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Analytical Study of Rainfall and Temperature Trend in Catchment States and Stations of the Benin- Owena River Basin, Nigeria

Obasi, R. A* Ikubuwaje C.O.
Department of Mineral Resources Engineering,
Federal Polytechnic, Ado-Ekiti, P.M.B 5351 Ekiti State, Nigeria.
Tel: 07032448351 Email: romanus914@yahoo.com

Abstract
The impart of climate change is felt worldwide, but the effects are more devastating in countries where flooding or drought has occurred. In the Nigerian context, the impact of climate change is felt majorly in terms of rainfall and temperature. It is on the basis of their variations that the analytical study of their trend is carried out in some catchment States of Nigeria using the Benin- Owena River Basin as case study. Climatic data of rainfall and temperature for 35years were collected and subjected to Cumulative Summation (CU-SUM) and the rank-sum tests. The trend analysis shows that as temperature increases there is a corresponding increase in rainfall. The trend also indicates that no significant departure of these climatic parameters occurred. The least square regression (r^2) and the trend as generated from the Microsoft Excel computations show that the temperature variation ranges from 0.4% in Delta to 3.5% in Edo, an indication that the temperature conditions in states understudy are not uniform even though the trend shows an increase. The rainfall least square regression variation ranges between 0.2% in Zaria and 2.7% in Plateau states, implying that the rainfall is varying in an upward trend.

Keywords: Analytical study, Climatic variation, Temperature and Rainfall.

1 INTRODUCTION

There is a global concern about climatic changes resulting from greenhouse gas emission from the industrialized nations. Many scholars have engaged themselves in studying this climatic variability in order to identify and quantify the extent and trend of the change. Climate variability is the variations of the normal state and other statistics of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from anthropogenic external forces (external variability) (IPCC 2001, 2005). Parida, et a;l.2005 are of the opinion that the global increase in temperature and changes of other climatic variables such as rainfall and evaporation are as a result of greenhouse gas emission. Once existing or potential climate change hazards have been identified, it must be demonstrated that these hazards pose a threat or risk to human populations and the systems on which they depend. It is therefore necessary to establish coping ranges and critical thresholds for proper adaptation interventions. This paper is aimed at determining the trend of this climatic variation with a view to finding out if rainfall and temperature have been influenced by internal or external factors. This is because precipitation is one of the key climatic variables that affect both the spatial and temporal patterns on water availability (De Luis et al., 2000).

1.1. Materials and Method

Environmental data of rainfall and temperature were collected from the Meteorological Survey Agency, Lagos - Nigeria. The rainfall data were subjected to step changes analysis to know whether anthropogenic or natural factors have brought in inconsistencies and non-homogeneity in the data. Individual rainfall data from different stations of the Benin-Owena River Basin were also subjected to intervention analysis as well as trend analysis. Rainfall data used covered an average of thirty five (35) years.

The rainfall data were analyzed using the Cumulative Summation (CU-SUM) and the rank-sum tests. These tests were used to identify and ascertain if there had been any interventions. The rank-sum test is based on a non-parametric procedure to overcome the problems of small sample sizes and distributional effects if any (CRCCH, 2005; Yue et al., 2002). Rainfall and temperature analyses were followed, intervention analysis

(CUSUM and rank-sum techniques), establishment of the null and alternate hypotheses, computation of the Regression Line over the data point to evaluate the results and the establishment of the trend from the fit of model.

Intervention analysis was carried out using the Cumulative Summation (CUSUM) technique of Parida et al., 2003 to determine inconsistencies in rainfall data collected from different rainfall stations. The results of this analysis will indicate if anthropogenic activities have occurred due to observational errors in data collection or equipment handling. Using the Parida (2003) equation,

$$y_{i}=(X_i + X_{i-1} + X_{i-2} + \ldots + X_n) - I \ldots m \qquad \ldots\ldots \qquad (1)$$

where n = sample size; m = average of the total series. y_i, is plotted against i *to* generate the oscillatory graph.

In step change analysis, the rank-sum test is a non-parametric test to find out the difference in median of two subsets of data representing pre- and post-intervention periods for rainfall data. The standard steps in computing the rank-sum test statistics as suggested by CRCCH (2005) are indicated below;

(i) Rank all the data, from **K** (smallest) to ***M*** (largest). In the case of ties (equal data values), the average of ranks is used.

