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TRENDS AND SPATIAL VARIABILITY OF CLIMATE CHANGE IN NIGERIA'S COASTAL REGION

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Graphical abstract

Abstract

A major challenge facing the Coastal Region of Nigeria is climate change and climate variability. An assessment of the trends and spatial variability of climate, critical for knowledge-based strategies needed for planning adequate mitigation and adaptation measures for the region, requires urgent attention. This study analysed spatial variability and temporary trends of climate change in the Nigeria Coastal Region .. Gridded monthly climatic data from the Climate Research Unit (CRU 0.5 x 0.5) for two climatic periods ((1956- 1986 and 1987-2016) were obtained. Tests for trend detection and magnitude determination utilized: Mann-Kendal and Linear Regression—Thei-Sen Slope test. Climatic maps for rainfall and temperature from 1956 to 2016 for the coastal regions of Nigeria were developed by ordinary kriging. The results from statistical analyses suggest that there is very high rainfall variability with the coefficient of variability (CV) values ranging between 62.43% and 69.46 % and low-temperature variability with CV values ranging between 4.314% and 6.037%. The annual rainfall and temperature increased at the average rate of 3.047 mm yr-1. and 0.0126 ºC yr-1 respectively. In 75% of the region, rainfall was decreasing, while in 25%, it was increasing. The implementation of adaptation and mitigation strategies should be mandatory due to the notable increase in temperature.

Keywords: Climate Change, Coastal Region, Linear Regression, Mann-Kendall, Spatial Variability

1.0 INTRODUCTION

Climate change and variability are serious issues of worldwide concern. Climate change and variability differ from continent to continent with Coastal Regions particularly vulnerable being adversely affected because of their location and topography. Increased rainfall, increased coastal flooding frequency, accelerated rising sea levels (because of the thermal expansion of ocean water), and accelerated coastal erosion due to elevated tidal inundation of shorelines, rising water tables, increased saltwater intrusion into aquifers, and a suite of ecological and changes are evidence of changing climate (Odjugo, 2001). The low nature and topography of Nigeria's entire coastline area make it extremely vulnerable to flooding, particularly during high tides and during the rainy season. (Nicholls and Mimura, 1998).

Girma -Eshety and Wayess (2016) used data from meteorological stations in Ethiopia to analyze Gatira - Setema rainfall pattern and variability. The Mann-Kendall test was applied for analysis of rainfall trends. An examination of trends revealed that Gatira's rainfall was rising, while it was decreasing in Setema. There was no statistically significant trend in rainfall at P = 0.05. Setema's coefficient of variation (CV) was 23%, in contrast to Gatira's 8%, indicating less inter-annual variation. Mann-Kendall's test result conducted in Ethiopia by Abebe et.al (2022) revealed that except for four stations, there is no significant yearly rainfall trend within the basin. Chombo et al, (2020), Birara,et al (2018), Akinsanola et al (2020), Allen ,and Allen,. (2019) and Arora et al (2017) investigated and confirmed Spatio-temporal Rainfall and temperature trends and variability in their respective areas. Also, Bishop et (2019), Brown et al (2020), Haghtalab et al (2020), Chen, et al (2020). Dollan, et al (2022) , Han et al (2021). Li et al (2021), Cooley and Chang. (2021), detected fluctuations in precipitation indices such as , maximum number of consecutive dry days, maximum number of consecutive wet days using observed data.

The majority of climate change researches conducted in Nigeria, have been on the probable consequences (Odjugo, 2001a; Adejuwon, 2006a, b;). Most of the available information on the Coastal Region of Nigeria has focused on flooding and sea-level rise (Ojile, et al., 2017). These studies have confirmed the existence of the incidence of Nigeria's climate change. The country is particularly vulnerable as it lacks the resources and technology to address these issues.

Furthermore, its economy is heavily reliant on climate-sensitive natural resources. Hence, proper planning is required before the allocation of land spaces for different uses because of climate change's impacts.

These studies did not consider the temporal and spatial characteristics of climatic dynamics. In the use of the remote sensing method in studying climatic change and variability, in Nigeria, only a few studies exist, (Okoro et al. 2014, Bibi et al. 2014;Aiyelokun, and Odekoya, (02016), investigated the annual average trend and variability of atmospheric temperature in Ijebu-Ode, Southwest Nigeria. They revealed that variability in temperature was significant over the period of study in the area Olasupo et al., (2017) focused on the coastal area (Calabar, Lagos, Port-Harcourt, and Warri). They compared both rainfall and temperature data sets derived from the University of Delaware (UDEL) archive and NIMET observations from ground stations over the overlapping time frame (1974–2013). They found that no discernible change existed between the two data sets at P = .05. Hence they rejected the hypothesis that there were differences in data set from the two different sources. P-values are tools for deciding in statistical hypothesis testing whether to reject the null hypothesis. For a small p-value (<=0.05), the null hypothesis is rejected For a large p-value (>0.05), the null hypothesis is true and should not be rejected

Climate variability has been shown by Roshani et al., (2020) to make a substantial contribution to agricultural production in Iran Nkhonjera et al., (2021) noticed a strong decreasing trend in precipitation in South Africa. Mzouri et al (2021) analyzed Rainfall and temperature in Morocco and confirmed Climate change in the three zones. They concluded that there was a significant precipitation variability, with monthly rainfall averages decreasing from month to month. The decrease was very significant from February to May in the three zones for the period under consideration. Also, there was a significant rise in temperature with minimum values in winter temperatures (December January) and maximum values in summer temperatures (July-August) averages decreasing from month to month.

It is evident from the available literature reviewed that while extensive studies have been done in concerning climate change, most of these studies rather focused on impacts using point-based climatic data. Moreover, apart from the fact that some of this climatic data are most time disjointed, they are point-based and lack spatial dimension. Determining the level of unpredictability and the extent of climate change is crucial using gridded data that has a comprehensive coverage of the study area. The results of such studies are needed for estimation of design events, generation of long-term time series, modeling and prediction of future trends which will aid mitigation and adaptation measures. This study is aimed at filling this gap of Non-availability of design information on the extent of climate change and variability in rural communities in Nigrians Coastal Region due to a lack of climatic data from Meteorological agencies.

This study is further justified as it will also help in a clearer understanding of the long-term changes in temperature, precipitation as climate parameters. This knowledge is vital to comprehend the evolving climate patterns and their impacts. Identifying trends allows us to develop strategies for mitigating the effects of climate change. It also informs adaptation efforts to prepare for and reduce the risks associated with changing climate conditions. Policymakers use climate trend data to create effective climate policies and regulations. Decision-makers in various sectors, such as agriculture, urban planning, and disaster management, rely on this information to make informed choices. Climate variability studies provide valuable data for scientific research. Variability in climate impacts natural resources like water, forests, and fisheries. Monitoring these changes helps in sustainable resource management and conservation.

Understanding climate trends helps to improve public consciousness about the urgency of addressing Changes in climate. It makes the issue more tangible and relatable to people's daily lives.

2.0 METHODOLOGY

2.1 Study Area

Nigeria's coastal regions are the study area. Geographically, the region lies between latitudes 4ºN and 8ºN and longitudes 3ºE and 9ºE (Figure 1). Nigeria's coastline is 853 kilometers long covering nine states namely Lagos, Ogun, Ondo, Edo, Delta, Bayelsa , Rivers, Akwa-Ibom , and Cross River states. For representative coverage, nine stations were chosen, one from each of these states. There are two distinct seasons in the Region. April through November is the wet season, and December through March is the dry season. Climate in Nigerian is characterized by high humidity and temperatures, along with distinct wet and dry seasons.

