

Analysis of Rainfall Trend in Selected States with in the Coastal Region of Nigeria using non-Parametric Mann-Kendall Test Statistics



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Abstract

Trend in rainfall data have a great impact on the hydrological cycle and thus involve both the character and quantity of water resources. Analysis of trend in rainfall data also aids to see the result of rainfall variability on the occurrence of drought and flood. The aim of this research is to detect and estimate the magnitude of trend associated with rainfall data from Akure and Calabar which are located within the coastal region of Nigeria using non-parametric Mann-Kendall test statistics. Monthly data for thirty six (36) years spanning from 1980 to 2016 was used as input parameters for the analysis. Infilling of the missing records was done with the aid of expectation maximization algorithm which is unarguably one of the best missing value analysis techniques. Preprocessing of the rainfall data was done by conducting numerous time series validation test such as test of homogeneity, test of normality and outlier detection. Homogeneity test was aimed at testing the assumption of same population distribution; outlier detection was to detect the presence of bias in the data while test of normality was done to validate the claim that climatic data are not always normally distributed. In addition to testing the normality assumption of the data, normality test was also employed to select the most suitable trend detection and estimation technique. Results of the analysis revealed that the rainfall data from Akure and Calabar are statistically homogeneous. The records did not contain outliers and they are not normally distributed as expected for most climatic variables. The non-parametric trend detection and estimation analysis revealed that the rainfall data from Akure shows statistical significant evidence of a decreasing trend with a computed M-K trend value of -129. Although, the rainfall records from Calabar do not have sufficient statistical evidence of a significant trend, the computed M-K trend value was +50 which is; evidence of an increasing trend.

Keywords: Homogeneity test; Normality test; Labeling rule; Mann-Kendall test; Non-Parametric analysis

Introduction

Adequate planning and management of water resources for sustainable development is an issue of concern and have developed into a widely studied area. Accurate knowledge of the past and present trend of climatic data can aid in visualization and characterization of the water resource situation both in the past and even presently [1,2]. The trend results will not only provide a general idea of any changes noticeable within the climatic data, it will also point out certain concerns for the area regarding extreme precipitation events such as drought and flooding. Climatic data trend

results will likewise suffice as a comparison for extreme precipitation events predicted by generalized time series forecasting models such as least square regression and multivariate regression model [3].

Trend in rainfall data have a great impact on the hydrological cycle and thus involve both the character and quantity of water resources. Analysis of trend in rainfall data also aids to see the result of rainfall variability on the occurrence of drought and flood [4]. Although numerous variables such as temperature, vegetation affects

the hydrological cycle, precipitation remains the key climatic variable that governs the hydrologic cycle and the availability of water resources. Numerous studies have analyzed the changes in precipitation patterns in global as well as regional scale. Recent studies have also suggested that analysis of hydro-climatic variables should be done at the local scale rather than at a large or global scale because the trends and their impacts may be different from one location to the other [5].

There are many different ways in which changes in hydro-meteorological series can take place. A change can occur abruptly (step change) or gradually (trend) or may take more complex forms. A time series is pronounced to have trends, if there is a significant correlation (positive or minus) between the observations and time. Trends and shifts in hydrologic time series are usually introduced due to natural or artificial changes. Natural changes in hydrologic variables are usually gradual and are caused by a global or regional climate change, which would be a representative of changes occurring over the study area. Changes in monitoring variables that may not be able to be extrapolated over a study area could be caused by a gradual urbanization of the area surrounding the monitoring site, changes in the method of measurement at the monitoring site, or by moving the monitoring site even a short distance away. The artificial change is usually mentioned in the overall record at a monitoring site, but this information is not always shown in the sites' data series. Thus, variables that appear to have a trend may actually just represent a change in climatological conditions near the monitoring site. In such a case, the affected climatological data should be changed so that the values are better represented of the study area as a whole [6].

A central factor in the modeling and analysis of the trend is the ability to establish whether a change or trend is present in the climatological record and to quantify this trend, if it is present. The trend in a time series data can be expressed by a suitable linear (parametric) or nonlinear (non-parametric) model depending on the behavior of the available data. The linear model is widely used in hydrology and the simplest of the linear models normally employed for trend detection is the Student's t-test which requires that the series under testing should be normally distributed [6]. Most importantly therefore, whether or not the sample data follow a normal distribution has to be examined prior to the analysis in order to choose the appropriate model for trend detection and analysis. Unfortunately, most researchers ignore this important check. If normality is violated (if the available data do not follow a normal distribution), then, the nonparametric test such as the Mann-Kendall Test is commonly applied to assess the statistical significance of trends [7,8].

