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Determination of the Extent of Climate Variability and Climate Change in Rivers State, Nigeria

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ABSTRACT

*Climate change is one of the defining issues of our time. The determination of the extent of climate variability and change in any location is very vital for environmental study assessment and proper planning. This study applied statistical analysis to rainfall and temperature data in the Rivers State of Nigeria. Climate Research (CRU 0.5 0.5) gridded data for 33 locations from 1956 to 2016 were chosen because NIMET only has one gauging station in the state. These data were sorted, validated with NiMet data, and utilized for analyses of various time series techniques such as Mann-Kendal, Spearman's Rho, Linear Regression, Thei-Sen Slope Cumulative sum, Cumulative Deviation, Rank Sum, Student's (t-test), and spectral analysis. The results obtained revealed that there had been increasing temperature and abrupt climatic changes in the state, especially in the 1976-1985 decade, with 1980 as the most probable year of abrupt change. The hottest decade was 1976-1985, with an average temperature change of 0.1255 ^{0}C /decade, while the coolest decade was 1996-2005 with an average temperature change of -0.0132 ^{0}C /decade. Also, there had been some changes in rainfall, with the wettest decade occurring in 2006-2015 with an average rainfall change of 96.8 **mm**/decade, while the driest decade occurred in 1996-2005with an average rainfall change of 29.7mm/decade. The output of spectral analysis showed that the most significant periodicity for rainfall and temperature was 15 years. The result further revealed that there was high rainfall variability with a coefficient of variability of 62.43%. There was a low-temperature variability of 4.314%. These rainfall fluctuations have implications for coastal flooding, quality, and quantity of available groundwater in the state. These results are useful to planners and policymakers in creating awareness of climate change's impact on rainfall in the study area.*

1. Introduction

One of the challenges posed by climate change/climate variability is ascertainment, identification, and quantification of trends in rainfall and their implications on river flows to assist in the formulation of adaptation measures through appropriate strategies of water resources management besides others. It is also recognized that precipitation is one of the key climatic variables that affect both the spatial and temporal patterns of water availability [1]. The vulnerability of the Nigerian coastline to sea level rise is particularly exacerbated by its low lying, densely populated nature, leading to high human activities and oil pollution caused by exploration in some areas. Rainfall, thermal expansion of water in ocean leading to wave heights, increase the risk of coastal flooding, which result in displacement of households, infrastructure loss, accelerated coastal erosion, salinization of surface and coastal aquifer causing declining water quality, an outbreak of waterborne diseases, and diminishing food security. These have been attributed to the impacts of climate change. The determination of the degree of variability and the magnitudes of climate change which have not gained much prominence are crucial for planning adaptation and mitigation measures. The Niger Delta region, where Rivers State is part of, is located within the coastal areas that are most vulnerable to climate change occasioned by a change in temperature, precipitation, and more frequent flooding. This is responsible for the ravaging issue of rising sea levels and wave heights, including accelerated coastal erosion. In addition, coastal communities also face numerous socio-economic challenges that promote their vulnerability to climate change and their ability to respond to changes in severe events such as storms. Examples of such socio-economic challenges include transitory populations, physical isolation, poor-quality housing, and low income [2]. According to projections, temperatures will continue to rise, and increasing sea levels will pose a threat to coastal populations' survival. Rain-fed agricultural and hydropower outages are already being impacted by less rainfall, resulting in severe reductions in industrial production. Flooding will become more common as a result of climate change, particularly in developing countries like Nigeria [3]. Preparation and formulation of appropriate policies to mitigate the impact of climate change and variability in the region require a holistic understanding of the climatic dynamics, both temporal and spatially. Sadly, there is a scarcity of data on current rates of climate variability, changes in coastal geomorphology, and socioeconomic developments in Africa [4]. This has a lot of ramifications for the creation of models that can be used to mitigate climate change and adapt to it. Furthermore, the majority of the information available on the region was either focused on flooding or sea-level rise. However, little research has been done on how the climate in Nigeria's Coastal Region, particularly Rivers State, is changing [5].

2.0 Methodology

2.1 Study Area and Data Used

Rivers State is one of the most prominent states in the oil-rich Niger Delta region of southern Nigeria. Formed in 1967, when it split from the former Eastern Region, it has a total area of 11,077 km² (4,277 mi²), making it the 26th largest state in Nigeria. It is located on latitude 4°44'59.06" (4.74974) N and longitude 6°49'39.58" (6.82766). The surrounding states are Imo, Abia, and Anambra to the north, Akwa Ibom to the east, and Bayelsa, Delta to the west. On the south, it is bounded by the Atlantic Ocean. It has Twenty-three local Government areas and a population of 6,689,087. Fishing and farming are the principal occupations in the state. The state capital, Port Harcourt, is a metropolis that is considered the commercial center of the Nigerian oil industries Its topography ranges from flat plains, with a network of rivers to tributaries.

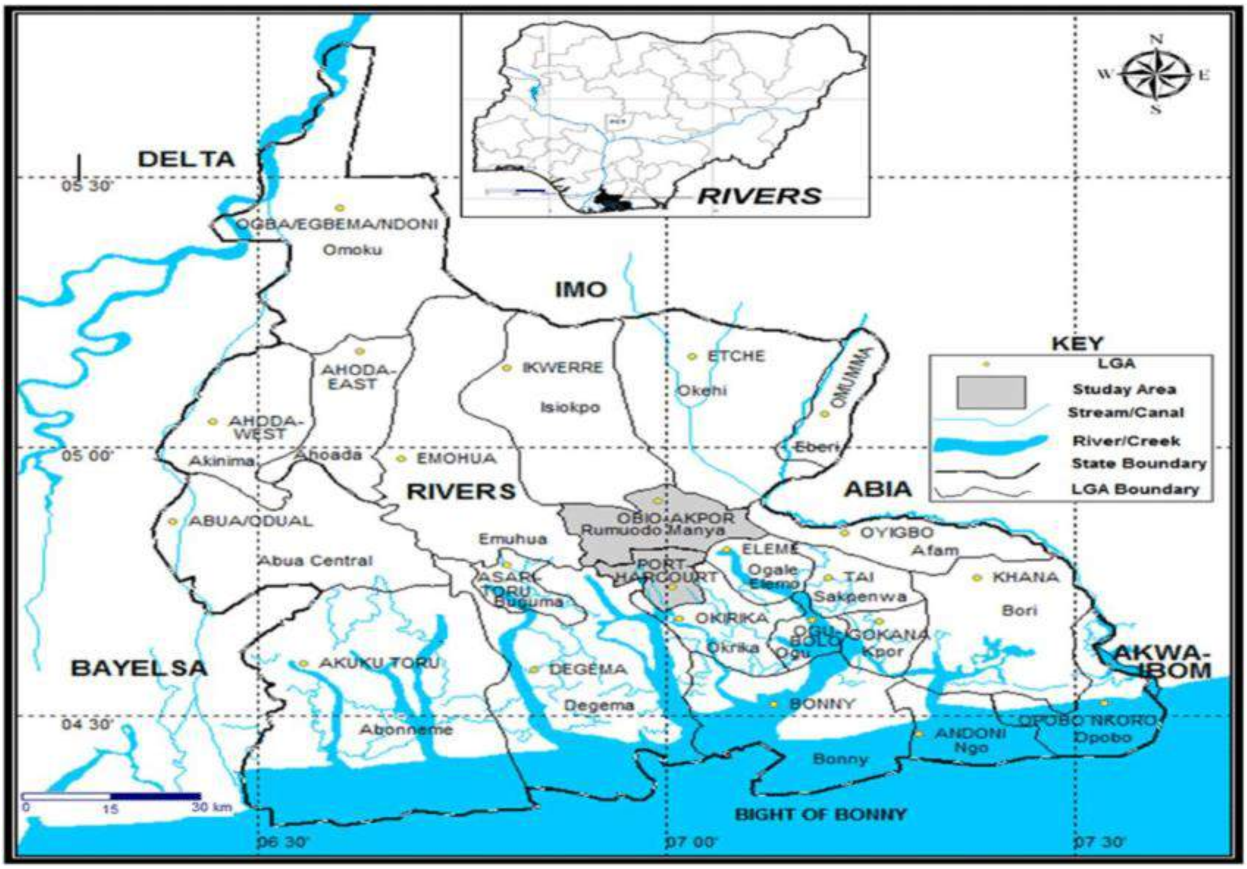


Figure 1 Map of Rivers State showing the study area

2.2. Data Collection

Climate Research Unit 0.5° latitude by 0.5° longitude (CRU 0.5× 0.5) gridded monthly climatic data for two climatic periods ((1956- 1986 and 1987-2016) for twenty -three locations in the state, downloaded from the internet, were sorted into annual rainfall series and validated with the Nigerian Meteorological Agency (NiMet) data. The performance of these data was assessed using a goodness of fit measure such as the coefficient of determination (R^2). When the value of R^2 is within the range of $0.75 < R^2 < 1$, the result is extremely good. The lack of fully accurate data hinders climate trend analysis, adding to the challenges of associated relevant study; thus, data validation was performed. The lack of fully reliable data hinders climate trend analysis, adding to the challenges associated with relevant study; thus, data validation was performed.