(ii) Compute a statistic 'S_m' as the sum of ranks of the observations in the smaller group (the number of observations in the smaller group is denoted as *k,* and the number of observations in the larger group is denoted as m), and

(iii) Compute the theoretical mean (μ) and standard deviation (σ) for the entire sample, as given by: $\mu=k(N+1)/2$ and $\sigma = [km(N+1)/2]^{0.5}$

The test statistic Z_{rs} is computed as:

$$Z_{rs} = (S_m - 0.5 - \mu)/\sigma \qquad \textbf{If } S_m > \mu$$
$$= 0 \qquad if\ S_m = \mu$$
$$= (S_m + 0.5 - \mu)/\sigma \qquad \textbf{If } S_m < \mu$$

The above step change formulae have been used to analyse the rainfall data for all the stations under study. Using the Jos rainfall data as an example, the workings are shown as follows;

(i) Ranking the data from K to M

(a) from 2003- 2005 = Small group (K) =7481 and (b) from 1971-2002 = Large group (M) =80,829.

Computing the statistic 'S_m'

$$S_m = K + M \ldots\ldots (2)$$

$$S_m = 7481 + 80{,}829 = 88{,}310$$

Theoretical mean (μ) and the Standard deviation (σ)

(ii) Computing for μ and σ , we have $\mu = k\frac{(N+1)}{2}$ ……(3)

$$\mu = \frac{7481\ (420+1)}{2} = 1574750.5$$

$$\sigma = \left(\frac{km(N+1)}{12}\right)^{0.5}$$

……(4)

$$\sigma = \left[\frac{7481(80{,}829)(420+1)}{12}\right]^{0.5}$$

σ= 145651.13

The test statistic Z_{rs} is Computed as; $Z_{rs} = \frac{(S_m + 0.5 - \mu)}{\sigma}$ If $S_m < \mu$ ……(5)

$$Z_{rs} = \frac{88310 + 0.5 - 1574750.5}{145651.13} = -10.21$$

Z_{rs} = -10.21

Since $Z_{0.5}$ = 1.65 (from normal distribution table)

Accept H_o if Zrs < Z, If otherwise do not accept. Therefore, we have statistical reason to accept $H_{o.}$

This step change analyses workings are repeated for Benin, Warri, Lagos, Plateau, Kano, Borno, Niger, Zaria and Ondo States. The results of the analyses from these towns are presented in Table 1. The null hypothesis, H_o, presupposes that no change has occurred in the time series or that the two samples come from the same population (i.e. have the same median). This condition is accepted when the computed Z_{rs} is less than the Z value derived from a normal distribution. Table at 5% significance level and as worked out in equation, 5. The combined rainfall and temperature data were later subjected to spatial analyses using Microsoft excel package in order to generate the curve, the trend patterns and the R-square values (charts 1-9) .

1.2 Results and discussion

In the intervention analysis, the computed CUSUM rainfall values (y_i) at any time i for each of the rainfall stations were obtained and plotted in Figs 1-9. Usually, when there is no intervention, the plot of rainfall values will oscillate around the horizontal axis (Parida, 2003). Based on this, Figs 1, 3 and 7 of Maiduguri, Ikeja and Benin respectively show oscillatory departures from the horizontal axis. In Fig 1, the departure occurred between 1971 and 1973 and between 1979 and 1982. In Fig 3, it occurred between 1976 and 1978 while in Fig 7 (Benin) the departure was between 2003 and 2005. These departures suggest the possibility of interventions due to the anthropogenic activities of rainfall data collectors. In some of the Figures, the rainfall values either plot above or below the horizontal axis in most of the computed years. Importantly some of the Figures show negative and positive slopes on the horizontal axis. Whitting, et al; 2003 suggest that positive slopes on the horizontal axis indicate wet periods (i.e above average values of rainfall), while negative slopes are indications of dry periods.

Table 1 shows the result of step change analysis for 9 States in Nigeria, indicating the test statists (Z_{rs}), the critical value a=0.05 representing Z and the remarks. Using null hypothesis, H_o and applying the results from equations 2 - 5 of the step change analysis, the test statistics values (Z_{rs}) obtained are less than the critical values (Z). When this condition prevails ($Z_{rs} < Z$), it means that H_o is accepted. This implies that the rainfall data are collected from areas that fall under the same climatic influence. The null hypothesis, H_o is accepted when the computed Zrs < Z obtained from a normal distribution table at 5% significant level. This suggests also that no change has occurred in the time series and that the samples come from the same population (Helse and Hirseh, 2002).

