration, and timing), and the best indicators of these impacts are precipitation irregularities (Shi, Yu, Liao, Wang, & Jia, 2013). In tropical Africa, previous studies revealed that rainfall variability and associated droughts led to food shortages (Tadross, Hewitson, & Usman, 2005; Usman, Archer, Johnston, & Tadross, 2005). The worrisome issue about rainfall attributes is that their changes are expected to continue, particularly in the Sahel and sub-humid areas of Africa. This has led previous researchers to recommend continued monitoring and detailed study of rainfall phenomena (Hachigonta, Reason, & Tadross, 2008; Bayer *et al*., 2014). Additionally, understanding the changes in rainfall patterns

remains an important climatic problem that needs continued study. The study adopted the parametric method (Man-Kendall test and Theil Sen slope Estimator) to investigate the trend in seasonal and annual rainfall distribution across the north central states, Nigeria.

Materials and Methods

The Study Area

This study is delimited to parts of North Central States. The study area covers Four States and the Federal Capital Territory, the States are; Niger, Kogi, Nassarawa, Kwara, and Federal Capital Territory (FCT), Abuja. The study areas lies between Latitude $7^0\ 48^1$ N and $9^0\ 36^1$ N and Longitude $4^0\ 32^1$ and $8^0\ 30^1$ E.

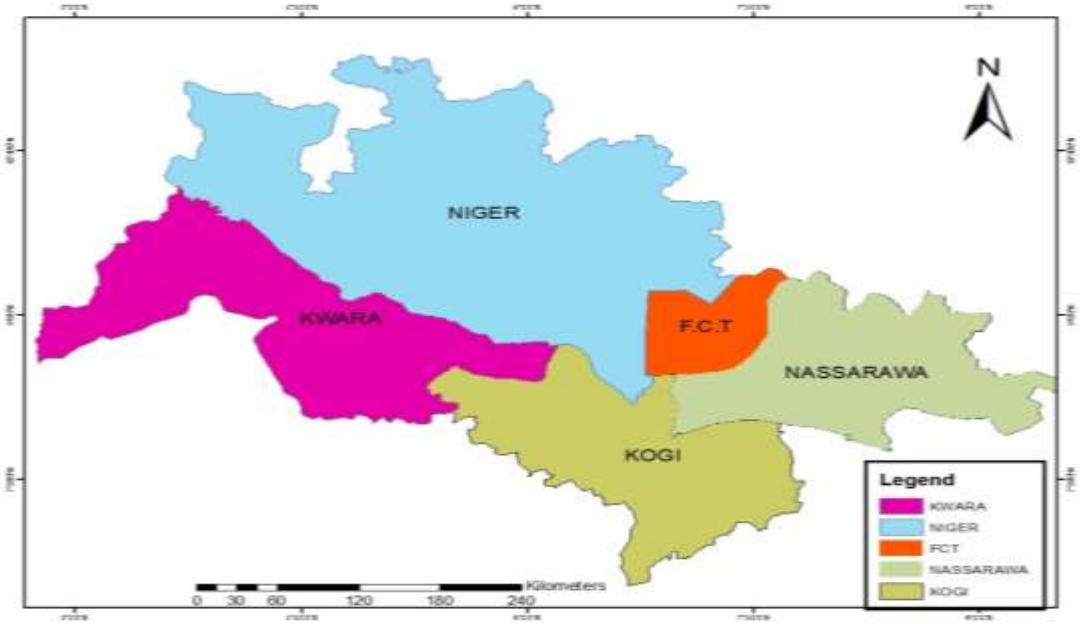

Figure 1: The Study Areas (Niger, Kogi, Kwara and Nasarawa and FCT, Abuja, Nigeria)

Data Used

Daily rainfall data from Climate Prediction Center Merged Analysis of Precipitation (CMAP) was utilized from 5 stations (Minna, Lokoja, Abuja, Ilorin and Lafia). With complete global coverage, extended period and

improved quality, the CMAP provides very useful information for climate analysis, numerical model validation, hydrological research, and many other applications (Xie and Arkin, 1997).