2.3. Preliminary Data Analysis

The XLSTAT program was used to implement descriptive statistics of yearly rainfall time series, including minimum, maximum, range, mean, standard deviation, variance, standard error of the mean, kurtosis, and skewness, as well as associated standard errors computations. . These figures aid in gaining a rough understanding of the dispersion and distribution of the mean annual rainfall data set. To evaluate whether the dataset could be characterized by a normal distribution or not, the Shapiro Wilk Test (SWT), D'Agostino-Pearson Test, and Skewness Test were used to compute how probable an underlying random variable was to be normally distributed. As a result, data screening, outlier detection, description, assumption checking, and describing variances among sub-populations became possible.

Homogeneity tests were performed to help assess trend dependability and identify appropriate sub-periods for the investigation. XLSTAT software was used to implement the following homogeneity tests: Pettit's Test, Standard Normal Homogeneity Test (SNHT), Buishand's Test, and Von Neumann Ratio. The extent to which observations in a series separated by different time differences tend to be similar is measured by serial correlation coefficients. Before the application of the Mann-Kendall (MK) test, the time series must be free of serial correlation, which can mislead the actual result of the trends [6]. Consequently, the serial correlation was checked by Durbin Watson' S Test and was implemented using XLSTAT software. The distribution of the residuals is assumed to be constant across the plot in linear regression. (Homoscedastic). To confirm this Breusch-Pagan & White heteroscedasticity test was implemented by using XLSTAT Software. This was to ensure that Linear Regression Model can be safely used for further analysis The time series must be devoid of serial correlation before applying the Mann-Kendall (MK) test, as this can mislead the true outcome of the trends (Yue et al.,2002).

2.4. Data Analysis

The following time series was used to discover a trend in the yearly rainfall data: Mann-Kendal, Spearman's Rho, and Linear Regression test. Thei-Sen Slope test was used to determine the magnitude of the trend analysis. The Distribution-free CUSUM (cumulative sum) test, Cumulative Deviation, and the Worsley Likelihood test were used for Rainfall abrupt change (Step Jump) detection. Rank Sum & Student's (t-test) were used to check for differences between means of two climatic periods using TREND Software. Finally, Periodicity (cycles) were determined by the spectral analysis were implemented using XLSTAT. This study revealed recurrent cycles of various lengths in a time series that appeared to be random noise at first. A periodogram is a graph that shows the amplitude (or power) of each cycle vs its frequency (or periods).

2.5. The Mann-Kendall (MK)

Spatial annual rainfall time series were examined for the presence of trends by using MK, a non - parametric testIt tests statistic *Z* was calculated as:

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{V(S)}}, & S > 0, \\ 0 & S = 0, \\ \frac{S+1}{\sqrt{V(S)}}, & S < 0. \end{cases} \tag{1}$$

Z_s is the standard normal test statistic in cases where the sample size is $n > 10$.

The variance *V(S)* of statistic *S* obtained as:

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{m}(t_k - 1)(2t_k + 5)}{18} \tag{2}$$

Where m signifies the number of ties for the value and denotes the number of connected groups. A tied group is a collection of samples with the same value.

For α=0.1, $Z_{(\alpha/2)} = Z_{0.05=1.645}$ (3)

If *UC* I > $Z_{0.05\ (1.645)}$, the null hypothesis of no trend is rejected at the α significance level

2.6. Theil-Sen Analysis

Theil-Sen estimator is used in quantifying the magnitude of trends. It has been widely used in analyzing hydrological time series data. Theil-Sen's estimator is computed as [7];

$$Q_{med} = median(Q),$$

$$Q = \frac{x_j - x_i}{j - i}, i < j, \quad (4)$$

Where Q_{med} = slope between data points *x*i and *x*j, *x*i = data measurement at time *i*, *x*j = data measurement at time *j*; and *j* = time after time *i*; respectively.

2.7. Spearman's Rho Test for Trend (R_S) [7]

This is a nonparametric and *Rank-based,* alternative to the Pearson R, which i (6) st

The hypotheses for a direct trend (one-sided) are:

H0: The values of the series represent a sequence of n independent events.

(7)

HA: The values show a positive correlation

For the two series x_i and y_i, the rank of each item within each series separately is determined, with a rank of 1 for the smallest value and a rank of n for the largest value. The ranks are represented by r_{xi} and r_{yi}, with the I corresponding to the ith magnitude. Using the ranks for the paired values r_{xi} and r_{yi}, the value of the Spearman coefficient RS is computed using:

$$R_s = 1 - \frac{6\sum_{i=1}^{N}(r_{xi} - r_{yi})^2}{n^3 - n} \quad (6)$$

For sample sizes greater than ten, the following statistic can be used to test the above hypotheses:

$$t = \frac{R_s}{\left[(1 - R_s^2)/(n-2)\right]^{0.5}} \quad (7)$$

where t follows a Student's t distribution with n - 2 degrees of freedom. For a one-sided test for a direct trend, the null hypothesis is rejected when the computed t is greater than the critical t_α for n - 2 degrees of freedom.

2.8. Linear Regression Test

The test statistic follows a t distribution with (n-2) degrees of freedom, where n is the total number of observations. This study revealed recurrent cycles of various lengths in a time series that appeared to be random noise at first. A periodogram is a graph that shows the amplitude (or power) of each cycle vs its frequency (or periods). The null hypothesis, Ho, is accepted if the test statistic's estimated value is such that: The regression formula is as follows:

$$y = a + bx \quad (8)$$

The regression gradient is estimated by:

$$b = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sum_{i=1}^{n}(x_i - \overline{x})^2} \quad (9)$$

And the intercept is estimated as:

$$a = y - bx \quad (10)$$

The test statistic is a t statistic (t), which is described by the equation:

$T_O = b_1 / SE$ (11)

where b1 is the sample regression line's slope and SE is the slope's standard error.

$SE = s_{b1} = \text{sqrt} [\Sigma(y_i - \hat{y}_i)^2 / (n - 2)] / \text{sqrt} [\Sigma(x_i - x)^2]$ (12)

$$-t_{\alpha/2,n-2} < T_0 < t_{\alpha/2,n-2}$$

where $t_{\alpha/2,n-2}$ and $-t_{\alpha/2,n-2}$ are the critical values of the two-sided hypothesis' crucial values. is the significance level, and is the percentile of the distribution corresponding to a cumulative probability of

2.9. Distribution Free Cumulative Sum (CUSUM) Test

Distribution free CUSUM test was used to identify the change point in a series of data This approach (Chiew and Siriwardena 2005) determined whether the means in two parts of a record were time series data (x1, x2, x3,... xn). The test statistic is:

$$V_k = \sum_{i=1}^{k} \text{sgn}(x_i - x_{mean}) \; k = 1,2,3,.....,n. \tag{13}$$

Where sgn(x) = 1 for x > 0

sgn(x) = 0 for x = 0

sgn(x) = -1 for x < 0

x_{medium} is the median value of the x_i data set.

The distribution of V_k follows the Kolmogorov-Smirnov two-sample statistic (KS=(2/n) max $|V_k|$) given by: CUMSUM values - Cumulative sum series.

2.10. Cumulative Deviation Test

This test is performed to find out if there has been a change in the mean. . The cumulative deviations from the mean are determined using the following formula:

$$S_o \dot{.} = 0 \; S_k = \sum_{i=1}^{k} \left(x_i - X \right) \; k = 1,2,3,.....,n.. \quad (14)$$

and by dividing the Sk* values by the standard deviation, the rescaled adjusted partial sums are obtained:

$$S_k^{**} = S_k^{*}/D \quad (15)$$

$$D_x^{\;2} = \sum_{i=1}^{n} \frac{\left(x_i - x \right)^2}{n} \quad (16)$$

The test statistic Q (sensitive to departure from homogeneity) is:

$$Q = \max | S_k^{**} | \quad (17)$$

Each year's value is calculated, with the highest value representing the year's changing point. Sk * with a negative value indicates that the mean of the latter section of the record is greater than the earlier part, and vice versa.

the critical value =Q/√ (n) at 95% confidence interval. The following formula is used to compute the cumulative deviations from the mean:

$$S_o \dot{.} = 0 \; S_k = \sum_{i=1}^{k} \left(x_i - X \right) \; k = 1,2,3,.....,n.. \quad (18)$$

and by dividing the Sk* values by the standard deviation, the rescaled adjusted partial sums are obtained:

$$S_k^{**} = S_k^{*}/D \quad (19)$$

$$D_x^{\;2} = \sum_{i=1}^{n} \frac{\left(x_i - x \right)^2}{n} \quad (20)$$

The test statistic Q (sensitive to departure from homogeneity) is:

$$Q = \max |S_k^{**}| \quad (21)$$

Each year's value is calculated, with the highest value representing the year's changing point. Sk * with a negative value indicates that the mean of the latter section of the record is greater than the earlier part, and vice versa.

he critical value =Q/√ (n) at 95% confidence interval

2.11. Worsley Likelihood

This method [8] determines whether the means of two segments of a recorded data set differ considerably (for an unknown period of change).

$$W = \frac{(n-2)^{0.5}V}{\left(1-V^2\right)^{0.5}}$$

$$where\ V \max |Z_k **| \quad . \quad (22)$$

A negative W number implies that the mean of the latter half of the record is greater than the earlier part, and vice versa.