Tables 2 and 3 show the temperature and rainfall values for least square regression and the trend as generated from the Microsoft Excel computations. The World Almanac and Book of facts (WABF) 1993 suggests that the least square regression calculates the best – fitting line for any observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line. The r^2 values (the square of the Correction Coefficient) indicate the degree of variation. The temperature variation ranges from 0.1% in Zaria station to 3.5% in Edo station an indication that the temperature conditions in the stations/states under study are not uniform even though the trend shows increase. (Table 2).

The percent rainfall variation ranges between 0.2% in Zaria station and 2.7% in Plateau station respectively (Table 3).

1.3 Conclusion

The trend analysis of temperature and rainfall in nine (9) states of Nigeria for 35years show that as temperature increases there is a corresponding increase in rainfall. The trend also indicates no significant departure of the climatic parameters in the nine (9) states under study. The analyses of the meteorological data of temperature and rainfall show no evidence of serious intervention although some insignificant departures were observed in station areas of Ikeja, Benin and Maiduguri respectively. This suggests that the rainfall data are collected from areas that fall under the same climatic influence, an indication that no significant change has occurred in the time series.

References

CRCCH, (2005). Co-operative Research Centre for Catchment Hydrology. TREND User Guide, . pp.(29.)

De Luis, M., Ravenlos. J., Conzalez-Hidalgo, J.C.. Sa"nchez. J.R., Cortina, J,. (2000). Spatial analysis of rainfall trends in the region of Valencia (east Spain). 2000. International Journal of Climatology 20 (12), pp.(1451-1469).

IPCC, (2007).Climate Change. Physical science basis. In: Solomon, S., Qin, D.,Manning. M., Chen Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L (Eds.), Contribution of Working Group I to the Fourth

Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Ndiritu. J.G., (2005), Long-term trends of heavy rainfall in South Africa. Regional hydrological Impacts of Climatic Change- Hydroclimativ Variability. In: Proceedings of symposium SG held during the seventh IAHS Scientific Assembly at Foz do iguacu, Brazil, April 2005. IAHS Publ.296, (p. 178-183)
Parida, B.P., Moalafhi, D.B.. Kcnabatho. P.K..(2003). Effect of urbanization on runoff coefficient: a case of Notwane catchment in Botswana. In: Proceedings of the international Conference on Water and Environment (WE-2003), Bhopal.Watershed Hydrology'. Allied Publishers Pvt. Ltd., (pp. 123-131).
Parida, B.P.. Moalafhi, D.R., Kenabatho. *P.K.,(* 2006). Forecasting runoff coefficients using ANN for water resources management: the case of Netware catchment in Eastern Botswana. Physics and Chemistry of the Earth 31.(pp. 928-934.)
Whiting, J.P., Lambert, M.F., Mercalfe, A.V., (2003). Modeling persistence in annual Australian point rainfall. Hydrology and Earth System Sciences 7 (2), (pp. 197-211).
Yue, S., Pilon, P., Cavadias, G., 2002. Power of the Mann-Kendall and Spearman's rhotests detecting monotonic trends in hydrological series. Journal of Hydrology 259, (pp 254-271).

Table 1. Results of step change analysis using rank sum method

STN	Test Statistic Zrs =	Critical value at a = 0.05 (Z)	Remarks Zrs < Z=Ho
Plateau	-10.21	1.65	Accept
Delta	-39.62	1.65	Accept
Edo	-61.6520	1.65	Accept
Lagos	-29.26	1.65	Accept
Kano	-19.21	1.65	Accept
Borno	-20.94	1.65	Accept
Niger	-31.079	1.65	Accept
Ondo	-107.6	1.65	Accept
Zaria	-28.88	1.65	Accept

Table 2: Results of Temperature Least-Square Regression and Trend

STN	Equation on Chart	R- Squared value on Chart	Correction Coefficient	Variation (%)	Trend
Plateau	0.0125X	0.0138	0.1175	1.4	increase
Delta	0.0144X	0.004	0.0633	0.4	increase
Edo	0.0147X	0.035	0.1871	3.5	increase
Lagos	0.0142X	0.017	0.1304	1.7	increase
Ondo	0.0141x	0.034	0.1844	3.4	increase
Kano	0.0148x	0.022	0.1483	2.2	increase
Borno	0.0155x	0.0297	0.1723	3.0	increase
Niger	0.0151x	0.0068	0.0825	0.7	increase
Zaria	0.0142x	0.0152	0.1233	1.5	Increase