2.2 Data Collection and Preparation

Climatic data for two climatic periods (1956–1986 and 1987–2016) were obtained from the Climate Research Unit (CRU 0.5×0.5). They were gridded monthly data collected in MS excel format from Research Unit CRU TS 3.21 dataset sourced for 254 locations in nine states of the region (http://badc.nerc.ac.uk) . They were validated using data from the Nigerian Meteorological Agency (NiMet). The mean rainfall and mean temperature monthly series of two Climatic periods of 30 (thirty) years each (1956-1986) and (1987-2017) were sorted. These CRU data series were tested for normality, homogeneity, autocorrelation, and heteroscedasticity with the aid of XLSTAT Software to evaluate their properties. Some other equations were implemented with Microsoft Excel and CLIMTREND Software in order to obtain desired result.

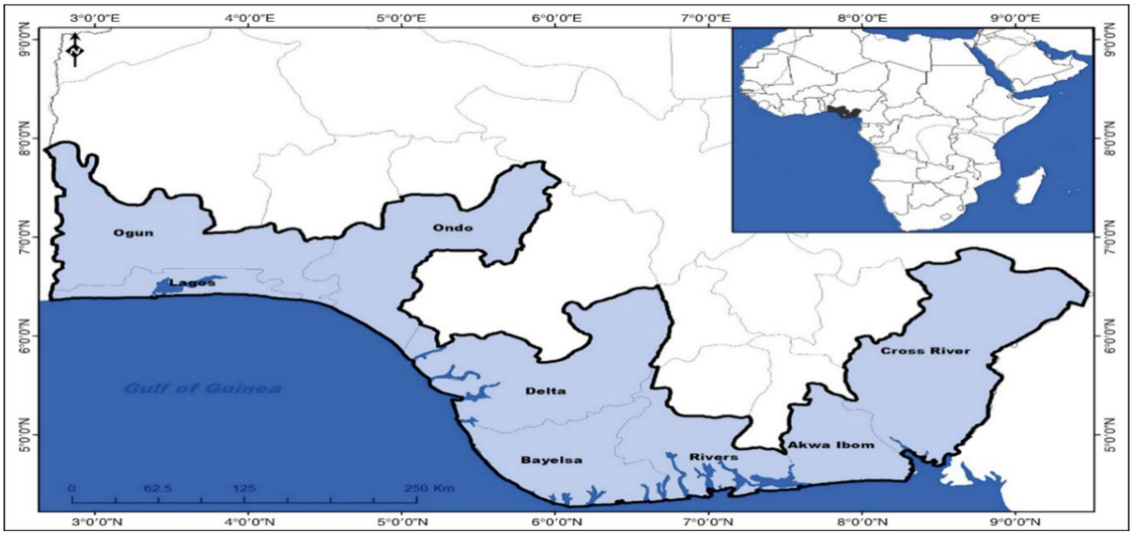

Figure 1 Nigeria Costal States (source: Adeleke et.al. 2018)

2.3 Data Analysis

The Descriptive Statistics Equations are presented in Table 1

2.3.1 Spatial Analysis of Climate Change

Spatial analysis is the process of studying entities by examining, assessing, evaluating, and modeling spatial data features such as locations, attributes, and their relationships that reveal the geometric or geographic properties of data. Spatial Analysis of Climate Change was executed in Microsoft excel by producing bar charts using the average monthly temperature or rainfall over two climate periods of 30 (thirty) years each (1956-1986 and 1987-2017). in each state of the study area. These bar charts were compared to see if there are significant differences in their values in each location for each of the climatic periods. Additionally, monthly temperature or rainfall over a thirty-year climate period in each state of the area of study was considered. Data of two climatic periods for location differences (Spatial) were applied to Student's two-sample t-test by using a significance threshold of 0.05 and comparing the means of different locations. Figure 2 shows the Flowchart of Methodology adopted

Table 1 Descriptive Statistics Equations

S/N	Text Statistic	Equations	Remark
1	Mean	$\bar{R} = \frac{\sum(R)}{N}$	It is expressed as the sum of all variates (∑(R)) divided by the total number of variates (N).
2	Standard Deviation	$\sigma = \sqrt{\frac{\sum(R-\bar{R})^2}{N}}$	The square root of the mean-squared deviation of each individual observation from the mean is used to compute it.
3	Variance	$\sigma^2 = \frac{\sum(R-\bar{R})^2}{N}$	Square of standard deviation.
4	Determination of coefficient of variation	$CV = \frac{SD\ x\ 100}{\bar{X}}$	This demonstrates the degree of data variability. It is computed simply dividing the data set's standard deviation by the mean.
5	Skewness	$\alpha = \frac{1}{N}\sum(R-\bar{R})^3$	R represents a variate, R̄ denotes the data set mean, and N is the total number of where variables.
6	Kurtosis	$K = n\frac{\sum_{i=1}^{n}(R_i-\bar{R})^4}{\left[\sum_{i=1}^{n}(R_i-\bar{R})^2\right]^2}$	Kurtosis indicates how peaked distribution is, usually considered relative to a normal distribution.