Research Methodology

Description of Study Area

Nigeria is located in West Africa between latitude 40 N and 140 N and between longitudes 20 E and 150 E. It has a total area of 925,796km². The ecological zones of the country are broad-

ly grouped into three, which are Sahel, Savannah and the Guinea zones. Nigeria is affected by the Tropical Continental and Tropical Maritime air masses. The Tropical Continental is responsible for the dry season while the Tropical Maritime is responsible for the rainy season. The intervening periods of transition from the real onset and cessation of rain falls between February and April and between September and November respectively. Also a depression is indicated in the rainfall amount during the month of August and this has been named the little dry season or August break or mid-summer [9].

The Nigerian coastal zone sprawls a total of eight states, out of the thirty-six states of the Federation, namely: Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Lagos, Ondo, and Rivers. The coastal states are estimated to account for 25% of the national population. The coastal areas stretch inland for a distance of about 15km in Lagos in the West to about 150km in the Edo/ Delta and about 25km east of the Niger River. The coastline stretches for about 853km comprising inshore waters, coastal lagoons, estuaries and mangrove especially in the Niger Delta. Figure 1 shows the Nigeria coastal zones. The areas chosen as case studies for this study are Calabar the capital of cross River State which is located within the coasted mangrove swamp region and Akure the capital city of Ondo State.

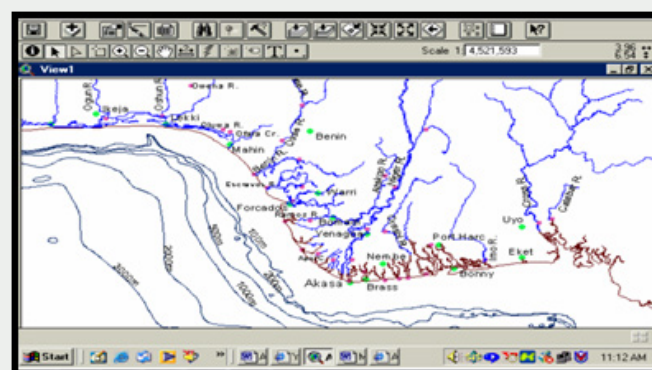


Figure 1: Nigeria's Coastal Zones.

Rainfall Data Collection

The data needed for this study was collected from Nigerian Meteorological Center, Oshodi, Lagos State, Nigeria. The data includes monthly precipitation data for 36 years spanning between; 1980 to 2016. Table 1 shows the records of the data from the different states under study

Table 1: Rainfall records for the states under study.

S/no	Study Area	Rainfall Records	No of missing values
1	Akure	432	47
2	Calabar	432	25

Preprocessing of Data

Climatic data collected was processed and used on monthly and seasonal basis for analytical convenience. Pre-processing of the data was aimed at:

From the correlation statistics of Tables 3a & 3b, a Probability (P) value of 0.256 and 0.428 were observed. Since $P > 0.05$ we accepted the null hypothesis H_0 and concluded that the data were missing completely at random. Based on this conclusion EMA was then employed to fill the missing values. The complete rainfall records for Akure and Calabar is presented in Tables 4a & 4b respectively. To detect the presence of outlier in the rainfall data, the labeling rule method was employed. The labeling rule is the statistical method of detecting the presence of outliers in data sets using the 25th percentile (lower bound) and the 75th percentile (upper bound). The underlying mathematical equation based on the lower and the upper bound is presented as follows:

Table 4a: Complete rainfall records for Akure using expectation maximization algorithm.