Table 3. Results of Rainfall Least-Square Regression and Trend

STN	Equation on Chart Y=	R- Squared value on Chart	Correction Coefficient	Variation (%)	Trend
Plateau	0.053x	0.027	0.1643	2.7	Increase
Delta	0.1127x	0.0063	0.0794	0.6	Increase
Edo	0.0911x	0.0068	0.0825	0.7	Increase
Lagos	0.0585x	0.0146	0.1208	1.5	Increase
Ondo	0.066x	0.0077	0.0878	0.7	Increase
Kano	0.0381x	0.0166	0.1288	1.7	Increase
Borno	0.0232x	0.0104	0.1020	1.0	Increase
Niger	0.05x	0.008	0.0894	0.8	Increase
Zaria	0.0427x	0.0015	0.0387	0.2	Increase

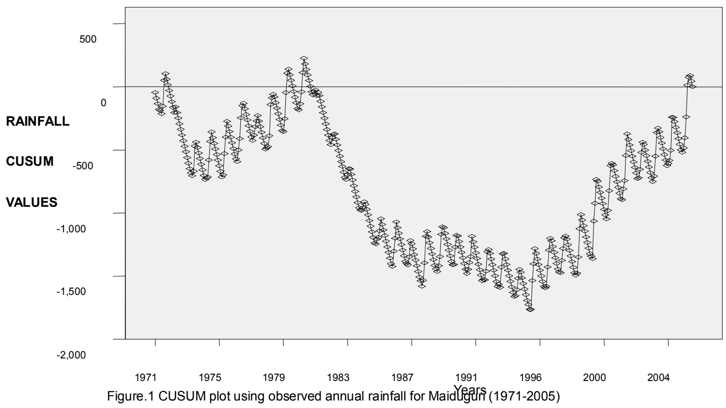

Figure.1 CUSUM plot using observed annual rainfall for Maidugun (1971-2005)

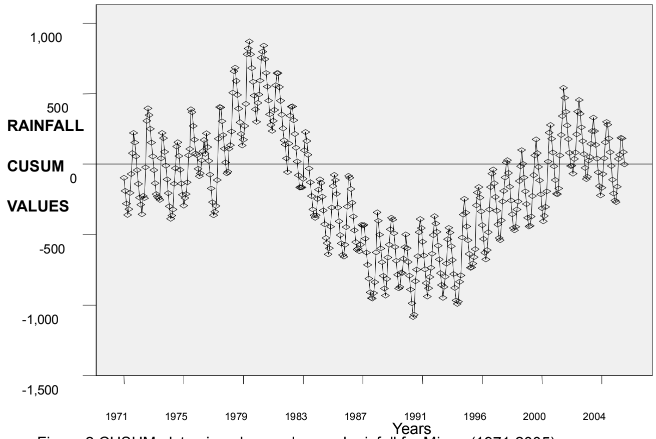

Figure.2 CUSUM plot using observed annual rainfall for Minna (1971-2005)

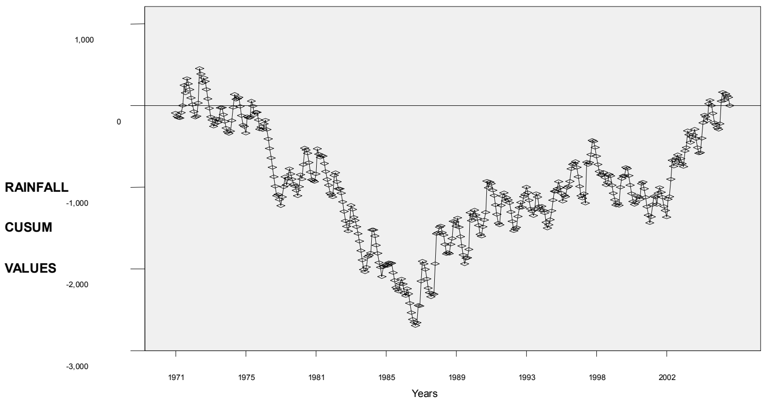

Figure.3 CUSUM plot using observed annual rainfall for Ikeja (1971-2005)