2.12. Mann Whitney U Test (Wilcoxon Rank Sum Test)

The Wilcoxon Rank Sum Test is used to determine whether two samples came from the same population (i.e., that the two populations have the same shape). The following are the null and two-sided study hypotheses for the nonparametric test: In the case of a two-tailed statistical test,

Null hypothesis**:** H_O: $\mu_1=\mu_2$, i.e. the two populations mean are equal

Alternative hypothesis: H_a: $\mu_1 \neq \mu_2$, i.e**.** the two populations mean are not equal

The decision rule for an α-level test: For large sample: Reject H_O ***in favour of*** H_a

According to Woolson and Clarke (*2002)* ***if***

$$Z_{obs} = T_{1-0.5}\ n_1\ (n_1 \cdot n_2(n_1+n_2+1))/_{)/sqr}\ (n_1 \cdot n_2(n_1+n_2+1))/12 \quad > Z_{1-\alpha/2} \quad (23)$$

or if Z_{obs} = $T_{1-0.5}$ n_1 $(n_1+n_2+1))/_{)/sqr}$ $(n_1 \cdot n_2\ (n_1+n_2+1))/12$ $<-Z_{1-\alpha/2}$ (24)

where n1 denotes the sample 1 number of subjects and n2 denotes the sample 2 number of subjects. n=n1+n2 is the total number of subjects.

2.13. Student's t-Test

This test is used to check the null hypothesis of whether equal means in two different periods are different [7]. The test is based on the assumption that the data is regularly distributed. The following is how the relationship is expressed:

$$t = \frac{(x\,y)}{S\sqrt{\frac{1}{n}+\frac{1}{m}}} \quad (25)$$

where x. and,y. in equation 24 are the first and second-period means, m and n are the first and second-period numbers of observations, and S is the sample standard deviation (of the entire m and n observations). The P-value is calculated using the t statistic test statistic and the degrees of freedom. The likelihood that a t statistic with 59 degrees of freedom is more extreme than 2.29 is given by the P-value. "More extreme" indicates greater than 2.29 or less than -2.29 in this two-tailed test.

The null hypothesis, H_0, is accepted if the calculated value of the test statistic is such that:

$-t_{\alpha/2,n-2} < T_0 < t_{\alpha/2,n-2}$ where $t_{\alpha/2,n-2}$ and $-t_{\alpha/2,n-2}$ are the critical values for the two-sided hypothesis. $t_{\alpha/2,n-2}$ is the percentile of the t distribution corresponding to a cumulative probability of $(1-\alpha/2)$, and α is the significance level.

3.0 Results

3.1 Preliminary analysis

Results of the analysis carried out are presented in Table1and Table 2.

Table .1: Comparison Between NIMET and CRU data for Rainfall and Temperature

S/N	R^2	Adj R^2	K tau	RSR	MAPE	Cp

1	Rainfall	0.927	V.good	0.903	V.good	0.818	V.good	0.312	V.good	18.17	Good	2	OK
2	Temp	0.905	V.good	0.922	V.good	0.855	V.good	0.278	V.good	0.623	H	2	OK

H=Highly Reliable, OK= capable or Reliable

3.1.1 Validity analysis

The results of validity analysis indicate that R^2 was 0.927 and. 0.905 for rainfall and temperature, respectively. This performance rating of R^2 is very good as $0.75 < R^2 \leq 1$. Hence, the CRU data obtained is very reliable and could be safely used for further analysis in this study. The descriptive statistics of mean annual rainfall (1956- 1986 and 1987-2016) are presented in Table 2 .

Table 2: Descriptive statistics of mean annual rainfall **(1956- 1986 and 1987-2016)**,

Climatic Type	Climatic period	Mean	SD	Min	Max	Range	Sum (mm)	%CV	Skewness	Kurtosis
		mm	mm	mm	mm	mm/				
Rainfall	NIMET	215.2455	133.545	17834.28	20.35	344.1312	369.75	2367.7	0.039566	-1.66506
Rainfall	CRU	246.76	154.04	23729.21	44.17	456.724	412.55	2961.13	0.030139	-1.58832
Temp	NIMET	27.017	0.972	0.947	25.76	28.508	2.75	297.187	0.2653	-1.2259
Temp	CRU	30.512	1.299	1.688	28.368	32.157	3.79	366.14	-0.3456	-1.1793
Rainfall	First	271.801	146.829	51.256	465.637	414.382	2989.82	54.021	-0.056	-1.409
Rainfall	Second	258.555	148.322	46.251	468.963	422.712	2844.11	57.366	-0.113	-1.481

Temp	First	30.195	1.288	28.298	31.937	3.639	332.140	4.266	-0.035	-1.326
Temp	Second	30.686	1.393	28.438	32.377	3.939	337.550	4.539*	-0.314	-1.306

Table 2 was obtained by use of XL Statistic software. The table shows that the mean annual rainfall varies from 258.555mm in (Second climatic period) to mm271.801 in (First climatic period). The standard deviation varied from 148.322 mm to 146.829 mm, while the skewness and kurtosis varied from -0.056 to-0.113 and-1.481 to -1.481, respectively. These skewness and kurtosis values indicate that the rainfall series is close to being a normal distribution.

3.1.2 Three common normality tests were carried out, namely Shapiro Wilk Test (SWT), D`Agostino-Pearson Test, and Skewness Test. The outcomes are shown in Table 3.

Table: 3 Result of Test for Normality of Spatial Rainfall and Temperature Data

SHAPIRO WILK TEST (SWT)				D`AGOSTINO-PEARSON TEST				SKEWNESS TEST (-0.59<s<0.59)		
W-STAT	P-value	Alpha	normal	DA STAT	P-value	alpha	Normal	S	alpha	Normality
0,92684	0.37975	0.05	YES	2.2976	0.3170	0.05	YES	0.03014	0.05	YES
0.9593	0.7775	0.05	YES	1.094	0.5787	0.05	YES	-0.3456	0.05	YES

Hypotheses

Null hypothesis =Ho: The data follow a normal distribution

Alternate hypothesis =Hi: The Data do not follow a normal distribution

We tested the above Hypotheses at a 0.05 significant level

When the p-value exceeds the significance level, the null hypothesis is not rejected because there is insufficient evidence to conclude that the data do not follow a normal distribution. The findings show that all three normality tests agree that the rainfall series has a normal distribution. In parametric testing, the normal distribution assumption is crucial for accuracy.

3.1.3 Using the statistical analysis program XLSTAT 2016, the homogeneity of the annual total rainfall was evaluated using the following four homogeneity tests: The Pettitt test Von Neumann's ratio (VNR) test, Buishand's test (BRT), and the standard normal homogeneity test (SNHT). Table 4 summarizes the results of the homogeneity tests.

Table 4 Results of Homogeneity Tests

PETTIT'S TEST				SNHT			
K-Value	Year	P-Value	T	To-Value	Year	P-Value	T
466	1980	0.004	Ha	14.12	1969	0.002	Ha

BUSHANDS TEST				VON NEUMANNS		
Q-Value	N	P-Value	T	N	P-Value	T
13.332	1980	0.002	Ha	1.124	0.00	Ha

Homogeneous data is a term used to describe a homogeneous set of data.

Ha: There is a point in time when the data changes.

As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis Ho and accept the alternate hypothesis Ha that the data is not homogeneous. The four homogeneity tests were in agreement that the data series is not homogeneous. A homogeneous climate time series is one where the variations are caused only by variations in climate [10]. The input data of CRU were homogenized. Hence the cause of noticed inhomogeneity may be due to climate variability. The plot of the homogeneity test showing abrupt changes for rainfall and significant abrupt changes for temperature are presented in Figures 2 and 3.