Data Analysis

The analysis were carried out using the Mann-Kendall test with significant level at α = 0.001, 0.01, 0.05 and 0.1 taken as thresholds to classify the significance of upward and downward trend. The Mann-Kendall test equation is given as:

$$S = \sum_{k=1}^{n-1} \sum_{i=k+1}^{n-1} \mathrm{sign}(\mathrm{x_j} - \mathrm{x_k}) \quad (1)$$

Where

$$sign\ (x_j - x_k) = \begin{cases} 1\ if\ (x_j - x_k) > 0 \\ 0\ if\ (x_j - x_k) = 0 \\ -1\ if\ (x_j - x_k) < 0 \end{cases} \quad (2)$$

To calculate the variance of S. VAR(S) the following equation is use;

$$VAR(S) = \frac{n(n-1)(2n-5) - \sum_{i=1}^{m} t_i\,(t_i - 1)\,(2t_i + 5)}{18} \quad (3)$$

Where n = number of data points; t_i = are the ties of the sample time series; and m = number of tied value (a tied group is a set of sample data having same value)

Equation 3.5 and 3.6 were then used to compute the test statistics Z. The computation for normalized test statistics Z is given as:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases} \quad (4)$$

A positive value of Z indicates upward trend; a negative value indicates a downward trend, and a zero value indicates no trend.

To determine the magnitude of trend changes in rainfall, the Theil-Sen slope estimator (β) was adopted to measure the magnitude of change (per

unit time) using a non-parametric procedure developed by Sen. The Theil-Sen slope approach gives a robust estimate of the magnitude of trend (Yue *et al.* 2002; Li *et al.* 2017; Ibrahim *et al.* 2018). The trend magnitude using this method is given as:

$$\beta = \left(\frac{x_{j-}\ x_k}{j-k}\right) \forall k < j \qquad (5)$$

Where β is the slope between data points x_j *and* x_k

The magnitude of trend change was analysed with the aid of Excel template software developed by Finnish Meteorological Institute MAKESENS 1.0

To understand the changes in rainfall event, this study considers how that event varies spatially and temporally using Inverse Distance Weighted (IDW) Interpolation GIS techniques. IDW is an exact interpolation method that enforces the condition that the estimated value of a point is influenced more by nearby known points than by those farther away.

An important characteristic of IDW spatial interpolation is that all predicted values are within the range of maximum and minimum values of the known points. The general equation for IDW method is given as:

$$Z_0 = \frac{\sum_{i=1}^{s} Zi \frac{1}{di^k}}{\sum_{i=1}^{s} \frac{1}{di^k}} \qquad (6)$$

Where $Z_0 =$ is the estimated value at point *0;* $Z_i =$ is the Z value at known point *I;* $d_i =$ is the distance between point i and point *0;* s = is the number of known points used in the estimation, and $k =$ is the specified power.

Results and Discussions

The trend in monthly rainfall distribution within the study area is depicted in Table 1. The months of May to October were primarily considered because they represent the growing season in the study area. Results shows that there was a downward monthly rainfall trend at the onset of rains in the month of May but gradually increased towards the cessation period in the month of October. Result depict upward and downward trends at varying alpha (α) levels across the study area. The magnitude of rainfall trends (Table 2) shows variation across the study area. Result

shows negative magnitude of change in most stations. The highest rate of change occurred in October at Lafia station (6.06 mm yr^{-1}) while the lowest occurred in June at Lokoja station (-6.12 mm yr^{-1}).

Table 1: Trend of Monthly Rainfall in the Study Area

Station	May	June	July	August	September	October
Minna	-0.04	-1.07	-0.76	-0.86	0.89	0.71
Lokoja	-2.07*	-3.07**	-1.71+	-0.39	-0.04	2.46*
Abuja	-1.82+	-1.26	-1.36	-0.64	1.25	0.64
Ilorin	-0.75	-1.29	-1.25	-1.49	0.71	0.25
Lafia	0.52	-2.43*	-2.36*	-2.21*	1.91+	2.50*

***Trend is significant at α=0.001 **Trend is significant at α=0.01 *Trend is significant at α=0.05, +Trend is significant at α=0.1

Table 2 Magnitude of Change (β) in Monthly Rainfall in the Study Area

Station	May	June	July	August	September	October
Minna	-0.09	-1.03	-1.61	-1.41	1.43	0.64
Lokoja	-2.15	-6.12	-3.09	-0.74	-1.53	3.72
Abuja	2.02	-1.67	-3.71	-1.43	1.88	0.59
Ilorin	-0.44	-1.19	-2.34	-2.18	1.06	0.28
Lafia	2.52	-4.03	-4.86	-4.59	4.56	6.06

Analysis of trend in annual rainfall distribution across the study area is depicted in Table 3. Result shows significant downward trend at alpha value of 0.01 n Lokoja station while Lafia stations shows significant upward trend at 0.001 alpha value. Table 4 depicts result for the seasonal and annual coefficient of variation in rainfall across the study area. Result shows that the lowest seasonal coefficient of variation occurred in Ilorin station at 20.36% and Lafia has the highest at 37.79%. Further result shows that the lowest annual coefficient of variation occurred in Ilorin station at 17% and the highest variation was found in Lafia with 37.7%. These variations in the seasonal and annual rainfall variability depicted a decrease trend towards the western axis of the study area, which implies

that the variation in climatic parameter increased with increasing longitude.

