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Statistical Analysis of Trend in Extreme Rainfall and Temperature Events in Parts of North Central States, Nigeria

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Abstract: *The study investigated trend in extreme rainfall and temperature indices using thirty (30) years daily climatic data from Climatic Prediction Center Merged Analysis of Precipitation (CMAP) for Five stations in the North Central States of Nigeria. Nine (9) extreme rainfall and Five (5) extreme temperature indices developed by Expert Team on Climate Change Detection and Indices (ETCCDI) under the World Meteorological Organization (WMO) were generated using the RClimDex Software. Mann-Kendall, a non-parametric test was used for trend detection while Theil-Sen slope estimator approach was used to examine the magnitude of trend change in the derived indices. Result showed mixed trends of significant and insignificant in the selected extreme indices across the stations. The extreme rainfall indices of Consecutive Dry Days (CDD) and Maximum 1-day rainfall (R1D) showed steady increase across the stations during the study period while the indices of Consecutive Wet Days (CWD) and Number of heavy rainfall days (R10) showed constant decreasing trend across the stations. Further result showed decreasing trend for the extreme temperature indices of Monthly minimum value of daily minimum temperature (TNn) and Diurnal Temperature Range (DTR) across the study area while the other variables showed mixed trend during the same period. The study established that the fluctuating trends in the variables are conceivable indicator of climate change in the study areas. The study recommended that future climate change adaptation strategies should take into account the observed and projected changes in the extremes.*

Keywords: *Trend, Extreme Climatic Indices, North Central States, Nigeria*

INTRODUCTION

The influence of climate and extreme events is particularly extensive, affecting diverse fields such as agriculture, public work, transportation, water resources etc. Because of the occurrence of extreme events such as floods, extreme heat and extreme cold, casualties have increased and the social infrastructure globally has become more vulnerable. The extent of damage and damaged areas has also increased. Therefore, accurate understanding and analysis of long-term changes in climate extreme event data are necessary to prevent future damages to the social infrastructure caused by climate change (Kim *et al.*, 2011).

Researches across the world shows mixed trend in extreme climate events for example Karl and Easterling (1999) in their study on extreme events caused by climate change in various countries, found that the number of extreme cold days has diminished whereas that of extreme hot days has increased in the last century. Kim *et al.*, 2011 found that spatially coherent and statistically significant changes in the extreme events of temperature and rainfall have occurred over South Korea. (Basher *et al.*, 2017) in Northeast Bangladesh found a decreased trend in the indices of extreme rainfall and Chandrashekar & Shetty, (2018) in Western Ghats and coastal regions of Karnataka found contrasting trends in the extreme rainfall indices. The study of Ibrahim, *et al.* (2020) found that three stations (Bauchi, Kano, and Katsina) in Sudano-Sahelian savanna zones of Nigeria showed consistent significant increasing trends in most of the extreme indices while two stations (Abuja and Yola) showed consistent decreasing trends in most of the extreme indices.

Though several studies exist on trend of climatic variables in the study area (Ibrahim, *et al.*, 2015; Musa, *et al.*, 2019; Itiowe, *et al.*, 2019), the trend in extreme climatic variables using the new indices by Expert Team on Climate Change Detection and Indices (ETCCDI) has rarely been documented for the study area. This study therefore, investigated trends in daily extreme rainfall and temperature in the study area.

MATERIALS AND METHODS

The Study Area

The study area lies between Latitude 7⁰ 48' N and 9⁰ 36' N and Longitude 4⁰ 32' E and 8⁰ 30' E. The study area includes: Minna, Lokoja, Abuja, Ilorin and Lafia.