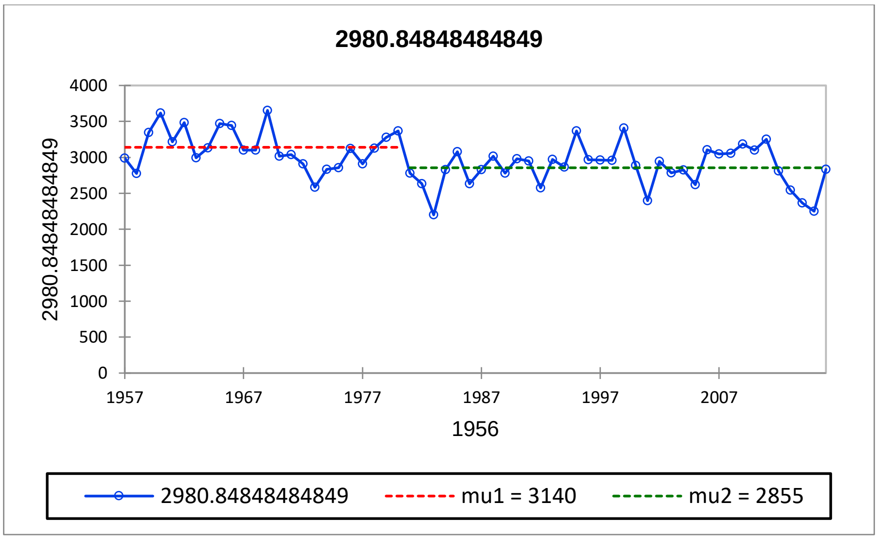


Figure 2. Homogeneity Plot showing abrupt change for Rainfall

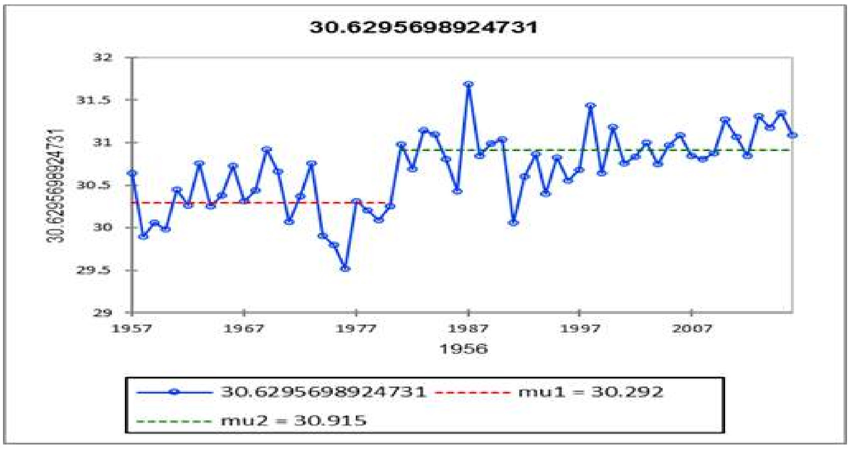


Figure 3 Homogeneity Plot showing abrupt change for Temperature

3.1.4 Detection of Autocorrelation Analysis

The Durbin Watson was used to detect autocorrelation analysis. Table 5 shows the results of the Durbin Watson' S Test conducted to detect autocorrelation.

Table 5 Result of Durbin Watson' S Test

DW	RHO	P-VALUE	ALPHA	DECISION (accept)

0.012	0.437	<0.0001	0.050	Ha

Test interpretation

H0: The residuals are not autocorrelated (order=1)

Ha: rho ≠ 0

Since the computed p-value is less than the significance level alpha=0.05, the null hypothesis H0 should be rejected, and the alternative hypothesis Ha that the residuals are autocorrelated should be accepted. Regression analysis is a useful tool for testing trends when a serial correlation is low. The time series must be free of serial correlation before the MK test can be applied, as this can cause the actual result of the trends to be misled [11]. Trend-Free Pre-Whitening (TFPW) was used in this study to remove serial correlation from a time series. This method has been used to remove serial correlation in various studies, such as [3].

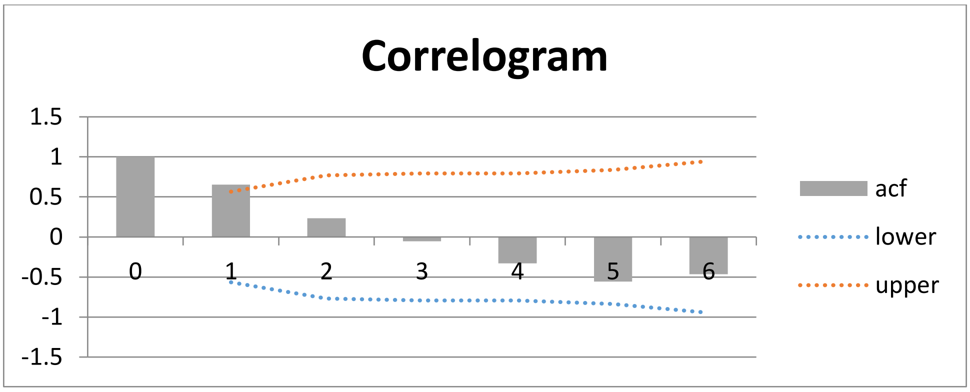


Figure 4 Correlogram of Rivers State Rainfall

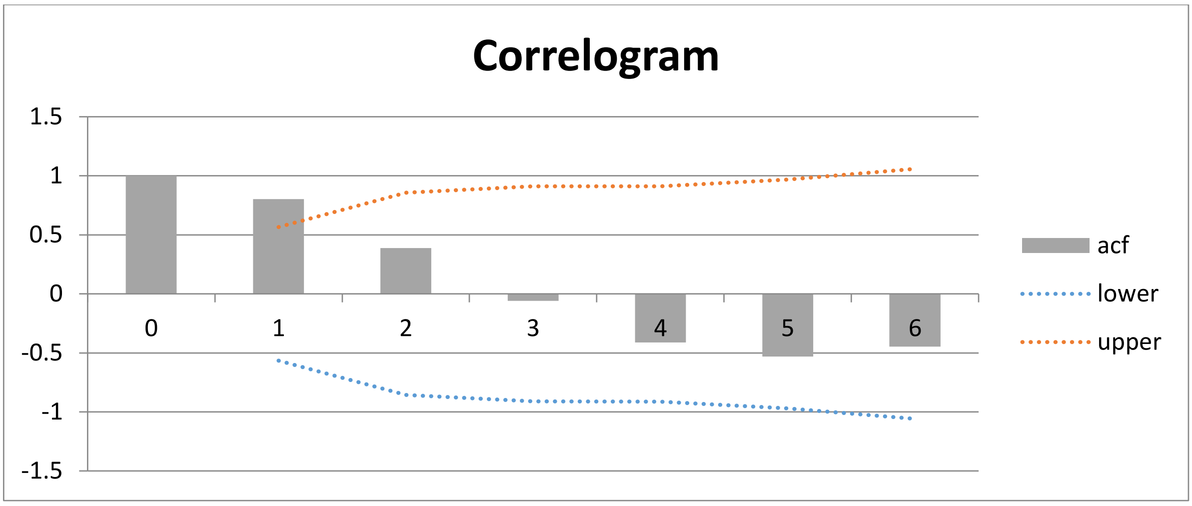


Figure 5. Correlogram of Rivers State Temperature

3.1.5 **Detecting Heteroscedasticity**: Breusch-Pagan & White Test under Regression in XL Statistic software was used. The results are presented in Table 6.

Table 6. Results of Heteroscedasticity Test of Rainfall and Temperature

LM Observed		LM Critical	Df	P-value Two tail	Alpha	Decision
Rainfall	0.746	5.991	2	0.689	0.05	Cannot Reject Ho
Temp.	6.136	5.991	2	0.047	0.05	Reject Ho

H0: Residuals are homoscedastic

Ha: Residuals are heteroscedastic

The null hypothesis H_0 cannot be rejected because the computed p-value is greater than the significance level alpha=0.05. As a result, the residual rainfall series exists. Homoscedastic. The spread of the residuals is assumed to be constant across the plot in linear regression. As a result, the Linear Regression Model can be used safely for further analysis.

3.2 Trend Series Analysis

3.2.1 The results of three trend detection tests carried out following the procedures of TREND software are presented in Tables 7. These tests are Mann-Kendal, Thei-Sen, Spearman's Rho, and Linear Regression. The plot of Linear Regression is presented in Figures 1 (a) and (b) and Table7

Table 7. Summary of Trend Detection for Rainfall **(1956 - 2016)**

TEST	• TREND DETECTION AND MAGNITUDE OF TREND			
STATISTIC	Mann-Kendal	Thei-Sen	Spearman's Rho	Linear
	α=0.05	α=0.05	α=0.05	Regression α=0.05
TEST STAT	-2.906	-6.3348	-2.87	-3.318
Critical value	**2.276**	**-**	**2.576**	**2.662**
Decision	Show no Significant TREND			

The values of the test statistics for Mann-Kendal, Spearman's Rho, and Linear Regression were in agreement as in Table 7 and indicated that there was no significant trend in annual rainfall. The Thei-Sen Slope test gave the magnitude of the trend to be 2.8276mm/year.