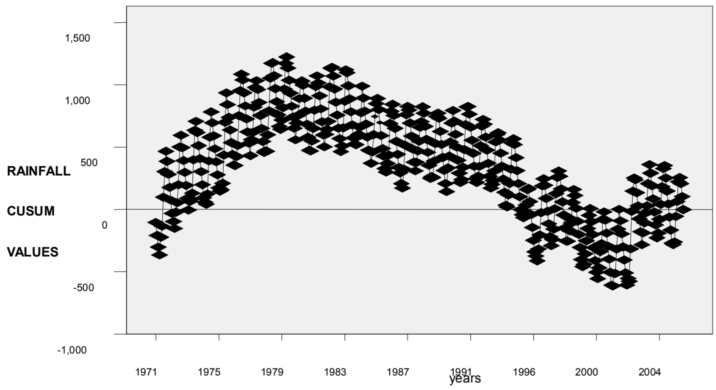

Figure.4 CUSUM plot using observed annual rainfall for Jos Rainfall (1971-2005)

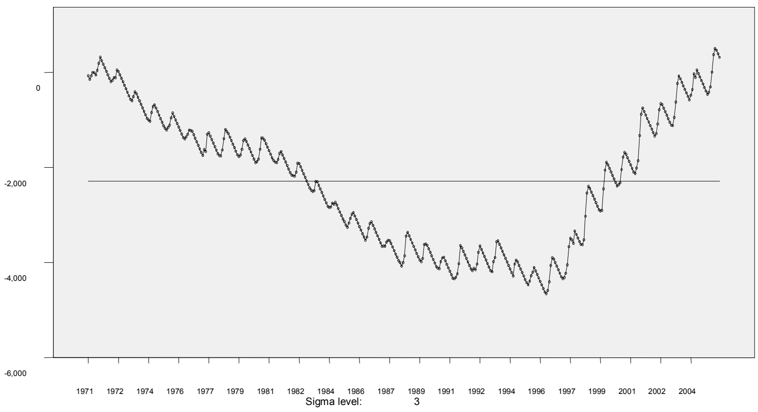

Figure.5 CUSUM plot using observed annual rainfall for Kano (1971-2005)

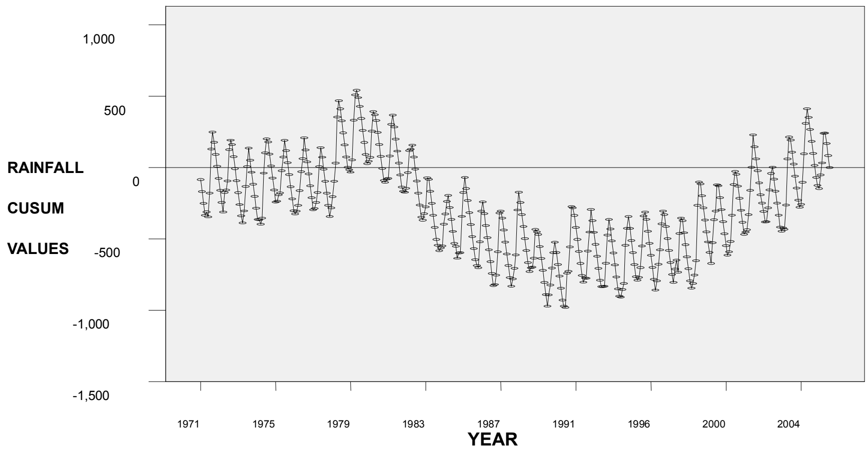

Figure.6 CUSUM plot using observed annual rainfall for Zaria (1971-2005)

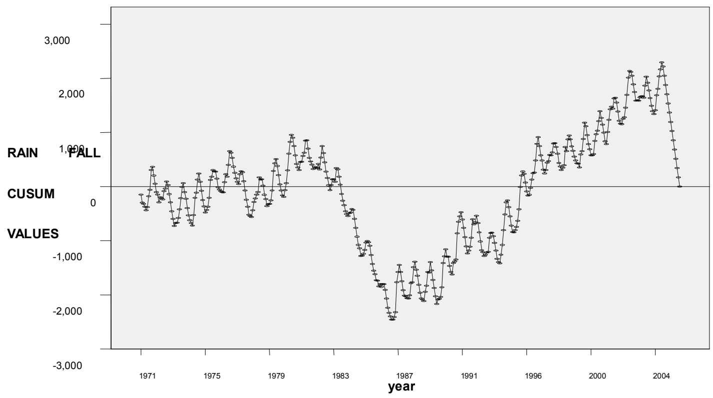

Figure.7 CUSUM plot using observed annual rainfall for Benin (1971-2005)