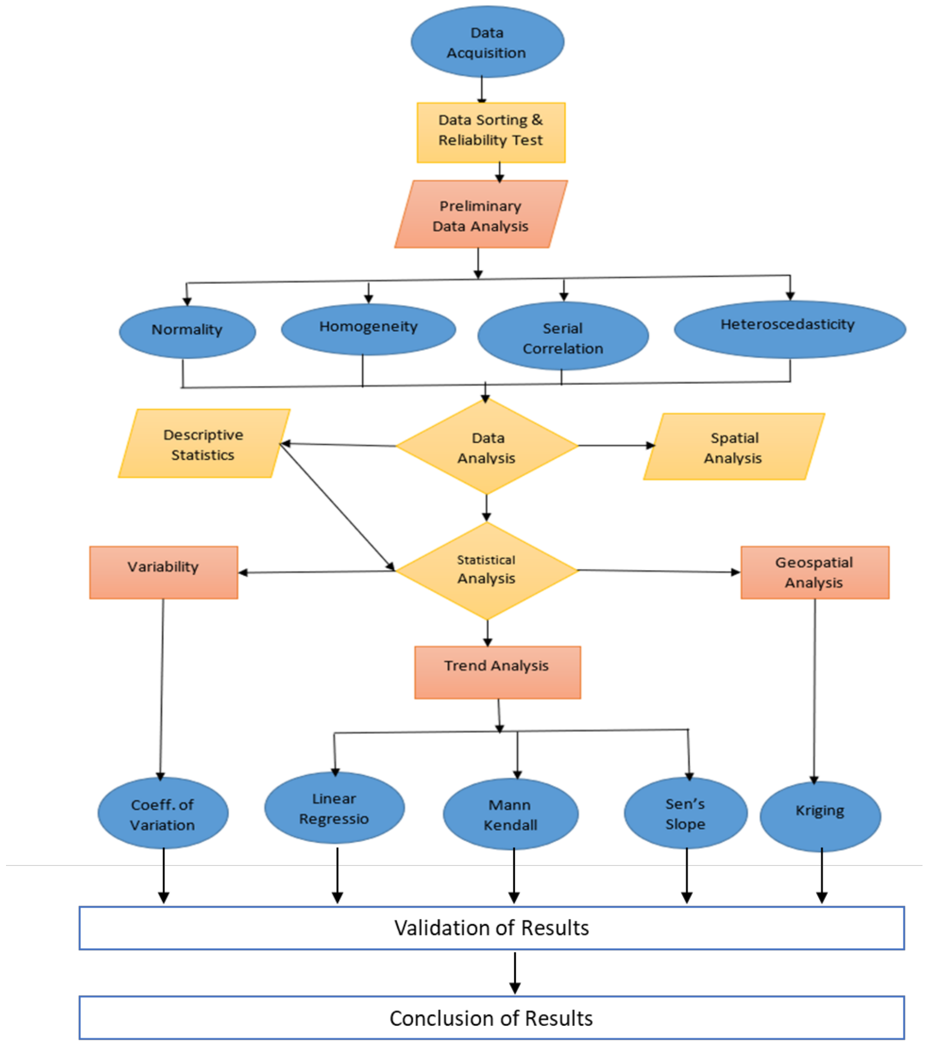

Figure 2 Flowchart of Methodology

2.3.2 Geospatial Analysis using Ordinary Kriging Interpolation.

Kriging is a geostatistical interpolation technique that considers both the distance and the degree of variation between known data points when estimating values in unknown areas A unique feature of Kriging is that it provides an estimation of the error at each interpolated point, providing a measure of confidence in the modeled surface.This gives it an advantage over other interpolation techniques such as inverse distance weighted tool.

Arc GIS 10.2 application software and standard kriging spatial interpolation techniques were used in this investigation. Statistical approaches were used to conduct the temporal analysis.

The fundamental formula of a semi-variogram is given below in the equation.1

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(X_i) - Z(X_i + h)]^2 \quad (1)$$

Where:

γ (h)= coefficient of semi-variance

N (h) = No of data placed in a vector separated by h.

Z (X_i) = a point of X at i.

h = The separation of two points in space

The location points become less similar as the value of γ increases. The variances of the nuggets, structural variances, sill, range, and gradient are all model coefficients that define the model fitted. The climate data for the research region was plotted to create the maps. This was accomplished using Arc View 3.2 and Arc GIS 10.0 software

The following were the basic tools used to make the maps:

1) latitudes, longitudes and altitudes of the locations.
2) Climatic data (Max, Mean, and Min) for Rainfall and Temperature for the period under consideration (1956-2016)

The following were part of the procedure: Make changes to geographic data; Geographic features can be searched for and selected from the layout and the map printed

2.3.3 Temporal Trend Analysis of Climate Change

Trend/ Patterns Detection and Characterization was achieved by various statistical techniques, both non-parametric tests, in addition to parametric testing. Various techniques for determining a pattern in a collection of data are published in the literature. Three common techniques for detecting trends/Patterns used in this study are:

a) Mann-Kendall Statistics

This test is not a parametric test that is based on ranking for ascertaining the significance of a time series trend (Machiwal and Jha. 2012)

Its statistics *S* is calculated as:

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\operatorname{sgn}\left(x_j-x_i\right) \qquad (2)$$

$$\operatorname{sgn}\left(x_j-x_i\right)=\begin{cases}+1, & x_j-x_i>0,\\ 0, & x_j-x_i=0,\\ -1, & x_j-x_i<0,\end{cases} \qquad (3)$$

The time series' duration $\left(x_1,x_2,...x_n\right)$ is denoted by n. The *ith* and *jth* data point in the time series $\left(j>i\right)$ are x_i and x_j correspondingly. The variance of statistic S, V(S) can be computed as follows:

$$V\left(S\right)=\frac{n\left(n-1\right)\left(2n+5\right)-\sum_{k=1}^{m}\left(t_k-1\right)\left(2t_k+5\right)}{18} \qquad (4)$$

Thus, *m* represents the numeric linked sets and t_k is the numeric link to the kth value. A set of sample data having the same value is called a linked group. The test statistical Z is computed using the equation 5:

$$Z_s=\begin{cases}\frac{S-1}{\sqrt{V(S)}}, & S>0,\\ 0 & S=0,\\ \frac{S+1}{\sqrt{V(S)}}, & S<0.\end{cases} \qquad (5)$$

The statistical normal test is employed when the sample size *n* > 10. Positivity Z_s represents a rising trend while negativity represents a declining trend. The Mann-Kendall Criterion was applied in this study to determine if the pattern is yearly and seasonal rainfall data is significant statistically (*p = 0.05)*

For S < 0 and S > 0 in Equations (4) and (5), m = 1 and m = –1, respectively., The data in the ith tied group is denoted by tk, while the number of tied groups is represented by g. The value of the test-statistic upper confidence (*UC*) is taken as zero for *S* = 0, For α=0.1, $Z_{(\alpha/2)} = Z_{0.05=1.645}$

These equations *were implemented with Microsoft Excel and*

In equation 5, For α=0.1, $Z_{(\alpha/2)} = Z_{0.05}$=1.645 then I uc I is greater than 1.645 ie Upper Confidence limit(UC) is greater than the standard normal distribution's critical value

The null hypothesis of no trend is invalidated at the significance level

b) Theil-Sen Technique

Theil-Sen estimator was used to quantify the magnitude of trends (Machiwal and Jha. 2012);

$$Q_{med}=median\left(Q\right), \qquad (6)$$

$$Q=\frac{x_j-x_i}{j-i}, i<j,$$

Where Q_{med} = slope amid data points *x*i and *x*j, *x*i = measuring of data at the time *i*, *x*j = data measured at time *j*; and *j* = time after time *i*; respectively The slope of an upward trend is indicated by a positive value, and the slope of a downward trend is indicated by a negative value..

c) Linear Regression Test

This test is parametric, data-driven, and outlier-sensitive. When the link between time (x) and the variable of interest (y) was examined, a linear trend was discovered ((Hennemuthet al., 2013).

The regression equation is:

$$y=a+bx \qquad (7)$$

The gradient of the regression is calculated using.:

$$b=\frac{\sum_{i=1}^{n}\left(x_i-\bar{x}\right)\left(y_i-\bar{y}\right)}{\sum_{i=1}^{n}\left(x_i-\bar{x}\right)^2} \qquad (8)$$

In addition, the intercept is expected to be: $a=y-bx$

The null hypothesis was rejected when the sample findings were unlikely. The significance level was compared to the P-factor. The null hypothesis was rejected if the P-value was less than the significance level. A significance level of 0.05 was established.

The following stages were used to test for significance: (1) establishing hypotheses, (2) deciding on an analysis strategy, (3) evaluating data samples, and (4) interpreting the outcomes. This was accomplished as follows:

I) State the hypotheses.

Below is a representation of two hypotheses: the alternative and the null.

Ho: The gradient of the regression line equals zero.

H_a: The gradient of the regression line is *not* equal to zero.

ii) Preparation of an analysis plan

A 0.05 significance threshold was used to see if the gradient there is a substantial difference in the regression line from zero for a t-test. linear regression.

iii) Analyses of data from a sample

In applying a t-test for linear regression to data. the gradient's standard error was required. as well as the gradient of the line of regression, the t-statistic test statistic, the test statistic's P-value and degrees of freedom.