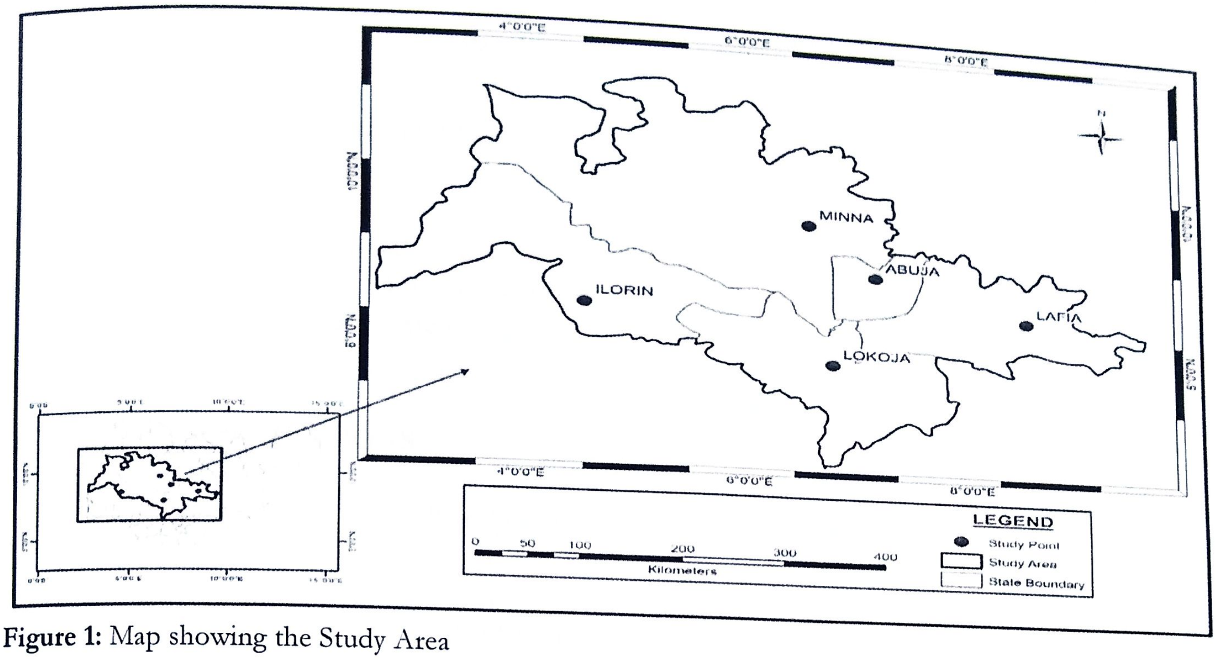

Figure 1: Map showing the Study Area

Data Analysis

Daily rainfall and temperature data for thirty years (from1989 to 2018) obtained from Climate Prediction Center Merged Analysis of Precipitation (CMAP) for the five stations were used. The study adapted Nine (9) indices on extreme rainfall and Five (5) on extreme temperature developed by Expert Team on Climate Change Detection and Indices (ETCCDI) under the World Meteorological Organization (WMO). The RClimDex software was used to extract the selected extreme indices.

Mann-Kendall test was used to examine trends in extreme rainfall and temperature indices with significance levels at $\alpha = 0.001, 0.01, 0.05$ and 0.1 taken as thresholds to classify the significance of upward and downward trend. The equation (Mann-Kendall statistic) is given as:

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

x_j is a time series ranked from $i = 1, 2, \ldots, n\text{-}1$ and x_j, ranked from $j = i + 1, 2, \ldots, n$.

Where

$$sgn\,(x_j - x_k) = \begin{cases} +1\ if\ (x_j - x_k) > 0 \\ 0\ if\ (x_j - x_k) = 0 \\ -1\ if\ (x_j - x_k) < 0 \end{cases} \qquad (2)$$

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

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

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 2 and 3 were then used to compute the test statistics Z. The computation for normalized test statistics Z is given as:

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

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

2.3.2 Magnitude of Trend Change

The Theil-Sen slope estimator approach was used to examine the magnitude of trend change. The equation is given as:

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

Where

β = is slope between data points x_j and x_k

$x_j - x_k$ = Data value at time j and k. j>k respectively.

The analysis of magnitude of trend change was done using MAKESENS 1.0 software developed by the Finish Meteorological Institute.

RESULTS AND DISCUSSIONS

Table 3 depicts the Mann-Kendall test result for extreme rainfall indices in the study area. Result shows consistent increasing trend for Consecutive dry days (CDD) and Maximum 1-day rainfall (R1D) across the stations. Conversely, the result for Consecutive wet day (CWD) and Number of heavy rainfall days (R10) shows consistent decreasing trends in all stations. Further, result shows significant increasing trend at 0.05 alpha level for R95T at Abuja station while other stations shows insignificant increasing and decreasing trend. The study revealed varying trend of significant and non-significant increase and decrease in the occurrence of SDII, R5D, R20 and R50 across the study area.

Table 3: Trend in Extreme Rainfall Indices over the Study Area (1989 – 2018)

Stations	CDD	CWD	SDII	R1D	R5D	R95T	R10	R20	R50
Minna	2.20*	-3.46***	2.11*	2.89**	1.68+	1.55	-1.83+	0.34	1.52
Lokoja	1.34	-2.63**	-2.09*2.	16*	-1.39	-.05	-3.32***	-2.76**	1.37
Abuja	2.41*	-2.75**	3.39***	3.28**	1.86+	2.57*	-1.66+	0.52	3.03*
Ilorin	1.23	-1.80+	1.59	1.64	0.64	1.53	-1.86+	0.00	2.38*
Lafia	1.04	-3.18**	-1.50	2.00*	-1.89+	-0.71	-3.59***	-3.42***	-0.71

***Trend is significant at $\alpha = 0.001$, **Trend is significant at $\alpha = 0.01$, *Trend is significant at $\alpha = 0.05$, +Trend is significant at $\alpha = 0.1$ confidence levels.