Year	January	February	March	April	May	June	July	August	September	October	November	December
1981	2.5	22.4	89.1	253.3	223.3	298.6	148.2	152.7	210.6	55.9	10.1	5.1
1982	10.6	68.1	79.3	221.8	211.8	169.8	180.9	25.2	131.0	269.6	11.0	20.9
1983	26.4	26.2	7.9	161.9	254.5	194.8	88.8	56.4	343.6	142.0	6.0	62.9
1984	15.0	57.0	174.9	189.6	203.0	218.3	151.3	206.6	197.1	186.1	0.5	13.2
1985	23.3	59.1	165.7	146.5	220.9	188.7	231.3	326.7	252.6	95.5	24.3	1.8
1986	12.7	150.2	130.8	41.8	167.5	142.2	100.6	77.5	217.9	82.0	46.6	17.9
1987	7.7	49.1	107.1	94.3	93.1	116.7	158.1	384.4	276.4	113.7	46.4	0.8
1988	18.4	74.7	74.3	182.0	156.9	203.5	193.1	82.6	278.1	229.9	44.7	17.6
1989	26.6	55.8	117.2	59.1	183.7	226.8	199.6	367.4	175.5	111.5	19.1	5.9
1990	4.4	15.5	44.0	158.5	113.6	90.7	370.3	245.8	230.9	213.3	72.4	62.5
1991	1.2	98.6	135.0	223.2	201.2	182.9	403.0	203.6	200.7	182.8	27.5	10.4
1992	2.5	49.3	40.0	107.8	151.1	237.9	265.3	101.7	340.1	194.6	35.6	65.9
1993	13.3	57.0	18.8	84.6	95.1	104.1	122.2	274.1	303.7	95.9	72.3	21.4
1994	11.2	39.4	44.4	97.8	169.9	225.8	147.6	162.8	181.3	157.3	26.0	26.5
1995	29.2	28.4	128.0	196.3	146.4	214.2	288.6	379.6	262.3	87.3	14.2	16.5
1996	40.4	68.0	67.8	218.3	220.0	154.0	106.2	116.2	286.8	111.0	17.6	8.5
1997	33.3	36.6	90.9	191.9	187.0	207.3	218.3	146.7	170.1	284.4	53.2	4.6
1998	32.7	33.7	10.9	122.3	231.1	243.5	155.3	90.4	256.3	273.3	46.8	51.9
1999	20.3	36.4	57.0	117.3	183.5	169.2	98.0	223.7	187.2	330.0	58.7	19.7
2000	44.7	-16.1	34.9	207.2	118.9	299.3	215.3	215.9	232.6	137.0	19.6	5.4
2001	30.7	46.4	70.7	255.0	106.6	125.9	155.1	52.0	185.4	24.5	1.2	24.9
2002	4.5	40.7	121.3	130.1	80.6	272.8	255.6	204.7	236.9	125.5	78.8	2.4
2003	1.1	44.5	20.5	87.3	115.3	158.7	89.7	80.7	114.0	62.0	41.5	8.2
2004	70.4	60.9	12.6	165.9	234.8	183.8	188.2	222.8	177.4	132.7	25.0	21.8
2005	15.3	37.0	186.4	85.0	211.4	252.8	189.6	182.0	236.0	151.0	31.1	7.9

2006	31.2	3.6	120.9	108.8	213.7	146.9	192.6	186.5	243.5	152.1	7.2	28.5
2007	40.8	86.7	59.6	90.0	208.3	172.6	181.9	188.6	276.6	193.1	52.2	2.8
2008	9.9	63.1	176.4	48.7	83.8	256.0	258.9	192.1	218.4	207.1	22.5	2.2
2009	26.1	48.5	154.7	177.4	142.0	151.5	252.7	100.5	80.1	136.7	59.4	25.8
2010	63.0	25.6	56.7	111.9	147.9	121.2	189.5	279.1	220.5	120.7	71.8	12.8
2011	11.4	88.1	96.1	113.1	144.9	158.2	176.3	172.4	326.0	187.8	25.8	0.0
2012	36.6	13.8	74.1	152.1	96.8	250.5	242.3	111.9	204.1	143.1	42.0	0.0
2013	2.5	35.6	215.1	126.2	176.0	186.5	256.6	97.9	273.3	84.3	33.3	17.0
2014	23.6	24.8	145.7	126.7	146.9	213.7	223.5	121.3	267.8	187.5	23.4	5.6
2015	12.8	65.4	98.5	87.6	119.7	134.5	176.0	188.7	243.6	154.3	21.5	1.2
2016	7.9	23.7	113.4	131.2	128.4	216.7	187.6	177.9	238.7	136.7	45.7	3.1

Table 4b: Complete rainfall records for Calabar using expectation maximization algorithm.