We obtained the gradient (b_1) and the standard error (SE) from the regression output

$$SE = s_{b1} = \text{sqrt} [\Sigma(Y_i - \hat{y}_i)^2/(n-2)] / \text{sqrt}[\Sigma(x_i - x)^2] \quad (9)$$

where Y_i stands for the dependent variable's value for observation *I*, $\hat{y}_i$, represents the dependent variable's estimated value for observation I, and xi represents the observed value of the independent variable. for observation *I*, the independent variable's mean is x, and the number of observations is n.

The degrees of freedom (DF) in a simple linear regression with one independent variable and one dependent variable are equal to

$$DF = n - 2 \quad (10)$$

where n is the number of observations in the sample or sample size. Analyzing the data, the expression in equation 11, provides the t-test statistic.

$$t_O = b_1 / SE \quad (11)$$

where b_1 stands for the gradient of the line of regression of the sample, while SE represents the gradient's standard error. These equations were implemented with Microsoft Excel and CLIMTREND Software

The P-value indicates the chance of finding a sample statistic that is as extreme as the test statistic. The t Distribution chart was used to assess the probability associated with the test statistic because the test statistic is a t statistic., The degrees of freedom computed above were used.

The total degrees of freedom of observations (n-2) is the distribution that the test statistic, T_O, adheres to. The null hypothesis, Ho, 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 two-sided hypothesis' critical values, $t_{\alpha/2,n-2}$is the percentile of the t A cumulative probability distribution of $(1-\alpha/2)$, and α is the level of significance

2.3.4 Climate Variability Study

The degree of variability in long-term mean distributions of climatic variables is indicated by the variation coefficient. It is employed to evaluate the dispersion of the data points around the mean. A metric is often used to compare data dispersion between several data series. Unlike the standard deviation, which is always relevant when analyzing the mean of the data, The coefficient of variation (CV) is a relative measure of variability that indicates the size of a standard deviation about its mean. It is a standardized, unitless measure that allows the comparison of variability between disparate groups and characteristics (Frost, 2024).

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By dividing the standard deviation of a set of data by the mean of the series, the coefficient of variation (CV) removes the unit of measurement (Curto and Pinto, 2009). The formula for the percentage coefficient of variation is;

$$CV = \frac{SD \ x \ 100}{\bar{x}} \quad (12)$$

The variation coefficient indicates how much data in a sample varies from the population mean. The higher the CV, the more unpredictable it becomes. as the amount of rain that falls on a location varies from year to year.

3.0 RESULTS AND DISCUSSIONS

3.1 Descriptive Statistics of Spatial Rainfall and Temperature

The Descriptive statistics of mean annual rainfall for the first and second climatic periods (1956- 1986 and 1987-2016) respectively, in the coastal region of Nigeria are presented in Table2

Table 2 illustrates that the average annual rainfall ranges from in 1606.79mm in Lagos (second climatic period to 3038.00mm in Bayelsa (second climatic period). These values are validated by research carried out by Statista (2022). They reported that the study of annual rainfall in Nigerians in 2018,by State, Bayelsa had the highest rainfall of 2625mm. This was followed by Cross River with 2599mm..Lagos state had the lowest rainfall of 1520mm followed by Ogun with 1626mm The skewness and Kurtosis ranged from -0.015 to 0. 407 and-0.246 to -1.640 respectively.

Table 2 Mean annual rainfall descriptive statistics (1956- 1986 and 1987-2016),

Climatic Station	Climatic period	Mean mm	SD mm	Min mm	Max mm	Range mm	Sum mm	%CV	Skewness	Kurtosis
Akwa Ibom	First	256.432	141.655	31,419	446.198	406.778	2820.75	55.241	-0.150	-1.428
	Second	253.454	145.712	40.227	470.165	429.938	2787.99	57.490	-0.124	-1.376
Bayelsa	First	274.493	149.599	55.805	475.693	419.889	3019.42	54.500	-0.015	-1.334
	Second	*276.182*	158.524	52.279	485.564	433.285	3038.00	57.398	-0.087	-1.472
Cross River	First	236.034	135.542	31.429	405.662	374.233	2596.00	57.425	-0.144	-1.512
	Second	263.23	157.897	36.292	490.555	454.264	2884.53	59.984	-0.114	-1.469
Delta	First	223.572	134.8	27.564	412.789	385.226	2459.29	60.294	-0.079	-1.344
	Second	221.053	141.228	22.596	414.844	392.248	2431.58	63.889	-0.139	-1.586
Edo	First	182.991	108.158	20.274	334.582	314.309	2012.91	59.106	-0.217	-1.255
	Second	185.668	116.391	15.556	337.091	321.535	2042.35	62.688	-0.295	-1.524
Lagos	First	147.865	93.264	16.924	327.6	310.677	1626.52	63.414	-0.455	-0.246
	Second	146.072	101.573	13.805	334.537	320.732	1606.79	69.536	0.407	-0.792
Ogun	First	149.942	86.752	15.808	274.283	258.475	1649.37	57.857	-0.138	-1.146
	Second	152.723	100.209	11.945	286.989	275.043	1679.95	65.615	0.018	-1.640
Ondo	First	177.673	101.729	22.792	324.987	302.194	1954.41	57.256	-0.172	-1.174
	Second	184.326	121.432	14.254	363.276	349..022	2027.58	65.880	0.004	-1.361
Rivers	First	271.801	146.829	51.256	465.637	414.382	2989.82	54.021	-0.056	-1.409
	Second	258.555	148.322	46.251	468.963	422.712	2844.11	57.366	-0.113	-1.481

Table 3 also shows detailed data on the average yearly temperature in Nigeria's coastal region for the first and second climatic eras (1956-1986 and 1987-2016, respectively)

Table 3 Descriptive statistics of annual Temperature, for different climatic Periods

Climatic Station	Climatic Periods	Mean	SD	Min	Max	Range	Sum	%CV	Skewness	Kurtosis
Akwa Ibom	First	30.276	1.336	28.220	32.126	3.906	333.035	4.213	-0.064	-1.222
	Second	30.760	1.143	28.399	32.538	4.138	338.361	3.716	-0.319	-1.200
Bayelsa	First	30.081	1.324	31.817	30.081	3’645	330.89	4.401	-0.171	-1.150
	Second	30.583	1.422	28.362	32.274	3.913	336.413	4.650	-0.392	-1.502
Cross River	First	30.363	1.469	28.021	32.382	4.361	333.991	4.838	-0.119	-1.121
	Second	30.674	1.520	28.107	32.598	4.491	337.418	4.955	-0.126	-1.069
Delta	First	30.271	1.565	27.999	32.269	4.270	332.978	5.170	-0.244	-1.554
	Second	30.759	1.680	28.155	32.733	4.578	338.345	54.618	-0.396	-1.522
Edo	First	30.129	1.848	27.441	32.292	5.053	331.428	6.134	-0.206	-1.571
	Second	30.614	1.970	27.573	32.965	5.393	336.755	6.435	-0.323	-1.535
Lagos	First	30.284	1.639	27.955	32.338	4.383	333.128	5.412	-0.189	-1.623
	Second	30.685	1.683	28.138	32.643	4.504	337.538	5.485	-0.329	-1.574
Ogun	First	30.491	1.875	27.755	32.882	5.127	335.401	6.149	-0.152	-1.619
	Second	30.911	1.938	27.398	33.244	5.346	340.022	6.270	-0.278	-1.562
Ondo	First	30.348	1.848	27.663	32.748	5.085	333.826	6.089	-0.155	-1.594
	Second	30.817	1.938	27.829	33.150	5.321	338.989	6.289	-0.291	-1.568
Rivers	First	30.195	1.288	28.298	31.937	3.639	332.140	4.266	-0.035	-1.326
	Second	30.686	1.393	28.438	32.377	3.939	337.550	4.539*	-0.314	-1.306

Table 3: shows that the Mean yearly Temperature varies from 30.081 ^oC in Bayelsa (First climatic period) to 30.911 ^oC in Ogun (second climatic period) . This significant difference is due to spatial climate variability. The standard deviation varied from 1.143 ^oC to1.970 ^oC while the skewness and Kurtosis varied from -0.035 to -0.396 to and -1.069 to -1.623 respectively.