The null hypothesis Ho: there is no trend in the data.

The alternate hypothesis Ha: there is a trend in the data

If the value is greater than the critical value, the null hypothesis is rejected. Accept the alternative hypothesis and assume there is no trend in the data. There is a trend in the data at the 0.05 significant level, indicating an increasing trend with an annual rate of 15.4 and 15.8mm, respectively. and the R^2 =0.5012 and 0.5178. For **0.5<** $^{R^2}$**≤0.65** as in the case above, R^2 is satisfactory as 50 to 52% can be explained by a linear regression line. Hence linear regression model can safely be used to model these series.

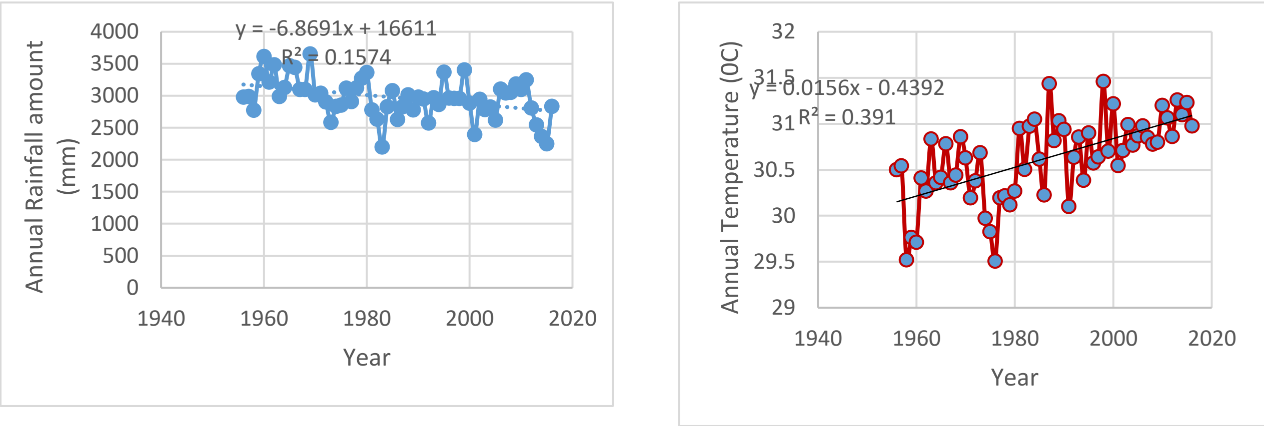


Figure 6(a) & (b). Annual rainfall and temperature spatial for Rivers

3.2. 2. We established the existence of trend and the magnitude of the trend using **Mann-Kendal**

and Thei-Sen Slope test, which was implemented by XLSTAT Software. The results obtained from 33 locations are presented in Table 8.

Table 8. Results of Trend Magnitude Using Thie Sen Slope

S/N	Town	SLOPE of Linear Regression	**Thie Sen Slope** Rainfall(mm/Yr)	**Mann-Kendal** Z-test
1	Ahoada	**-2.7202**	-2.36041	-1.462
2	Alalabo Obenikiri	**-11.016**	-10.4563	-3.958
3	Apiboko	**-13.373**	-12.8377	-3.976
4	Arugbana	**-8.9408**	-8.3312	-3.329

5	Ataba	**-6.9664**	-6.37705	-1.96
6	Bane	**-9.9768**	-9.86941	-3.528
7	***Bomu**	**-18.799**	**18.1594**	**-5.52**
8	Bonny	**-0.4772**	-3.57484	4.86
9	Degema	**-6.4779**	-5.93489	-2.993
10	Eberi	**-0.4729**	1.720343	-0.056
11	Egbeda	**1.0793**	1.720343	0.983
12	Egbolom	**-4.0603**	-3.74895	-1.848
13	Elem Ifoko	**-5.6304**	-6.54478	-1.711
14	Emaguo	**-4.6006**	-3.71964	-1.637
15	Igwuruta	**-7.4515**	-6.67726	-3.578
16	Ikodi	**3.7375**	-1.7045	1.861
17	Ikuru	**-1.5183**	**-0.38838**	-0.131
18	Isiokpo	**-0.534**	0.159813	0.131
19	Ke ke	**-9.2391**	-9.26941	-2.037
20	Mbiama	**5.0091**	5.584748	2.632
21	Obete	**-10.044**	-9.74393	-4.001

22	Ogoni	**-12.487**	-11.8996	-4.443
23	Okoloma	**-7.224**	-6.14033	-2.993
24	Okwali	**-9.6348**	-9.08485	-3.777
25	Oloma	**-2.2721**	-0.70818	-0.199
26	Omoku	**-2.2721**	0.707778	0.423
27	**Opobo**	**0.0983**	**0.962707**	**0.274**
28	**Opuoko**	**-13.748**	**-13.7074**	**-4.81**
29	Port Harcourt	**-13.278**	-13.2074	-4.91
30	Rumuekini	**-8.8757**	-8.19053	-4.076
31	Rumuji	**-1.9893**	-1.26454	-0.697
32	Umuede	**-1.2435**	-0.83985	-0.591
33	**Woji**	**-17.22**	**17.20**	**-5.862**
	MAXIMUM	**-18.799**	17.20	-5.862
	MINIMUM	**-0.0983**	-0.38838	-0.056

Table 8 shows that Bomu and Woji had an annual rate of change of 18.799 l(mm/Yr) and 17.22 (mm/Yr) for rainfall. The results of Linear Regression Analysis of rainfall Trends obtained from 33 locations are presented in Table 9.

Table 9. Linear Regression Analysis of Rainfall and Temperature Trends

Town	EQUATION	R^2	SLOPE	NATURE	EQUATION	R^2	SLOPE	NATURE
Ahoada	Y=-2.72X+7939	**0.0406**	**-2.7202**	**De**creasing	Y=0.166X-2.3002	**0.4154**	**0.0166**	Increasing
Alalabo Obenikiri	Y=-11.016+24997	**0.2587**	**-11.016**	**De**creasing	Y=0.0161X-1.5084	**0.4013**	**0.0161**	Increasing
Apiboko	Y=-13.373X+29694	**0.2719**	**-13.373**	**De**creasing	Y=0.0158X-0.8181	**0.3848**	**0.0158**	Increasing
Arugbana	Y=-8,94X+20934	**0.202**	**-8.9408**	**De**creasing	Y=0.016X-1.2471	**0.3993**	**0.016**	Increasing
Ataba	Y=-6.966X+17470	**0.0954**	**-6.9664**	**De**creasing	Y=0.0155X-0.0896	**0.3868**	**0.0155**	Increasing
Bane	Y=-9.977X+23097	**0.2176**	**-9.9768**	**De**creasing	Y=0.0149X+1.099	**0.3721**	**0.0149**	Increasing
Bomu	Y=**-18.799**X+40465	**0.4877**	**-18.799**	**De**creasing	Y=**0.0155**X+0.2167	**0.3892**	**0.155**	Increasing
Bonny	Y=**-0.4772**X+2568	**0.0233**	**-0.4772**	**De**creasing	Y=**0.0152**X-0.1867	**0.375**	**0.0152**	Increasing
Degema	Y=**-6.4779**X+1550	**0.1531**	**-6.4779**	**De**creasing	Y=**0.0165**X-2.1195	**0.4079**	**0.0165**	Increasing
Eberi	Y=**-0.473**X+3422.8	**0.0011**	**-0.4729**	**De**creasing	Y=**0.0152**X+0.3428	**0.3731**	**0.0152**	Increasing
Egbeda	Y=**1.079**X+357.18	**0.007**	**1.0793**	Increasing	Y=**0.0163**X-1.793	**0.4083**	**0.0163**	Increasing