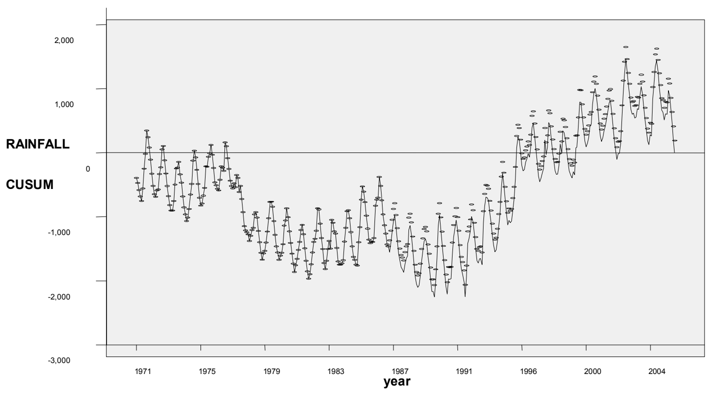

Figure.8 CUSUM plot using observed annual rainfall for Warri (1971-2005)

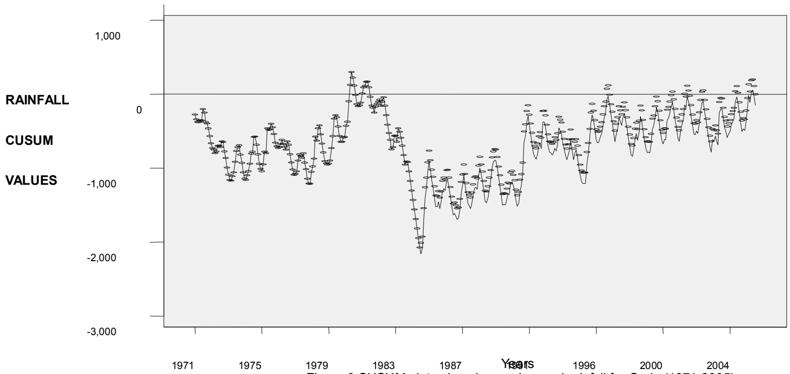

Figure.9 CUSUM plot using observed annual rainfall for Ondo (1971-2005)