3.2 Assessing the Quality of Spatial Data for Climate Variability Analysis

In a study carried out by Agbonaye and Izinyon (2021), CRU data have been proven to be reliable and could safely be utilized for further analysis in this study (Furthermore, their results showed that The CRU climate data series were normally distributed, thus they could be analyzed using parametric methods. These states' rainfall data were found to be homogeneous: Bayelsa, Delta, Edo, Lagos, Ogun, and Ondo. They being very reliable, justified their use for further analysis and research. Additionally, the results showed that the CRU climate data series had a normal distribution and that the data could be further analyzed using parametric techniques. It was discovered

The Spatial analyses mean annual Temperature for the first and second climatic periods (1956- 1986 and 1987-2016) respectively, in the coastal region of Nigeria is presented

3.3 Coefficient of Variability (CV%) Analysis

Using equation 12, the coefficient of Variability obtained in computing the spatial mean annual rainfall and temperature data, are shown in Table 4

Table 4 - Variability of Spatial Average yearly Rainfall and Temperature Data

S/N	Location	Rainfall			Temperature		
		MEAN RAINFALL(Rm)	SD	CV (%)	MEAN TEMPERATURE(Tm)	SD	CV (%)
1	Akwa Ibom	236.54	150.75	63.73	30.569	1.328	4.344
2	Bayelsa	256.17	160.73	62.74	30.393	1.324	4.356
3	Cross River	230.25	153.82	66.81	30.561	1.431	4.682
4	Delta	206.05	142.87	69.34	30.579	1.562	5.108
5	Edo	170.35	117.34	68.88	30.447	1.838	6.037
6	Lagos	136.28	99.56	73.06	30.597	1.629	5.324
7	Ogun	140.02	96.94	69.23	30.811	1.856	6.024
8	Ondo	167.34	116.23	69.46	30.665	1.826	5.955
9	Rivers	246.76	154.04	62.43	30.112	1.299	4.314

According to Hare (2003), CV is used to classify the extent of variability of rainfall and temperature events as less (CV < 20), moderate (20 < CV < 30), high (CV >30), very high CV>40% and CV>70% show extremely high inter-yearly rainfall variability. If the observed data is taken into account, all of the states, except Lagos, had a coefficient of variation (CV) between 62.43% and 69.46 %. This indicated a very high variability of precipitation over the Region. The coefficient of variation (CV) for Lagos state is 73.06 % indicating extremely high inter-annual variability of rainfall. This is in harmony with the result of the study carried out in the Niger- Delta by Adejuwon (2018) .He concluded that The CV was lowest in May and June with a variation of 22.28 to 54.60% and highest in January and December with the range of 68.54 to 151.20% .

The CV of yearly rainfall is a climatic risk index that indicates the likelihood of year-to-year fluctuations in reservoir storage or crop yield. In agricultural terms, it may be a more important statistic in marginal areas, as opposed to very dry areas, where farming practices have adapted to variability, or wet areas, where relatively lower inter-annual variability is generally expected.

The coefficient of variation (CV) of Spatial Mean Annual Temperature Data varied between 4.314% and 6.037% in all the States in the study area. indicating low inter-annual variability of Temperature. SD= Standard Deviation, CV= Coefficient of Variability

. That is the opposite of what we observed in the mean and rainfall in the study This is indicated by the shades of colours varying from blue through green, yellow and red (364.717mm to 369.73mm).

3.4 Investigation of Trend - Mann Kendall Test Result

The Summary of **the** Trend Analysis of the Mann-Kendall Test for Rainfall and Temperature (1956-2016) is presented in Table5.

Table 5 : Mann-Kendall Test Result

S/N	State	Availability of Trends in Annual Rainfall	Availability Of Trend in Annual Temp
1	Akwa Ibom	insignificant TREND	Significantly Rising TREND
2	Bayelsa	insignificant TREND	Significantly Rising TREND
3	Cross River	Significantly Increasing TREND	Significantly Rising TREND
4	Delta	Significantly decreasing TREND	Significantly Rising TREND
5	Edo	insignificant TREND	Significantly Rising TREND
6	Lagos	insignificant TREND	Significantly Rising TREND
7	Ogun	insignificant TREND	Significantly Rising TREND
8	Rivers	Significantly decreasing TREND	Significantly Rising TREND

In Table 5 , Mann-Kendall Test revealed Significantly Increasing TREND in rainfall in Cross River state and Significantly decreasing TREND in Delta and Rivers States.There were insignificant Trend in rainfall in other locations studied (62.5%). Also,there was Significantly Rising TREND in Temperature in all locations studied.

3.5 Determination of Trend Magnitude -Theil-Sen Technique

Thei-Sen Slope test was used to determine the magnitude of the trend analysis

A summary of Theil-Sen Technique Trend magnitude obtained from Table 5 is presented in Table 6

Table 6 A summary of Trend magnitude obtained from Table 5

S/N	State	Rainfall(mm/Year)	Temperature (°C /Year)
1	Akwa Ibom	-1.354	0.0062*
2	Bayelsa	-2.8276	0.0155*
3	Cross River	8.0258*	0.0127
4	Delta	-4.155	0.0152
5	Edo	-0.5612	0.0148
6	Lagos	-1.0051	0.0104
7	Ogun	0.1104*	0.0109
8	Rivers	-6.3348	0.0149
	Absolute Average	3.047	0.0126
	Maximum	8.0258	0.0155
	Minimum	0.1104	0.0062

*Extreme values

Table 6 shows that the annual rainfall rate declined from -0.5612 (mm/year) in Edo State to -6.3348 (mm/year) in River State, having a mean of – 2.612 (mm/year) in both states. At Ogun, the rate climbed by 0.1104 (mm/year), peaking at 8.0258 mm yr-1 at Cross River, bringing the overall rate to 3.047 mm yr-1. Also, the temperature rate increased from 0.0062 °C yr^{-1} at Akwa Ibom to 0.0155 °C yr^{-1} at Bayelsa having a mean of value of 0.0126 °C yr^{-1}. This value is comparable with the rate of 0.0105 °C yr^{-1} obtained by Odjugo (2010) for Nigeria. It is also lower than the value of 0.016 °C yr^{-1} obtained by Collins (2011) for Africa. This is expected since temperature values are normally lower in the coastal region than in the inland. Considering the slope, elevation, drainage density land use, and land cover of Cross River state,a spike in rainfall increases the volume and intensity of water entering river systems and urban drainage networks, thereby overwhelming existing infrastructure and exacerbating flood risk (Njoku ,et al,2020)

3.6 Summary of Linear Regression Analysis

Analysis of Annual Rainfall Regression Lines and Annual Temperature Regression Lines (1956 -2016) are presented in Figures 3 to 4

Figure 4 depicts the annual rainfall amount in mm and the yearly temperature in °c (1956 -2016) An Overview of the Analysis of Linear Regression is introduced in Table 7

The gradient for mean annual rainfall range from 7.8 to 0.466 with The R^2 coefficient of determination ranging from 28.12 to 0.09 percent.