Year	January	February	March	April	May	June	July	August	September	October	November	December
1981	10.5	77.2	189.0	163.5	360.7	355.8	549.8	430.4	333.9	325.4	67.6	10.3
1982	57.7	57.4	159.2	190.1	351.3	396.0	505.7	381.7	476.8	531.8	73.4	27.9
1983	17.7	13.5	15.4	141.5	382.0	182.4	291.4	362.4	292.4	324.1	114.1	67.6
1984	38.5	24.8	167.8	143.2	312.0	437.3	274.5	121.2	414.5	310.4	273.4	41.5
1985	3.0	66.5	153.6	250.0	520.5	486.6	370.1	326.3	403.2	313.3	148.9	4.5
1986	45.1	72.1	263.8	119.5	274.4	153.0	533.4	284.1	403.9	414.6	91.9	28.0
1987	24.3	37.4	193.6	110.9	337.6	377.0	550.8	493.8	329.7	329.7	112.3	54.8
1988	51.2	31.1	196.1	378.6	224.1	487.9	367.0	147.3	536.3	233.1	131.6	56.5
1989	33.8	24.2	121.5	341.8	256.6	540.5	626.5	286.9	279.0	218.3	96.9	43.1
1990	20.8	141.1	5.4	53.6	344.0	473.6	702.7	225.7	336.5	310.0	303.3	96.5
1991	3.0	11.0	88.3	289.3	258.4	479.0	439.6	526.6	189.8	380.0	72.2	19.7
1992	2.6	0.5	271.5	208.3	161.8	387.7	465.1	400.2	481.4	408.5	120.7	0.1
1993	64.3	39.9	177.7	161.2	230.1	281.0	272.4	479.1	430.5	242.6	119.7	22.8
1994	40.7	14.0	167.1	328.2	255.3	294.2	609.3	424.5	290.0	265.2	229.7	22.0
1995	44.2	21.1	186.1	248.3	328.6	375.2	632.4	487.4	724.2	486.2	188.0	19.8
1996	2.4	162.7	161.5	314.5	299.5	435.3	401.1	425.4	615.2	367.4	40.5	11.5
1997	61.0	86.1	139.4	238.7	328.2	633.1	796.6	482.6	211.2	319.7	214.3	68.2
1998	25.4	6.0	174.0	149.1	217.6	584.5	255.2	353.7	365.0	437.1	170.0	33.5
1999	66.0	48.8	203.0	311.4	180.0	270.3	349.9	484.5	369.3	403.7	257.2	0.8
2000	66.0	147.5	95.9	186.4	217.0	290.6	617.9	390.2	627.6	232.9	153.6	57.5
2001	34.2	11.6	151.7	371.8	491.4	390.5	288.5	457.0	455.7	381.0	217.1	5.7
2002	29.9	13.5	154.6	216.2	315.3	344.6	274.1	623.5	424.3	395.5	24.0	6.8
2003	26.7	103.2	236.5	283.8	375.2	227.4	398.6	487.4	399.2	324.1	148.5	0.6
2004	9.9	19.9	7.9	278.4	270.2	388.0	272.4	381.9	338.0	196.4	168.3	0.8
2005	33.8	35.3	285.9	288.9	263.9	615.5	627.2	634.4	238.4	279.6	279.9	68.1

2006	84.7	57.1	323.0	166.1	431.8	227.7	486.9	273.4	535.3	175.3	134.4	0.1
2007	61.7	51.1	181.0	265.9	384.2	583.5	480.2	415.5	581.7	197.6	262.1	33.1
2008	75.1	184.1	178.7	178.9	386.8	437.0	587.8	510.2	190.1	342.7	94.4	78.1
2009	89.7	38.5	87.2	147.7	311.6	224.7	577.5	507.2	289.9	148.3	126.9	41.4
2010	31.8	86.9	63.2	125.7	305.5	681.4	287.0	395.9	451.3	302.6	271.6	56.2
2011	52.3	153.5	123.1	208.8	340.9	388.6	648.6	573.7	251.8	519.9	325.2	43.8
2012	32.9	376.4	36.0	83.2	438.4	398.8	630.1	861.7	619.7	410.4	126.7	30.6
2013	141.0	79.4	231.4	279.4	473.0	522.3	477.0	405.1	340.4	355.1	228.4	81.1
2014	58.7	88.4	124.5	257.4	305.7	388.1	458.7	403.7	423.6	175.9	104.3	21.3
2015	34.5	67.9	98.7	146.8	321.2	204.5	256.9	412.4	521.7	291.7	124.9	7.8
2016	47.1	103.4	157.8	243.9	367.8	226.5	287.3	454.6	527.9	423.6	192.1	43.2