Egbolom	Y=-**4.06**X+10744	**0.066**	**-4.0603**	**De**creasing	Y=**0.0158**X+0.16212	**0.3915**	**0.0158**	Increasing
Elem Ifoko	Y=-5.63X+14900	**0.0545**	**-5.6304**	**De**creasing	Y=**0.0156**X-1.5757	**0.387**	**0.0156**	Increasing
Emaguo	Y= -**4.6006**X+12060	**0.0679**	**-4.6006**	**De**creasing	Y=-**0.0157**X-0.7226	**0.387**	**0.0i57**	Increasing
Igwuruta	Y=-**7.4515**+1732	**0.214**	**-7.4515**	**De**creasing	Y=**0.0158**X-0.6619	**0.3915**	**0.0158**	Increasing
Ikodi	Y=**3.73**X-4574.3	**0.0494**	**3.7375**	Increasing	Y=**0.016**X+0.12817	**0.4018**	**0.016**	Increasing
Ikuru	Y=-1.518X+6745.8	**0.0054**	**-1.5183**	**De**creasing	Y=**0.0146**X+1.6226	**0.3557**	**0.0146**	Increasing
Isiokpo	Y=-**0.534**X+3536.8	**0.0016**	**-0.534**	**De**creasing	Y=**0.0157**X-0…7634	**0.392**	**0.0157**	Increasing
Ke ke	Y=-**9.239**X+2178	**0.1317**	**-9.2391**	**De**creasing	Y=**0.0158**X-1.0418	**0.3954**	**0.0158**	Increasing
Mbiama	Y=**5.009**X-7156.7	**0.0968**	**5.0091**	Increasing	Y=**0.0161**X-1.3611	**0.0161**	**0.0161**	Increasing
Obete	Y=-**10.044**X+22819	**0.2913**	**-10.044**	**De**creasing	Y=**0.0146**X+1.7619	**0.0146**	**0.0146**	Increasing
Ogoni	Y=-**12.487**X+27628	**0.3423**	**-12.487**	**De**creasing	Y=**0.0157**X+0.4591	**0.3889**	**0.0157**	Increasing
Okoloma	Y=-**7.224**X+17139	**0.1862**	**-7.224**	**De**creasing	Y=**0.0154**X+0.0644	**0.3786**	**0.0154**	Increasing
Okwali	Y=-**9.6348**X+21997	**0.2635**	**-9.6348**	Increasing	Y=**0.0151**X+0.6393	**0.373**	**0.0151**	Increasing

Oloma	Y=-**2.2721**X+8513.8	**0.0086**	**-2.2721**	**Dec** reasing	Y=**0.0148**X+1.0331	**0.356**	**0.0148**	Increasing
Omoku	Y=-**2.2272**X+0.8948	**0.0086**	**-2.2721**	**Dec**reasing	Y=**0.0164**X-1.732	**0.4103**	**0.0164**	Increasing
Opobo	Y=**0.0983**X+3493	**2E-05**	**0.0983**	Increasing	Y=**0.0145**X+1.852	**0.3583**	**0.0145**	Increasing
Opuoko	Y=-**13.748**X+30438	**0.3854**	**-13.748**	**Dec**reasing	Y=**0.0147**X+1.5988	**0.3618**	**0.0147**	Increasing
Port Harcourt	Y=-**13.278**X+29131	**0.3737**	**-13.278**	**Dec**reasing	Y=**0.016**X-0.9229	**0.3975**	**0.016**	Increasing
Rumuekini	Y=-**8.8757**X+20176	**0.2645**	**-8.8757**	**Dec**reasing	Y=**0.0157**X-0.516	**0.3924**	**0.0157**	Increasing
Rumuji	Y=-**1.94**X+6559.6	**0.0194**	**-1.9893**	**Dec**reasing	Y=**0.0164**X-1.9176	**0.4076**	**0.0164**	Increasing
Umuede	Y=-**1.2435**X+4899.9	**0.0082**	**-1.2435**	**Dec**reasing	Y=**0.0155**X-0.1192	**0.3803**	**0.0155**	Increasing
Woji	Y=**-17.22** X+36777	**0.5305**	**-17.22**	**Dec**reasing	Y=**0.0162**X-1.3398	**0.4022**	**0.0162**	Increasing

Table 9 shows the result of **the** Linear Regression Analysis of rainfall and Temperature Trends**.** Rainfall significantly decreased in all locations except at Egbeda, Ikodi, Mbiama, and Opobo where it increases significantly. However, there was a significant increase in temperature in all locations.

3.2.3 The Summary of the result of the Abrupt Change/Jump Detection test.

The summary of the result of the Abrupt Change/Jump Detection test for rainfall **(**1956-2016) is presented in Table 10.

Table 10 (a). Summary of Abrupt Change/Jump Detection for Rainfall **(1956-2016)**

TEST	ABRUPT CHANGE/JUMP DETECTION		
STATISTIC	CUSUM	Cumulative deviation	Worsley Likelihood
TEST STAT	14	1.724	4.164
Critical value	**12.73**	**1.527**	**3.78**
Decision	Significant Step Jump		

The null hypothesis Ho for the tests for step jump in mean/median is that there is no significant step jump in the mean/median. The alternative hypothesis Ha for the tests for step jump in mean/median is that there is a significant step jump in the mean/median. We reject the null hypothesis Ho that there is no significant step jump in the mean/median and accept the alternate hypothesis Ha that there is a steep leap in the mean/median in the data at the 0.05 significant level if the test statistics is more than the critical value. The test results are smaller than the crucial value in the example above. As a result, at the 0.05 significant level, we are unable to reject the null hypothesis Ho that there is no significant step leap in the mean/median.

Table 10 (b) Summary of Abrupt Change/Jump Detection for Rainfall and Temp. **(1956-2016)**

CHANGE DETECTION ANALYSIS OF ANNUAL	
RAINFALL	TEMP
Show statistically Significant Step Jump between 1969-1971	Show statistically Significant Step Jump in 1980

3.2.4 The Summary of the result of Difference Between Means of Annual test for rainfall **(**1956-2016) is presented in Table 11.

Table 11 Summary of Difference Between Means of Annual for Rainfall and Temp.

TEST	DIFFERENCE BETWEEN MEANS OF ANNUAL			
STATISTIC STATISTIC	**Rank Sum Z-stat**		**Student 't' (t-test)**	
	Rainfall	**Temperature**	**Rainfall**	**Temperature**
TEST STAT		-4.566		
Critical value		**2.576**		**2.662**
Decision	Significantly Different; Increasing and decreasing rainfall Significantly Different; Increasing Temperature			

For the test of difference in means/medians, the null hypothesis H0 states that there is no difference in means/medians between two data periods, while the alternative hypothesis Ha states that there is a difference in means/medians between two data periods. If the test statistics are greater than the critical value, we reject the null hypothesis Ho, which states that there is no significant difference in the mean/median, and accept the alternate hypothesis Ha, which states that there is a difference in the mean/median in the data at the 0.05 significant level. The test results are greater than the crucial value in the example above. As a result, we reject Ho and embrace the alternative hypothesis.

Table 12. Student's T-test for differences in mean annual rainfall during the two climatic periods (Student t-test)

Mean1	253.4907	Variance2	25,129.85	df	11
Mean2	23,622.35	Observations	12	t Stat	-1.966427
Variance1	24,117.17	Pearson Correlation	0.988277	P(T<=t) one-tail	1.795885

Table13. Percentage variation in Annual rainfall (mm) pattern		: Percentage variation in Annual Temp. (^{0}C) pattern	
First Climatic Year	3041.889	First Climatic Year	363.222
Second Climatic Year	2880.373	Second Climatic Year	369.059

Change	-161.516	Change	5.8837
% Change	-5.309	% Change	1.607

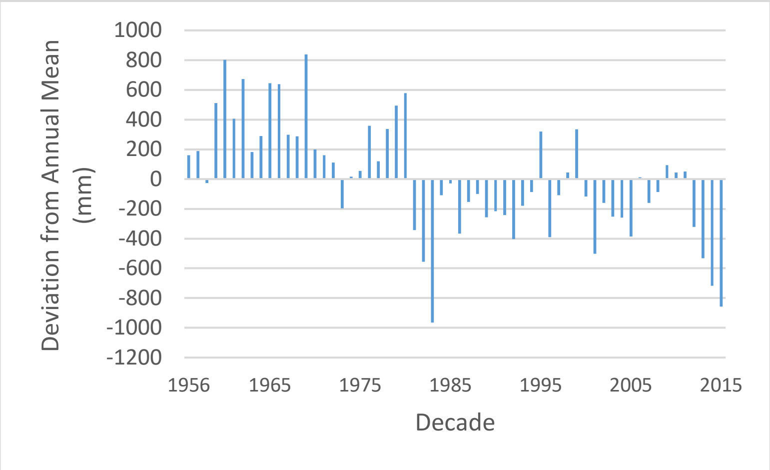
Table 14. Variability of Spatial of Mean Annual Rainfall and Temperature Data

MEAN(Rm)	SD	CV (%)	MEAN(Tm)	SD	CV (%)
246.76	154.04	62.43	30.112	1.299	4.314

According to [13, 14, 15, 16], CV is used to classify the degree of variability of rainfall and temperature events as low (CV < 20), moderate (20 < CV < 30), high (CV >30), very high CV>40% and CV>70% indicate extremely high inter-annual variability of rainfall. The coefficient of variation (CV) between 62.43 indicated a very high variability of precipitation over the state. The coefficient of variation (CV) for temperature is 4.314 % indicated low variability. This study has established that there is very strong evidence of climate variability and climate change.