R^2 values for mean annual temperature, on the other hand, range from 39.1 percent to 23.34 percent. The slopes are all positive, ranging from 0.0156 to 0.0113, demonstrating a steady rise in temperature due to global warming over time.

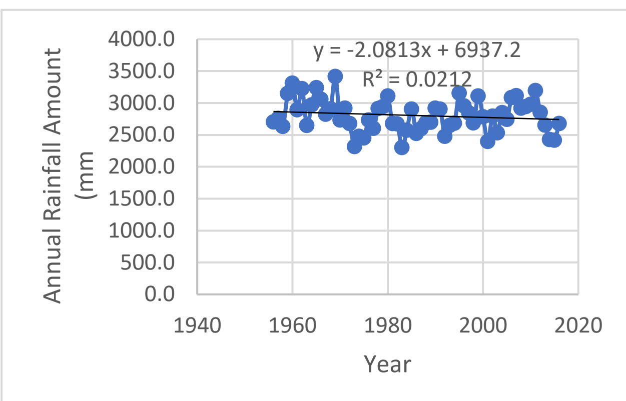

Figure3 (a) Annual rainfall spatial for Akwa-Ibom

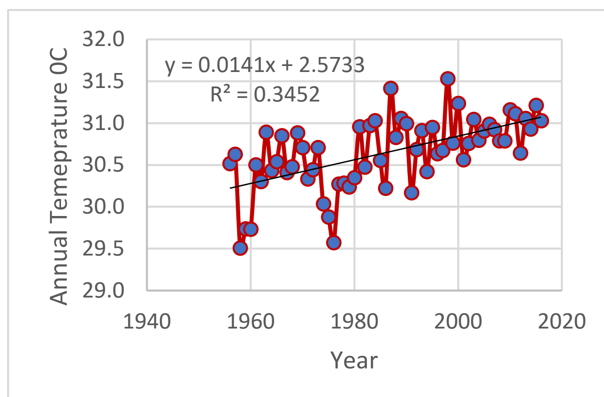

Figure3 (b) Annual temperature spatial for Akwa-Ibom

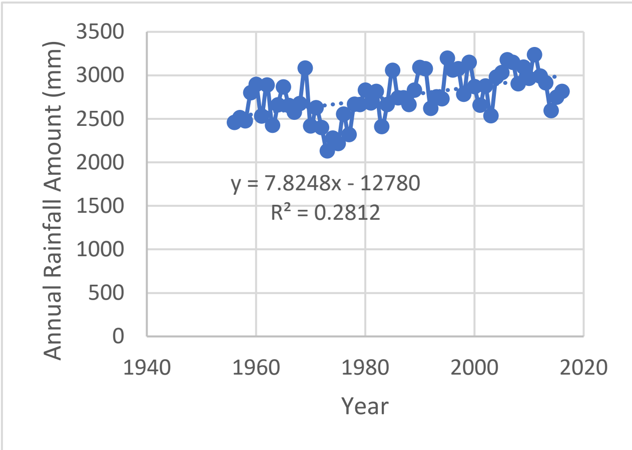

Figure 4 (a) Annual rainfall spatial for Cross River

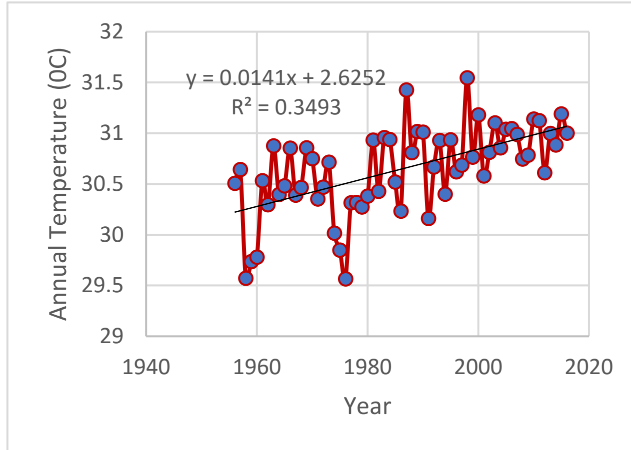

Figure 4 (b) Annual temperature spatial for Cross River

Table 7 Overview of the Analysis of Linear Regression

S/N	Location	Rainfall			Temperature		
	States	**Equation**	**Slope**	**Nature of Trend**	**Equation**	**SLOPE**	**Nature of Trend**
1	AKWA IBOM	Y=-2.08X+6937.2	-2.081	Decreasing	Y=0.0141X+2.573	0.014	Increasing
2	BAYELSA	Y=-3.0872X+9227.1	-3.087	Decreasing	Y=0.152X+0.0959	0.015	Increasing
3	CROSS RIVER	Y=7.8248X-12780	7.825	Increasing	Y=0.0141X+2.625	0.014	Increasing
4	DELTA	Y=-3.4521X+9349.2	-3.452	Decreasing	Y=0.0153X+0.347	0.015	Increasing
5	EDO	Y=-0.5437X+3118.4	-0.544	Decreasing	Y=0.015X+0.7087	0.015	Increasing
6	LAGOS	Y=-2.0035X+5602	-2.003	Decreasing	Y=0.0113X+8.216	0,011	Increasing
7	OGUN	Y=-4.6226X+10432	-4.623	Decreasing	Y=0.0119X+7.252	0.012	Increasing
8	ONDO	Y=0.4666X+1110.8	0.467	Increasing	Y=0.0135X+3.937	0.013	Increasing
9	RIVER	Y=-6.86991X+16611	-6.869	Decreasing	Y=0.0156X+0.492	0.016	Increasing

In Table 7, Linear Regression Test revealed Increasing TREND in rainfall in Cross River and Rivers states and decreasing TREND in in rainfall in other locations studied (75%). Also,there was Significantly Rising TREND in Temperature in all locations studied.

3.7 The Spatial analyses of mean annual Rainfall

The Spatial analyses of mean annual rainfall for the first and second climatic periods (1956- 1986 and 1987-2016) respectively, in the coastal region of Nigeria are presented in Figure 5.

Figure 5 revealed that Bayelsa and Rivers States had the highest rainfall for the 1st Climatic (1956-1986) and Ogun and Lagos States had the lowest. There was a near equal amount of rainfall in all states except in Cross River State where the rainfall in the second climatic period (1986-2016) was higher than that of the first climatic (1956-1986) period which is indicative of an increase in rainfall. Also, the mean annual rainfall in River State is higher in the first Climatic period (1956-1986) than that of the second climatic period (1986-2016) indicating an amount of decreasing rainfall.

The changes in mean rainfall values in the two climatic periods are more noticeable in Cross River and the River States. There was also a steady progressive increasing rainfall from Lagos through Ogun, Ondo, and River States.