$$\text{Lower Bound } Q_1 - (2.2 \times (Q_3 - Q_1)) \quad (3.1)$$

$$\text{Upper Bound } Q_3 + (2.2 \times (Q_3 - Q_1)) \quad (3.2)$$

At 0.05 degree of freedom, any data lower than Q_1 or greater than Q_3 was considered an outlier [10]. The descriptive statistics of the data based on the outlier detection analysis is presented in Tables 5a & 5b respectively.

Table 5a: Descriptive statistics of Akure rainfall data

Descriptives				Statistic	Std. Error
Rainfall	Mean			122.386	4.3415
	95% Confidence Interval for Mean	Lower Bound		113.853	
		Upper Bound		130.919	
	5% Trimmed Mean			117.951	
	Median			113.850	
	Variance			8.143E3	
	Std. Deviation			90.2362	
	Minimum			.0	
	Maximum			463.0	
	Range			463.0	
Rainfall	Interquartile Range			147.1	
	Skewness			.541	.117
Rainfall	Kurtosis			-.300	.234

Percentiles				5	10	25	50	75	90	95
Weighted Average	Rainfall			5.530	13.230	40.475	113.850	187.575	243.500	273.300
Tukey's Hinges	Rainfall					40.550	113.850	187.550		

Table 5b: Descriptive statistics of Calabar rainfall data.

Descriptives				Statistic	Std. Error
Rainfall	Mean			249.089	8.6542
	95% Confidence Interval for Mean	Lower Bound		232.080	
		Upper Bound		266.099	
	5% Trimmed Mean			239.328	
	Median			230.900	
	Variance			3.235E4	
	Std. Deviation			1.7987E2	
	Minimum			.1	
	Maximum			881.4	
	Range			881.3	
Rainfall	Interquartile Range			288.6	
	Skewness			.621	.117
Rainfall	Kurtosis			-.020	.234

Percentiles				5	10	25	50	75	90	95
Weighted Average	Rainfall			12.835	30.110	87.475	230.900	376.100	493.440	579.600
Tukey's Hinges	Rainfall					87.750	230.900	376.800		

The extreme value statistics of Akure and Calabar rainfall data which shows the highest and lowest case numbers is presented in Tables 6a & 6b respectively.

Table 6a: Extreme value statistics of Akure rainfall data.

Extreme Values				
Rainfall		Case Number	Value	
Highest	1	127	463.0	
	2	80	384.4	
	3	176	379.6	
	4	115	370.3	
	5	104	357.4	
Lowest	1	384	.0	
	2	372	.0	
	3	47	.5	
	4	84	.8	
	5	265	1.1	

Table 6b: Extreme value statistics of Calabar rainfall data

Extreme Values				
Rainfall		Case Number	Value	
Highest	1	354	881.4	
	2	380	861.7	
	3	295	827.2	
	4	199	796.6	
	5	177	704.2	
Lowest	1	312	.1	
	2	144	.1	
	3	228	.3	
	4	134	.5	
	5	288	.6	

From the result of Table 6a, it was observed that the highest rainfall value is 463.00mm which is less than the calculated upper bound of 511.195mm. The lowest rainfall value was observed to be 0.00 which is greater than the calculated lower bound of -283.145mm. Since no rainfall value is greater than the calculated upper bound or lower than the calculated lower bound, it was again concluded that the rainfall data from Akure is devoid of possible outliers. From the result of Table 6b, it was observed that the highest rainfall value is 881.40mm which is less than the calculated upper bound of 1011.075mm. The lowest rainfall value was observed to be 0.10 which is greater than the calculated lower bound of -547.50mm. Since no rainfall value is greater than the calculated upper bound or lower than the calculated lower bound, it was again concluded that the rainfall data from Calabar is devoid of possible outliers.