Table 4 depict the result of magnitude of trend change in the extreme rainfall indices in the study area. Result shows increasing magnitude of change for CDD at 1.5 mm yr^{-1}, 0.82 mm yr^{-1}, 2.20 mm yr^{-1}, 0.63 mm yr^{-1} and 1.00 mm yr^{-1} in Minna, Lokoja, Abuja, Ilorin and Lafia stations respectively. while CWD shows decreasing magnitude of change at 0.12 mm yr^{-1}, 0.17 mm yr^{-1}, 0.20 mm yr^{-1}, 0.05 mm yr^{-1} and 0.33 mm yr^{-1} in Minna, Lokoja, Abuja, Ilorin and Lafia stations respectively. Further result shows varying magnitude of change for the derived indices across the stations.

Table 4: Magnitude of Trend Change in Extreme Rainfall Indices Over the Study Area

Stations	CDD	CWD	SDII	R1D	R5D	R95T	R10	R20	R50
Minna	1.55	-0.12	0.10	1.36	0.87	4.55	-0.33	0.00	0.00
Lokoja	0.82	-0.17	-0.07	0.45	-0.86	-2.80	-1.00	-0.41	0.00
Abuja	2.20	-0.20	0.19	1.98	1.93	8.68	-0.33	0.06	0.07
Ilorin	0.63	-0.05	0.05	0.44	0.34	3.83	-0.25	0.00	0.00
Lafia	1.00	-0.33	-0.07	0.53	-1.44	-1.52	-1.71	-0.77	0.00

Table 5 shows result of trend in extreme temperature indices. Generally, the Tables shows decreasing trend in bulk of the stations. Result for Monthly minimum value of daily minimum temperature (TNn) and Diurnal Temperature Range (DTR) shows consistent decreasing trend across the stations while other indices showed varying trend of significant and non-significant increasing and decreasing trends.

Table 5: Trend in Extreme Temperature Indices over the Study Area

Stations	TXn	TXx	TNn	TNx	DTR
Minna	0.11	0.98	-0.80	0.89	-1.27
Lokoja	-0.50	2.05*	-2.03*	-2.03*	-3.48***
Abuja	1.71+	-0.34	-2.37*	-1.82+	-2.50*
Ilorin	-0.70	0.39	-2.46*	3.09**	-1.07
Lafia	1.62	-0.36	-1.96*	-2.18*	-3.03**

Table 6, depict the result of magnitude of trend change in the extreme temperature indices. Result for Monthly minimum value of daily maximum temperature (TXn) shows increasing magnitude of change in Minna, Abuja and Lafia stations at 0.01^{0}C, 0.07 ^{0}C and 0.05 ^{0}C, and a decreasing magnitude of change in Lokoja and Ilorin stations at 0.03 ^{0}C and 0.02 ^{0}C, while Minna station shows no change. Result for Monthly maximum value of daily minimum temperature (TNx) shows increasing rate of change in Minna and Ilorin at 0.02 ^{0}C and 0.04 ^{0}C, while Lokoja, Abuja and Lafia depict decreasing rate of change at 0.07 ^{0}C, 0.06 ^{0}C and 0.11 ^{0}C, respectively.

Table 6: Magnitude of Trend Change in Extreme Temperature Indices Over the Study Area

Stations	TXn	TXx	TNn	TNx	DTR
Minna	0.003	0.052	-0.027	0.016	-0.012
Lokoja	-0.028	0.094	-0.074	-0.073	-0.058
Abuja	0.065	-0.018	-0.122	-0.057	-0.050
Ilorin	-0.022	0.008	-0.036	0.043	-0.007
Lafia	0.051	-0.006	-0.188	-0.106	-0.097

CONCLUSION

The study examined trend in extreme rainfall and temperature indices for the period of thirty years (1989 to 2018) from the Five (5) stations that constitute the study area. Result shows varying trend of significant and insignificant increase and decrease across the stations. The mixed trend could be an indicator to the influence of station's specific physical characteristic. The study concluded that the fluctuating trends in the extreme variables are likely pointer to the evidence of climate change in the study areas. It is recommended that future adaptation strategies should take into account the observed and projected changes in the extremes.

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