Spatial Map Produced for the study area using ordinary kriging presented in figure 6 illustrates the progressive increase in maximum annual rainfall amount for sixty (60) years along the coastline from Lagos to Cross River State with the highest values being in Bayelsa State. This is indicated by the shades of colours varying from blue through green, yellow and red (1635.453mm to 3074.098mm)

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3.8 The Spatial Analysis Means Annual Temperature.

The Spatial analyses mean annual Temperature for the first and second climatic periods (1956- 1986 and 1987-2016) respectively, in the coastal region of Nigeria is presentedin Figure 7. Figure 7 revealed that Ogun State had the highest temperature in both the first and second periodic periods (31, 0 ^{c} and 30.6, 0 ^{c} respectively) which is obviously due to the higher number of industries in the State generating heat in addition to greenhouse emission which led to climate change. The temperature in Lagos, Delta, Bayelsa, and Akwa- Ibom were about the same (30.8, ^{0}c) in the second climatic period. This was not the case in the first climatic period with only Lagos and Cross-River having the same temperature (30.4, ^{0}c).

There is generally a significant increase in mean annual temperature in the entire study area as the values for the mean annual temperature in the second climatic periods are higher than that of the first climatic period.

Spatial Map Produced for the study area using ordinary kriging presented in Figure 8 illustrates that there was a progressive increase in the mean temperature from the lowest value in Bayelsa to the highest value in Ogun State. This was the opposite of what we observed in the mean rainfall in the study are This is indicated by the shades of colours varying from blue through green, yellow and red (29.93 °C to 31.54°C).

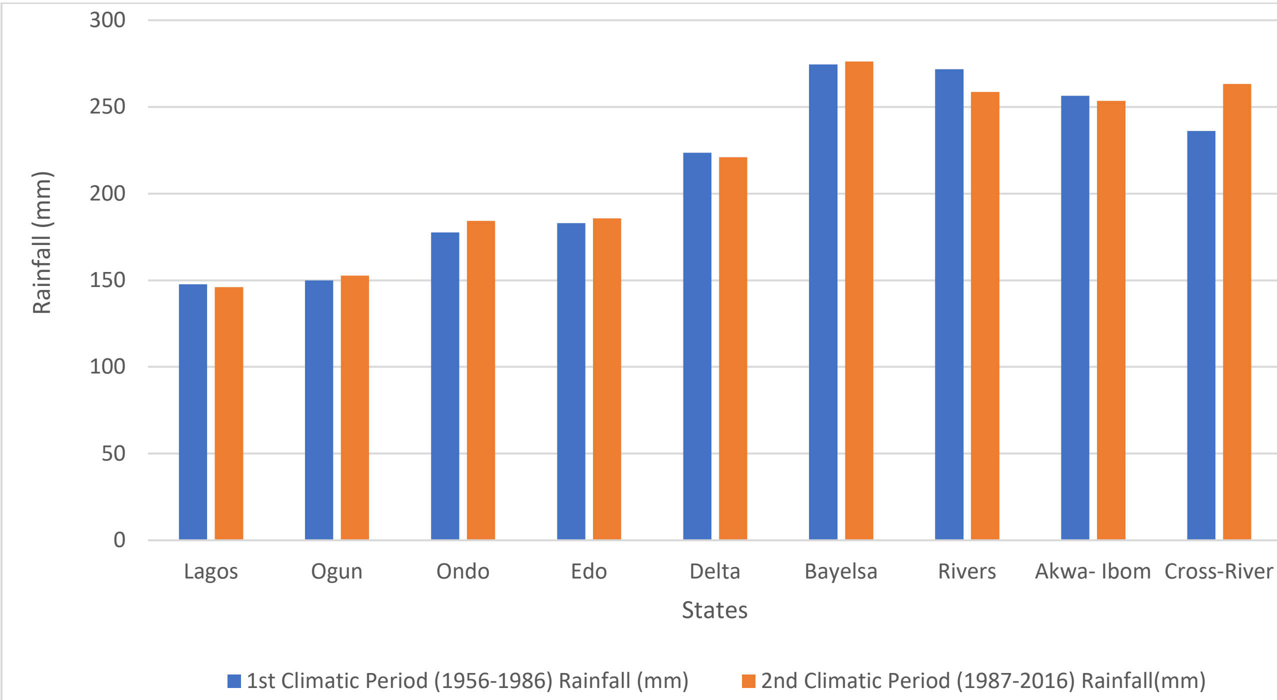

Figure 5 The first and second climatic periods' spatial distribution of mean yearly precipitation. In that order, from 1956 to 1986 and from 1987 to 2016.