To ascertain that the rainfall data are from the same population distribution, homogeneity test was conducted. Homogeneity test is based on the cumulative deviation from the mean as expressed using the mathematical equation proposed by Raes et al. [11].

$$S_k = \sum_{i=1}^k (X_i - \bar{X}) \quad k = 1, \dots, n \quad (3.3)$$

where

X_i = The record for the series $X_1 X_2 \dots X_n$

\bar{X} = The mean

S_{ks} = the residual mass curve

For a homogeneous record, one may expect that the S_{ks} fluctuate around zero in the residual mass curve since there is no systematic pattern in the deviation X_i 's from the average values. To perform the homogeneity test, maximum rainfall values were extracted from the monthly rainfall data and analyzed using the Rainbow software. Results of the homogeneity test are presented in Figures 2a & 2b respectively.

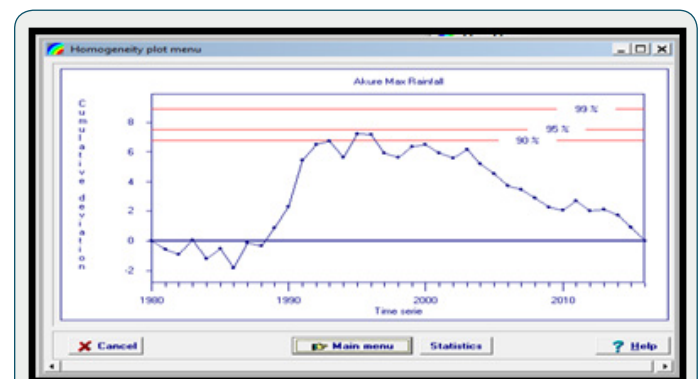


Figure 2a: Homogeneity test of Akure rainfall data.

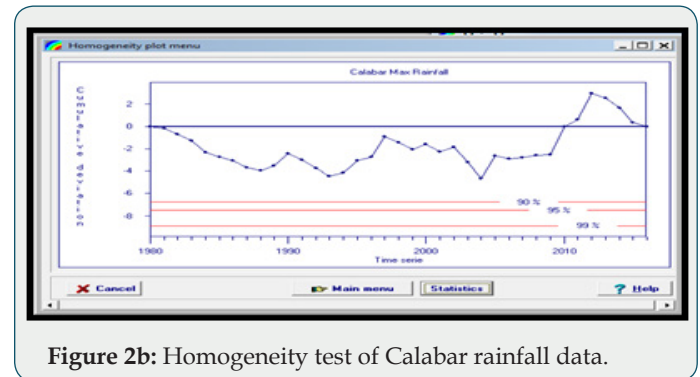


Figure 2b: Homogeneity test of Calabar rainfall data.

Results of Figures 2a & 2b shows that the data point fluctuate around the zero center line an indication that the rainfall data are statistically homogeneous. To further confirm that the rainfall data are statistically homogeneous, test of hypothesis was done as follows:

H_0 : Data are statistically homogeneous


H_1 : Data are not homogeneous




The null and alternate hypothesis were tested at 90%, 95% and 99% confidence interval that is 0.1, 0.05 and 0.01 degree of freedom and results obtained are presented in Tables 7a & 7b respectively. From the result of Table 7a & 7b, the null hypothesis (H_0) was accepted, and it was concluded that the rainfall data collected from Akure and Calabar, are statistically homogeneous at 95% and 99% confidence interval that is 0.05 and 0.01df.

On whether the rainfall data employed in this research are normally distributed, normality test was conducted. In addition to checking the distribution of the data, normality test was also aimed

at selecting the most appropriate model for trend detection and estimation. If the data are normally distributed then parametric model such as least square linear regression will be most appropriate for trend detection and estimation otherwise non-parametric model such as Mann-Kendall and Thiel Sen's slope estimation will be employed for detection and estimation of trend in the data.