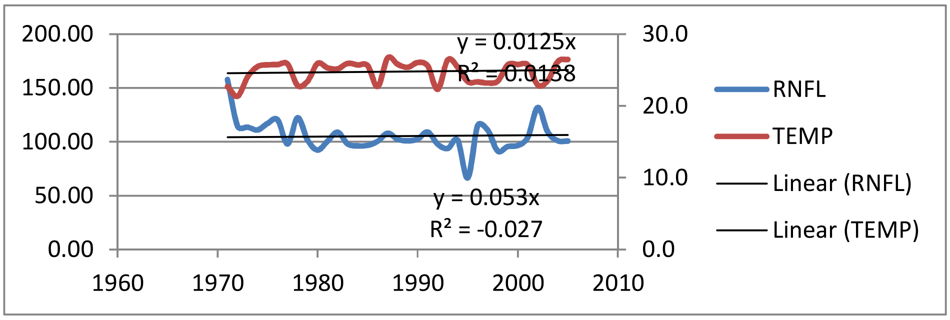

Chart 1; Annual mean Rainfall and Temperature for Plateau State years 1971-2005

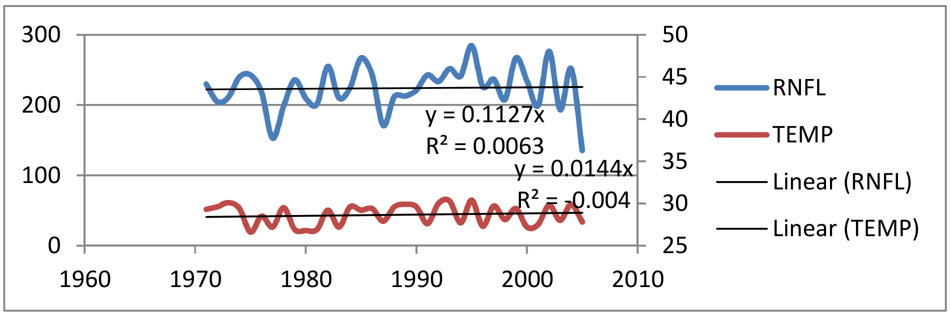

Chart 2; Annual mean Rainfall and Temperature for Delta State years 1971-2005

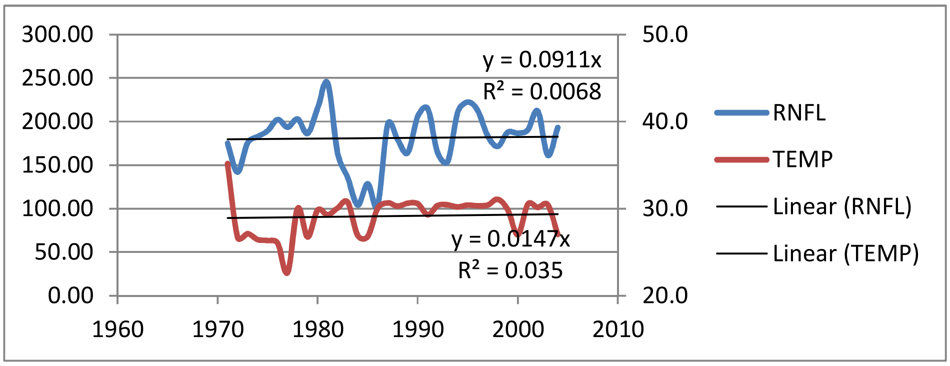

Chart 3; Annual mean Rainfall and Temperature for Edo State years 1971-2005

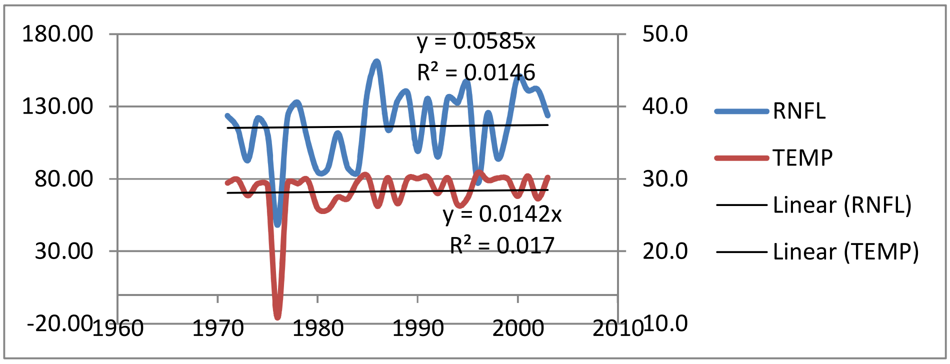

Chart 4; Lagos State Annual mean Rainfall and Temperature for years 1971-2005

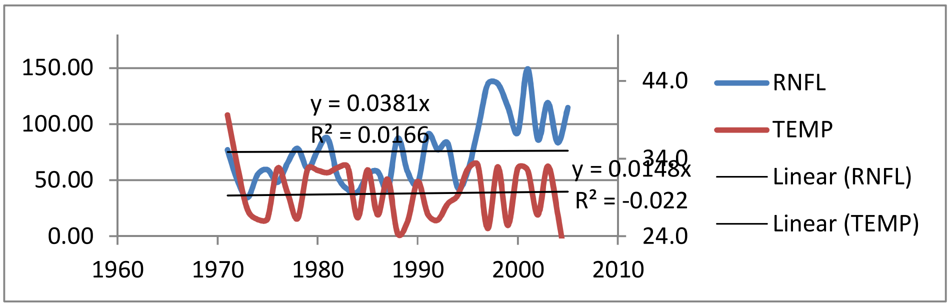