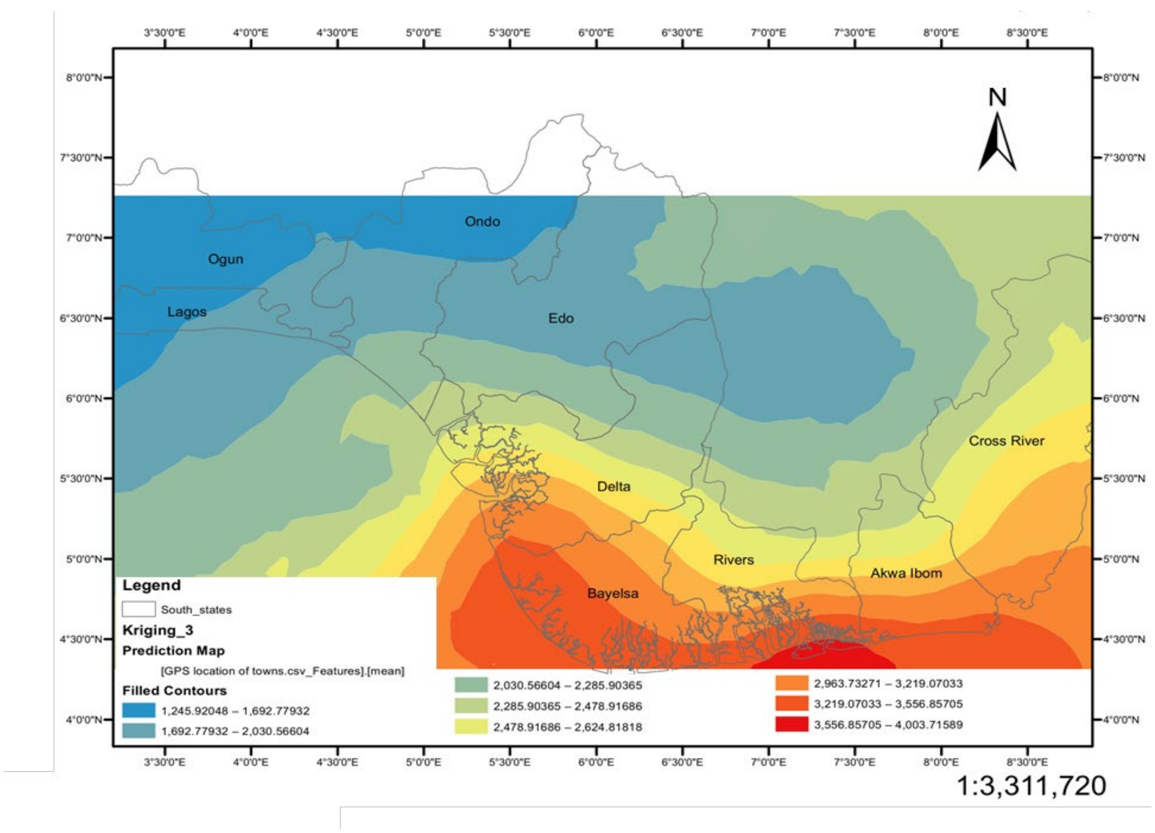

Figure 6 Annual mean rainfall for Nigeria's coastal Area

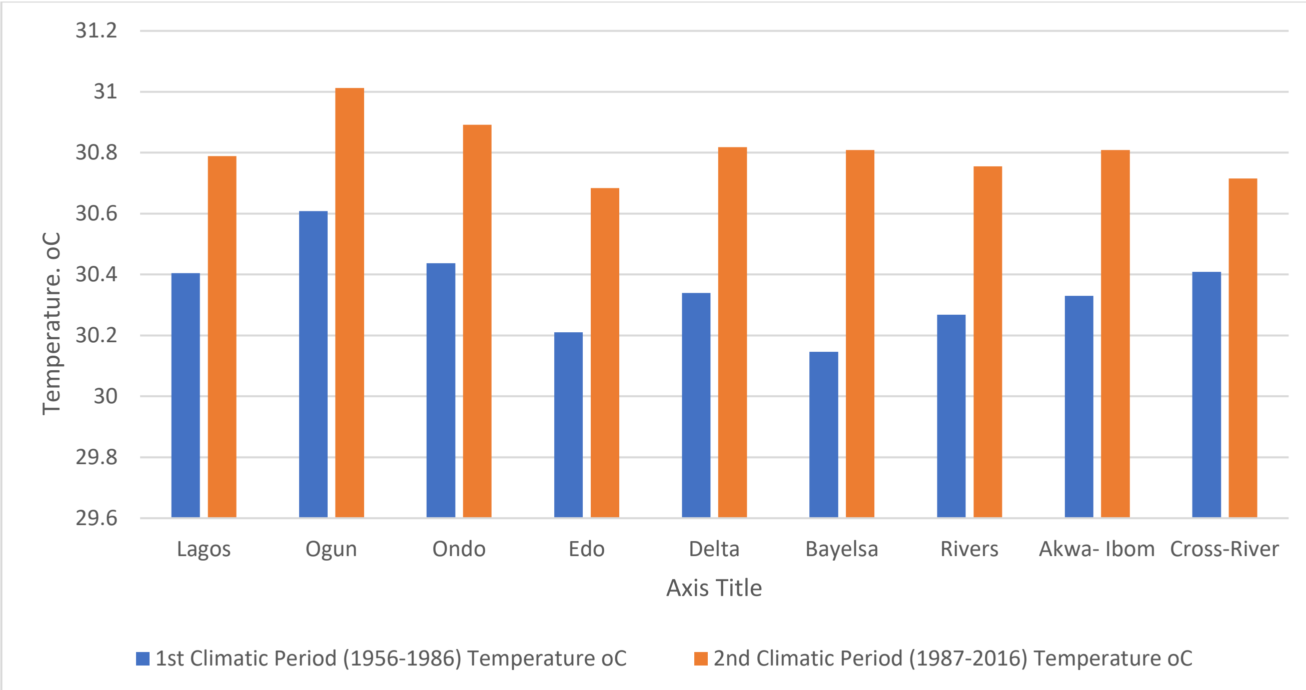

Figure 7 Mean annual temperature spatial distribution for first a.

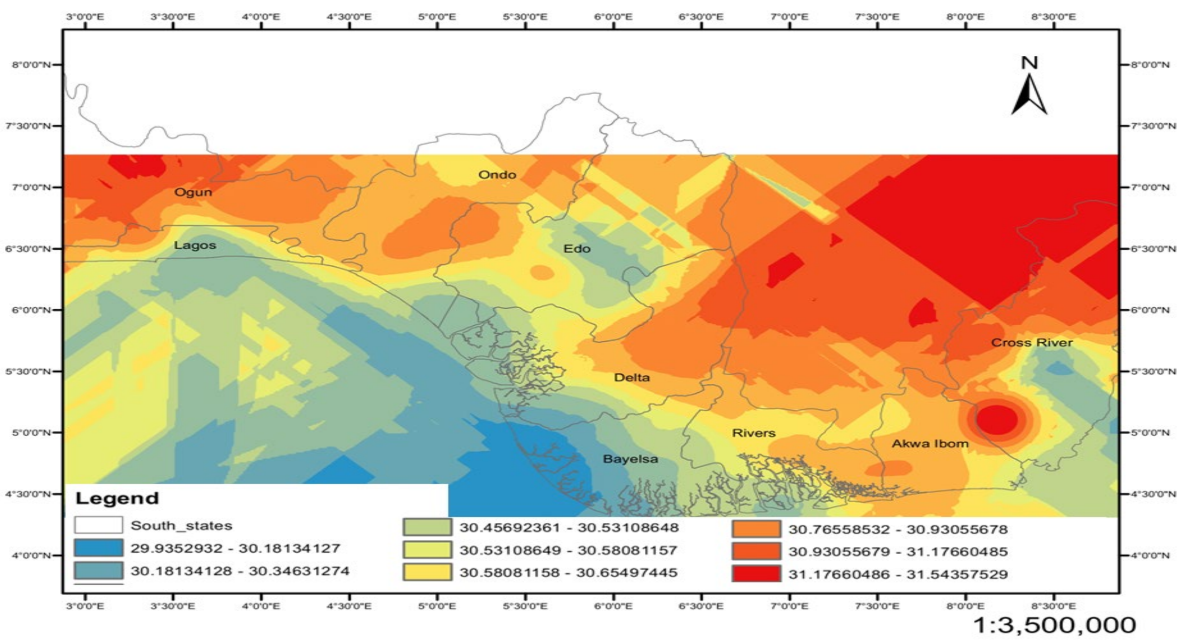

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Figure 8 Average Annual Temperature for Coastal Region of Nigeria

4.0 CONCLUSIONS

The study shows rainfall variability over the study areas. Results from the temporal analysis show that Lagos recorded the lowest annual rainfall amount (1626.52mm) while Bayelsa recorded the highest annual rainfall amount (3019.40mm) across the study areas and over the first climatic season. In the second climatic period, there was a slight decrease in rainfall amount in Lagos (1606.78mm) and a slight increase in Bayelsa (3038.00), but their positions were the same. The annual rainfall and temperature increased at the average rate of 3.047 mm yr-1. and 0.0126 ^{o}C yr-1 respectively. In 75% of the region, rainfall was decreasing, while in 25%, it was increasing. The implementation of adaptation and mitigation strategies should be mandatory due to the notable increase in temperature. The coefficient of variability (CV) showed extremely significant rainfall variability with values in most of the range between 62.43% and 69.46 % and low-temperature variability with CV values ranging between 4.314% and 6.037%.

While Rainfall has decreased in most of the locations, the temperatures have risen in all locations. There were rapid climatic shifts within the region between 1956 and 2016. These occurred primarily between 1976 and 1985, with 1980 being the most likely year of dramatic change. Nigeria is experiencing a trend toward a warmer and drier environment, according to the documented regional and temporal variations. as heatwaves are already beginning to occur because of the high temperatures.

These modifications were linked to climatic change brought on by global warming, which changed historically typical rainfall patterns.

The results of this study provide essential information for decision-making, effective climate action, and the sustainable management of resources and ecosystems in a changing world.

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There is no conflict of interest.

Consent For Publication

The authors of this work provide their approval for the publication of identifiable details, including figures included in the text.

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