3.2.5 The decadal variability for rainfall for the period under consideration (1956-2015) is presented in Table 15. The decadal mean and percentage changes are also contained in Table15 accordingly. The table shows the decadal variability of the rainfall, the decadal mean, and percentage changes in the rainfall accordingly. The positive sign signifies much rainfall (wet), while the negative sign signifies less rainfall (dry) for the particular decade under consideration. It was discovered that three decades (1976-1985, 1996-2005, and 2006-2015) accounted for 50 percent of total rainfall, while the remaining decade (1986-1995) accounted for 16.7% of total rainfall.

The representative plot of deviation from annual mean against decades is presented in Figure 7. for rainfall and temperature for Port-Harcourt.



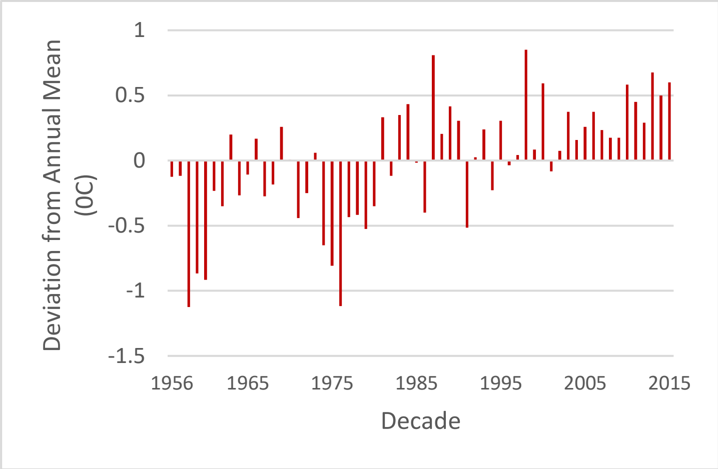


Figure 7 (a) and (b). Decadal Deviation from mean of rainfall and temperature for Port Harcourt

Table 15. Percentage of decadal deviation from mean rainfall. State: rivers

S/N	TOWN	1956-1965	1966-1975	1976-1985	1986-1995	1996-2005	2006-2015
1	Ahoada	0.5599	0.0564	-0.2521	0.2399	-0.1365	-0.4095
2	Alalabo obenikiri	1.8575	1.0294	-0.0747	-1.1203	-0.9601	-0.6427
3	Apiboko	2.2077	1.3782	-0.2957	-1.4560	-0.8638	-0.8329
4	Arugbana	1.2962	0.4562	0.0425	0.1904	-0.8789	-0.9790
5	Ataba	1.4106	0.4406	-0.3387	-1.0548	-0.6102	0.1739
6	Bane	1.6773	0.6527	0.1386	-0.9863	-0.9570	-0.3411
7	Bomu	2.8107	1.7757	0.2832	-1.4831	-1.6364	-1.5111
8	Degema	1.3132	0.5955	-0.3398	-0.5030	-0.3234	-0.7282
9	Eberi	0.3901	-0.3082	-0.3532	0.0760	0.1599	0.0686

10	Egbeda	0.0596	-0.4347	-0.4924	0.3076	0.3994	0.1851
11	Egbolom	0.8549	0.2434	-0.3435	-0.1510	-0.0618	-0.5625
12	Elem ifoko	1.0748	0.1832	-0.6253	-0.3007	0.1129	-0.4219
13	Emaguo	0.9175	0.3202	-0.2955	-0.4664	0.0453	-0.5339
14	Igwuruta	1.4581	0.7315	-0.1483	-0.5836	-0.4175	-0.9235
15	Ikodi	-0.3105	-0.7732	-0.7240	0.8882	0.4727	0.3270
16	Ikuru	0.7022	-0.2681	-0.4072	0.0203	-0.5403	0.4314
17	Isiokpo	0.2677	-0.3149	-0.3269	0.1874	0.4091	-0.1851
18	Ke ke	1.7582	0.8721	-0.5804	-1.4759	-0.4379	-0.0762
19	Mbiama	-0.5020	-0.9214	-0.7478	1.0231	0.5080	0.5580
20	Obete	1.8724	0.8503	0.0514	-1.0607	-0.8885	-0.6831
21	Ogoni	2.1914	1.2910	-0.1164	-1.2300	-0.8197	-1.1775
22	Okoloma	1.3595	0.5082	-0.1923	-0.4304	-0.3901	-0.7338
23	Okwali	1.8579	0.8934	-0.0255	-1.1563	-0.9355	-0.5178
24	Oloma	0.7935	-0.1214	-0.6360	-0.6023	0.3930	0.2877
25	Omoku	0.1678	-0.2575	-0.5053	0.4721	0.1869	-0.0745
26	Opobo	0.6307	-0.3448	-0.3802	-0.4380	-0.3483	0.7872

27	Opuoko	2.0249	0.9758	0.3834	-0.5928	-1.4593	-1.0629
28	Port Harcourt	2.2730	1.4308	-0.0671	-1.0021	-1.0662	-1.4675
29	Rumuekini	1.7311	0.9759	-0.1506	-0.6795	-0.7380	-1.0465
30	Rumuji	0.5346	-0.0718	-0.3860	0.0803	0.2001	-0.3716
31	Umuede	0.5245	-0.1176	-0.3015	-0.2764	0.1946	0.0205
32	Woji	0.4944	-0.1109	-0.2842	-0.2605	0.1835	0.0193
	TOTAL	**36.2595**	**11.6160**	**-8.4915**	**-13.8252**	**-11.2043**	**-12.4243**
	MEAN	**1.1331**	**0.3630**	**-0.2654**	**-0.4320**	**-0.3501**	**-0.3883**

Table 16. Percentage of decadal deviation from mean temperature. State: rivers

S/N	TOWN	1956-1965	1966-1975	1976-1985	1986-1995	1996-2005	2006-2015
1	Ahoada	-13.2350	-7.598	-5.6190	3..3748	7.8862	13.9556
2	Alalabo Obenikiri	12.8743	-7.0522	-6.3954	3.6369	7.8398	13.4467
3	Apiboko	-12.1762	-7.0012	-6.5093	3.7241	7.7632	13.2216
4	Arugbana	-13.1522	-6.5758	-6.0288	3.7861	7.5239	13.3074
5	Ataba	-13.3793	-5.7207	-5.8020	4.0946	7.1983	12.4729

6	Bane	12.9645	-5.4931	-5.6827	4.0621	7.4253	11.4854
7	Bomu	-13.1246	-5.9858	-5.6623	4.2057	7.2680	12.1292
8	Bonny	-12.6796	-5.9196	-6.0291	3.8489	6.9805	12.7658
9	Degema	-13.1279	-7.0784	-6.2602	3.4394	8.0902	13.8119
10	Eberi	-12.5037	-6.8974	-5.3428	4.0215	7.3654	12.0039
11	Egbeda	-12.3890	-7.7016	-5.8271	2.8442	7.7667	14.0856
12	Egbolom	-12.6231	-7.3674	-6.0039	3.3260	7.7838	13.7123
13	Elem Ifoko	-12.7260	-6.3240	-6.2965	3.8779	7.3395	13.0791
14	Emaguo	-12.2514	-7.6114	-5.5053	3.6229	7.4214	13.1761
15	Igwuruta	-12.5367	-6.9167	-5.9652	3.6602	7.5640	12.9558
16	Ikodi	-12.4220	-7.9066	-5.3328	3.4509	7.4778	11.5910
17	Ikuru	-12.1283	-5.5577	-5.9394	3.7573	7.1834	13.2381
18	Isiokpo	-12.1358	-7.3409	-5.8652	3.2203	7.7167	13.5869
19	Ke ke	-12.7987	-6.6716	-6.3156	3.7387	7.8083	11.1800
20	Mbiama	-12.4932	-7.9032	-5.3910	3.6182	7.3028	12.8740
21	Obete	-12.2145	-5.8912	-5.4853	3.8699	7.2770	12.5239
22	Ogoni	-12.7796	-6.6351	-5.7644	3.9837	7.1836	11.8636

23	Okoloma	-12.5721	-6.5566	-5.6584	4.0732	6.9349	12.6054
24	Okwali	-12.6782	-6.2043	-5.6066	4.1419	7.2483	13.7255
25	Oloma	-11.5119	-6.2599	-6.2599	3.7140	6.7416	11.2320
26	Omoku	-12.3928	-8.0290	-5.5668	3.0574	7.9008	11.3807
27	Opobo	-12.2373	-5.5987	-5.8159	4.0146	7.2577	13.1670
28	Opuoko	-12.4144	-5.6632	-5.5820	3.8723	7.2252	11.3807
29	Port Harcourt	-12.6803	-6.8654	-6.0273	3.7644	7.5060	13.1670
30	Rumuekini	-12.2914	-7.0276	-5.9428	3.6268	7.4363	13.0140
31	Rumuji	-12.4589	-7.4890	-6.3177	3.1596	7.9646	13.8936
32	Umuede	-12.5638	-6.9802	-5.6190	4.0057	7.5867	12.3220
33	Woji	-12.7838	-6.4210	5.6392	4.0647	7.4977	13.1253
	MEAN	**-11.0189**	**-6.7347**	**-5.5085**	**3.7169**	**7.4687**	**12.7721**
	TOTAL	**-363.6229**	**-222.2445**	**-181.7805**	**122.6589**	**246.4656**	**421.48**