Chart 5; Annual mean Rainfall and Temperature for Kano State years 1971-2005

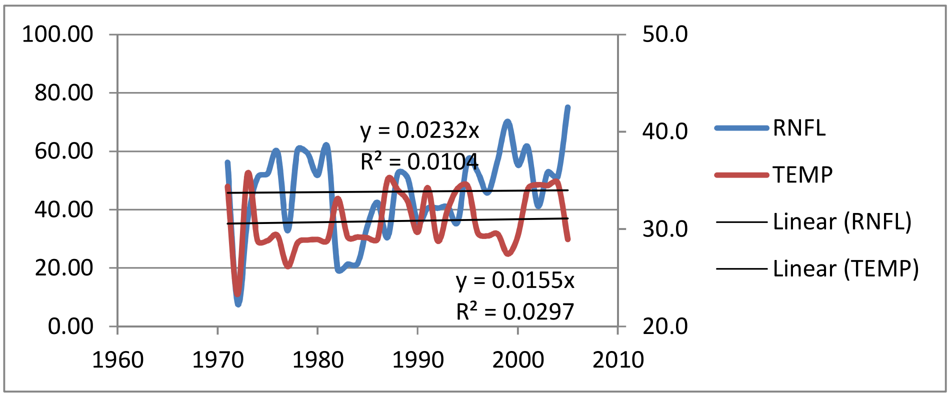

Chart 6; Annual mean Rainfall and Temperature for Borno State years 1971-2005

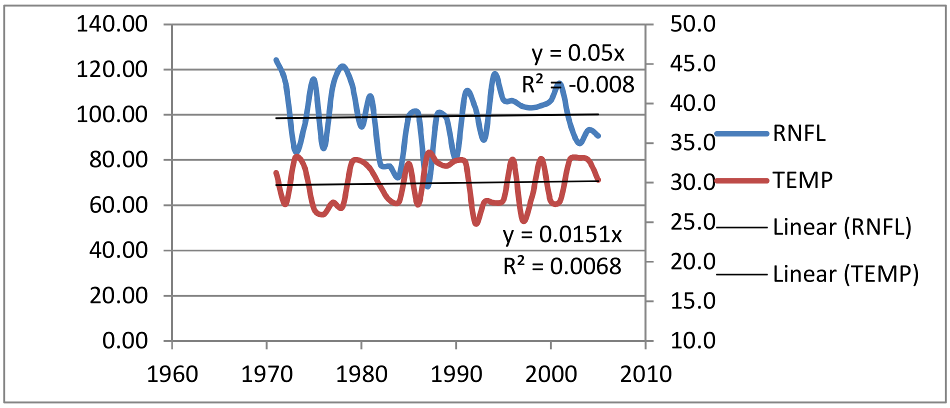

Chart 7; Annual mean Rainfall and Temperature for Niger State years 1971-2005

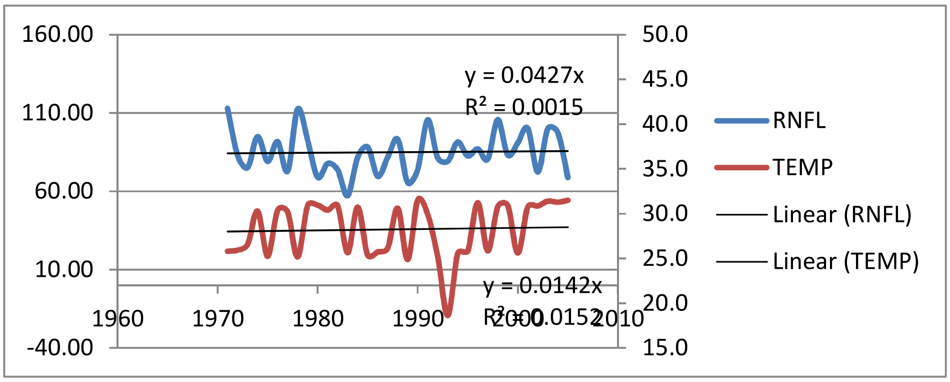

Chart 8: Annual mean Rainfall and Temperature for Zaria State years 1971-2005

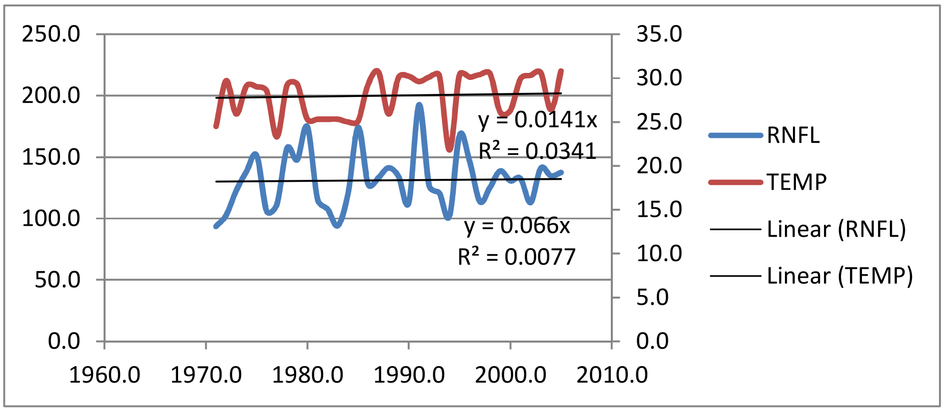

Chart 9; Annual mean Rainfall and Temperature for Ondo State years 1971-2005