Table 3 Trend of Annual Rainfall in the Study Area

Station	Range of Years	Total Number of Years used	Test-Z
Minna	1989 - 2018	30	-0.75
Lokoja	1989 - 2018	30	-3.14**
Abuja	1989 - 2018	30	-0.86
Ilorin	1989 – 2018	30	-0.86
Lafia	1989 - 2018	30	3.68***

***Trend is significant at α=0.001, **Trend is significant at α=0.01, *Trend is significant at α=0.05, +Trend is significant at α=0.1.

Table 4 Seasonal and Annual Coefficient of Variation in Rainfall (%)

Stations	Seasonal	Annual
Minna	24.75	22.84
Lokoja	29.84	27.69
Abuja	31.97	31.08
Ilorin	20.36	17.82
Lafia	37.79	37.70

Figure 2 (a, b) depict result of interpolation of coefficient of variation in seasonal and annual rainfall distribution in the study area. Result shows that Ilorin and Minna stations has the lowest coefficient of variation in seasonal rainfall at 20.36% and 24.75% and the highest was found in Lafia at 37.79%. Result for the annual variation shows that Ilorin and Minna has the lowest values at 17.82% and 22.84% and the highest variation was found in Lafia at 37.7%. The variations in the seasonal and annual rainfall depicted a decrease trend towards the western axis of the study area, which implies that the variation in climatic parameter increased with increasing longitude.

(a) (b)

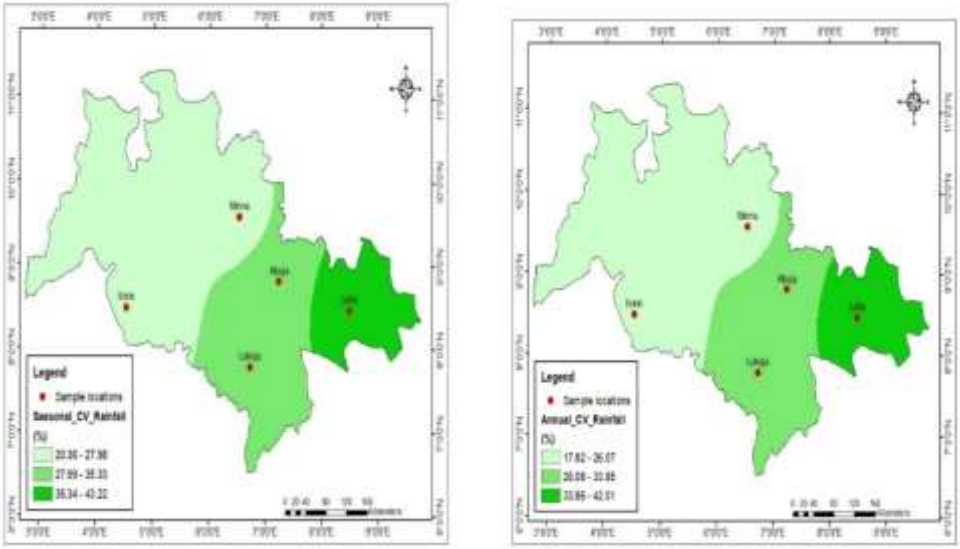

Figure 1 (a, b): Coefficient of Variation in Seasonal and Annual Rainfall

Conclusion

The study adopted the non-parametric test, Mann-Kendall trend test and Theil-Sen slope estimator to investigate spatio-temporal trends and changes in rainfall at five stations in the North Central States of Nigeria at monthly and annual time scale for 1989 – 2018 period. The study revealed that a shift in rainfall occurred across the study area. It revealed that over the years there is decreasing trend in rainfall during the onset period in May and increased towards the cessation period in October. The rate of the significant upward trend in seasonal rainfall were 4.56 mm yr^{-1} at Lafia in the month of September, 3.72 mm yr^{-1} at Lokoja in the month of October and 6.06 mm yr^{-1} at Lafia in the month of October, respectively. The study established that both significant and non-significant upward and downward changes occurred in the study area and therefore recommended continuous monitoring of changing pattern of rainfall in the study area so as to provide remedial measures for agricultural adaptation.

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