Table 7a: Extreme value statistics of Calabar rainfall data



Homogeneity statistics menu

Data file

File name

Description

 **Restrictions**


Homogeneity test




Probability of rejecting homogeneity

statistic	rejected ?		
	90 %	95 %	99 %
Range of Cumulative deviation	YES	No	No
Maximum of Cumulative deviation	YES	No	No

Estimate of change point (year)

Table 7b: Homogeneity statistics of Calabar rainfall data



Homogeneity statistics menu

Data file

File name

Description

 **Restrictions**

Homogeneity test

Probability of rejecting homogeneity

statistic	rejected ?		
	90 %	95 %	99 %
Range of Cumulative deviation	No	No	No
Maximum of Cumulative deviation	No	No	No

Estimate of change point (year)

For normality the histogram of the rainfall data collected from Akure and Calabar should assumed the bell shaped configuration otherwise, it is concluded that the data are not normally distributed. The histogram of the rainfall data collected from Akure and Calabar are presented in Figures 3a & 3b respectively. From the result of Figure 3a & 3b, it was observed that the rainfall data from Akure and Calabar are not normally distributed which is expected for most climatic variables owing to their stochastic nature. To conclude the assumption of normality, statistical hypothesis were formulated as follows:

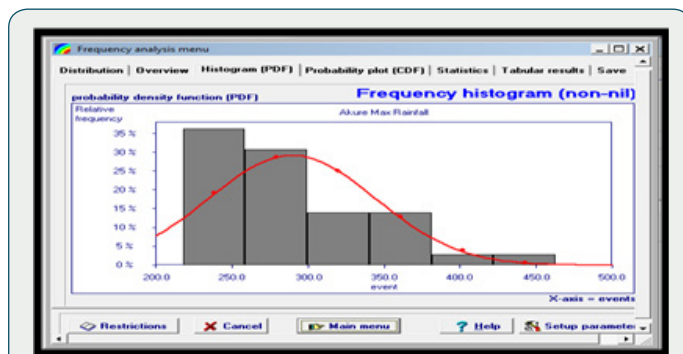


Figure 3a: Histogram of Akure rainfall data.

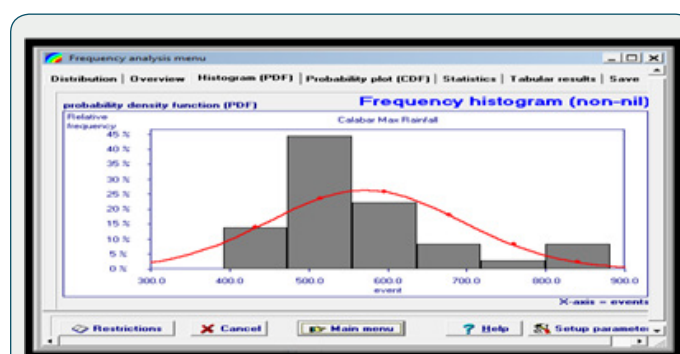


Figure 3b: Histogram of Calabar rainfall data.

H0: The data are normally distributed

H1: The data are not normally distributed

To validate the strength of the null hypothesis, normal probability analysis software was employed to test the normality behavior of the rainfall data at 99% confidence interval (0.01 degree of freedom). Result of the statistical analysis is presented in Figures 4a & 4b respectively. Result of Figures 4a & 4b revealed that rainfall data from Akure and Calabar are not normally distributed at 99% confidence interval. The implication is that non-parametric test will be most suitable in detecting and estimating the magnitude of trend associated with the data.

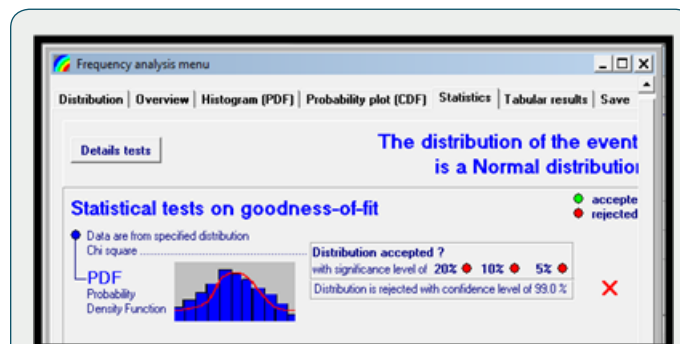


Figure 4a: Statistical test of Akure rainfall data.