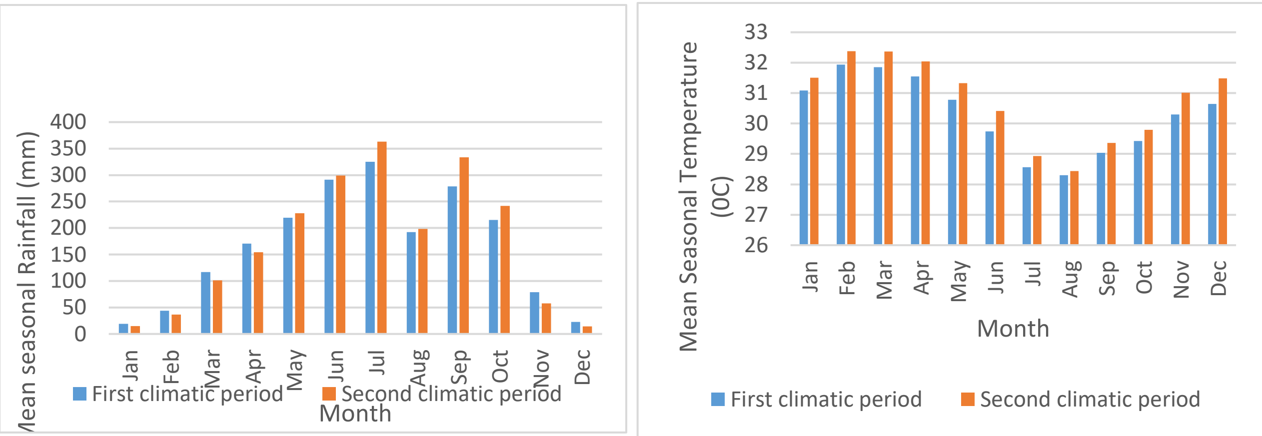
The magnitude of trend analysis of decadal rainfall using **Theil sen' slope analysis** (mm/decade) is presented in **Table 17.**

Table 17. Magnitude of Trend Analysis of Decadal Rainfall and Temperature Using **Theil Sen' Slope Analysis** (Mm/Decade).

S/N		**1956-1965**	**1966-1975**	**1976-1985**	**1986-1995**	**1996-2005**	**2006-2015**
1	Rainfall	46.97	48.73	**-36.36**	**29.79**	-29.2	-96.8
2	Temperature	0.0474	-0.0786	**0.1295**	**-0.0253**	0.0132	0.0323

3.2.6 The result of the comparison of the mean seasonal Rainfall and Temperature pattern

Figures 8 (a) & (b) show the results for the twelve months of the year for two climatic eras (1956-



1986 and 1987-2016).

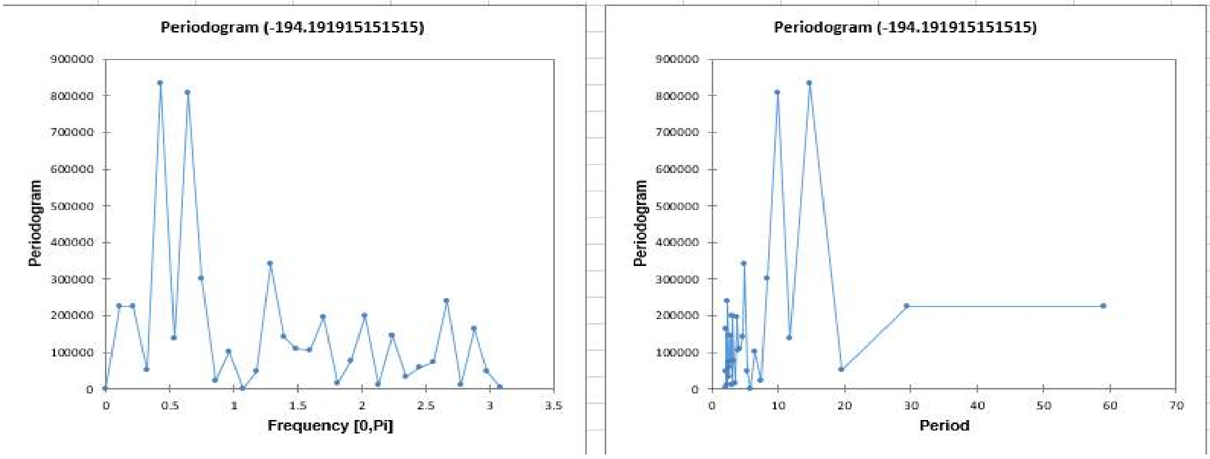
Figures 8 (a) & (b) Mean Annual Seasonal Distribution of rainfall and temperature for River

Figure 8 show the comparison of the mean seasonal rainfall and temperature pattern for two climatic periods for the twelve months of the year. It indicated that July recorded the highest rainfall for the first and second climatic years. The least rainfall happened in January and December for the two climatic periods.

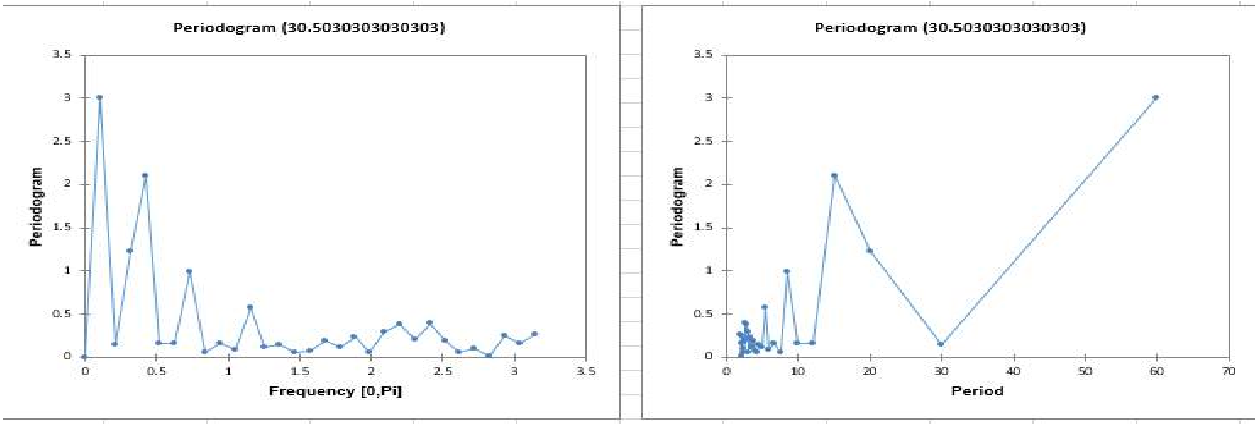
3.3. Spectral analysis

Spectral analysis of the time series is used to detect a cyclic component of the time series both with high and low frequency.

The result of spectral analysis is presented in Figures 9 and 10.



Figures 9 (a) & (b Periodogram Frequency Curve for Rivers State. Periodogram Period Curve for Rivers State.



Figures 10 (a) & (b Periodogram Frequency Curve for River State Periodogram Period Curve for River State.

The rainfall output of spectral analysis showed that the test STATISTIC Fisher's Kappa was 4.699, the P-Value was 0.207, and the most significant Periodicity was 15years. Also, The Temperature output of spectral analysis showed that the test STATISTIC Fisher's Kappa was 7.618, the P-Value was 0.006, and the most significant Periodicity was 15years.

4.0. Conclusion

Statistical evidence has shown that there had been changes in temperature data which displayed a significantly increasing trend. This was mainly in 1976-1985 decade with 1980 as the most probable year of abrupt change and the hottest decade was 1976-1985 with an average temperature change of 0.1255 (^{0}C /decade), while the coolest decade was 1976-1985 with average rainfall change of -0.0132 (^{0}C /decade). The wettest decade was 2005-2015, with an average rainfall change of -96.8 (mm/decade), whereas the driest decade was 1996-2005, with an average rainfall change of 29.7 (mm/decade). The result further revealed that there was high rainfall variability, with the coefficient of variability in the range of 62.74%. This rainfall fluctuation has implications for coastal flooding, quality, and quantity of available groundwater in the state. These results are useful to planners and policymakers in creating awareness of climate change's impact on rainfall in the study area. Climate change presents decision-makers with significant uncertainty, necessitating the use of Robust Decision Analysis to help them make effective judgments by identifying system vulnerabilities and evaluating mitigation options. The findings of this study will be valuable in such an examination.

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