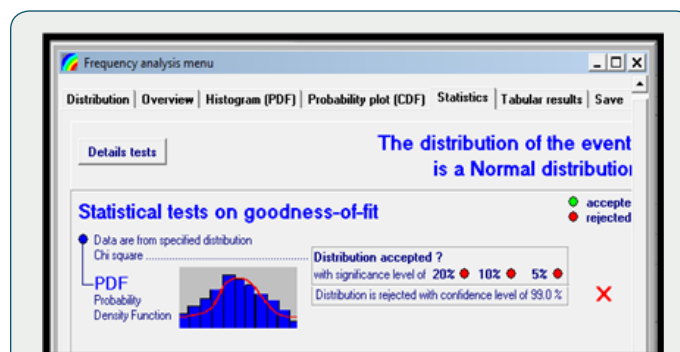


Figure 4b: Statistical test of Calabar rainfall data.

To perform the non-parametric analysis, the Mann-Kendall Trend test was employed. The test was conducted using Environmental Data Analysis Software (ProUCL). Results of the test are presented in Figures 5a & 5b respectively. From the results of Table 8, it was observed that there was insufficient statistical evidence

of a significant trend in rainfall data collected from Calabar. That was not so with rainfall data from Akure as the non-parametric test result revealed a statistical evidence of a decreasing trend with M-K value index of -129.

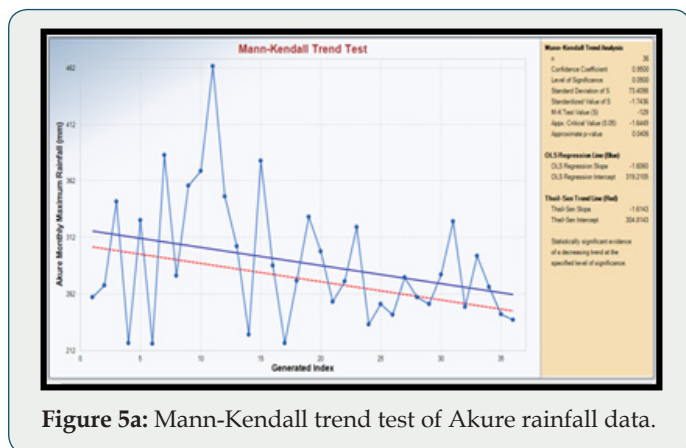


Figure 5a: Mann-Kendall trend test of Akure rainfall data.

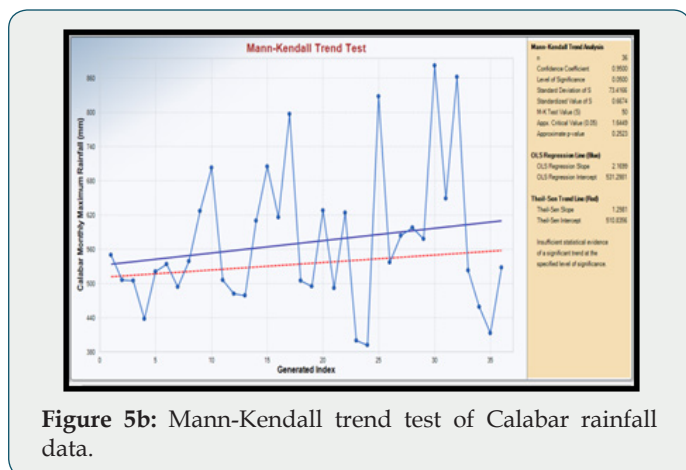


Figure 5b: Mann-Kendall trend test of Calabar rainfall data.

Table 8: Summary of trend analysis of rainfall data.

S/No	Rainfall data location	Nature of Trend	M-K Test Value (S)
1	Akure	Statistical significant evidence of a decreasing trend	-129
2	Calabar	Insufficient statistical evidence of a significant trend	50

Conclusion

The focus of the present study was to analyze time series data such as rainfall collected from Akure and Calabar using different time series analysis procedures. Based on the overall results, the following conclusions were made:

- Expectation maximization algorithm was highly effective for the infilling of missing climatic data

such as rainfall. It was observed in all cases that the null hypothesis of missing completely at random was satisfied since p-value was always greater than 0.05

- Based on the outcome of the outlier detection analysis, it was concluded that climatic data used

for this present analysis are devoid of possible outliers

- Results of normality test further support the existing claim that climatic data are not always

normally distributed owing to their stochastic nature.

- Although, the non-parametric statistical analysis based on Mann-Kendall test revealed that

statistical evidence of an increasing trend was observed in rainfall data from Akure, it was also observed that there was insufficient statistical evidence of a significant trend in rainfall data collected Calabar.

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