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Analysis of rainfall trend, fluctuation and pattern over Port Harcourt, Niger Delta coastal environment of Nigeria

Abstract

Rainfall affects man in all spheres of his life, especially in a one city state like Rivers State. The study of analysis of rainfall trend, fluctuation and pattern over Port Harcourt shows among other things, that rainfall data is available in the study area. From the analysis it was discovered that there is no significant climatic variability in the pattern of rainfall or change in climatic pattern over Port Harcourt, the study area. The general RF condition has not change over the years. The rainfall pattern shows double Maxima with an August break or dry spell in between the two peak months of July and September. The harmattan dry season starts from late November to late February, this situation has not changed. Finally, it was also discovered that there is hardly any month without rainfall. However, the study further shows that the trend in rainfall is negative (Decreases over the years) a gradual decrease over the years in the study area implies that the amount of rainfall and the intensity is decreasing. However, this has not change the pattern or characteristics of rainfall. The fluctuation shows that the intensity of rainfall and amount is decreasing over the years. Finally a projection into 10 years shows a very gradual decrease in rainfall. It was also discovered that variability are high during the dry months than the wet months. The five lowest RF variability months accounted for 63.85% of the entire RF over Port Harcourt during the study period. Whereas, the five high RF variability months accounted for just 15.84% of the total RF over Port Harcourt for the 84 years of study.

Keywords: climate, rainfall characteristics, rainfall variability, trend, weather

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Introduction

The history of mankind shows that man had experienced one form of climatic variability or another. Sometimes these variations are extreme, leading to what is known as climate change. The case of Noah's flood and famine of Joseph's days all in the Bible are few cases of extreme climatic variability.[1] Rainfall is a form of precipitation commonly experience in the tropical regions of the world. The abundant heat or solar energy within the tropics melts super cold water molecules at high altitude. The melting reduces the volume, but increases the weight of the water molecules, which when responded to gravity give raise to rainfall (RF)[2,3] it is beyond this paper to state theories of RF formations.

Rainfall is liquid water dropping from the atmosphere to the Earth surface, ranging from 1–5mm in diameter. The type of RF produced reflects the circumstance in which it is formed.[3] The importance of RF in the tropics can never be underestimated. In fact RF is everything for tropical indigenous people. It determines the food they eat, clothes they wear, the types of activity and their agricultural calendar. RF provides most of the needed water for agriculture in the tropics. The interest in the study of RF in the tropics shows its importance. It is the most unreliable element and the least predictable element of climate in the humid tropics. Its role in agriculture is ever more spectacular in the tropics because of relatively high temperature throughout the year, and the rate of evaporation is constantly high. On the other hand, RF is highly seasonal over most parts of the tropics with exceptions of few mountain areas, the growing season/harvest unlike in the temperate region is determined by the availability of RF.[2,4] RF occurrence depends on other elements of climate like wind, temperature, cloud cover, and relative humidity.

Extreme environmental events, such as floods, droughts, rainstorms, and high winds, have severe consequences for human society. Planning for weather-related emergencies, design of engineering structures, reservoir management, pollution control, and insurance risk calculations, all rely on knowledge of the frequency of these extreme events.[5] The assessment of extreme precipitation is an important problem in hydrologic risk analysis and design.

Climate variation and fluctuation are normal natural experiences, but a shift from the mean climate is of great concern to scholars as it consequence to the environment is inimical. In the face global climate change, many scholars have engaged in studying various element of climate to understand the present pattern and characteristic of climate. For instance, Ifabiyi et al.,[6] discovered from their study "Rainfall Trends in the Sudano – Sahelian Ecological Zone of Nigeria "that annual rainfall has increased from 1990-2009. Ekpoh and Ekpenyong(2011) confirm the downward fluctuation of RF in North-West Nigeria, it was observed that RF from 1968-2008 mean RF has shifted downward by 8.8% from the long term mean. Climate is the mean state of the atmosphere of a location or an area over a defined period of 25 to 30 years or more. It imposes cost on man but also bestows benefits. For instance storms and floods causes damage and sometimes loss of life, but the day to day variations contributes to the rich variety of flora and fauna, which add so much to the quality of lives.[4,7,8]

Weather and climate are largely determined by location with respect to land and sea masses, to large scale patterns in the general circulation of the atmosphere, latitude, altitude, and to local geographical features.[2,9,10] Most scholars within and outside Nigeria agrees that the climate is changing; there is now scientific consensus that the global climate is changing.[11] Abaje, et al.,[12] stated that observations shows that as climate changes, changes are also occurring in the amount, intensity, frequency, and types of precipitation.

The causes of the flooding which could be natural and or manmade have not been established. However, among the possible causes could have been the changing world climate which triggered excessive rainfall, bursting dams and overflowing river banks. With the high tide in the Atlantic Ocean, rivers Niger and Benue (and their tributaries), which run through the centre of the country experienced a back lash and surge of water into the hinterlands. Thus all the areas along the plains of the two rivers experienced flooding for some time. With twist in the world climate, disasters of this nature are bound to occur. Hence there is need for proper study of the pattern in the variations of these climatic parameters, such as rainfall. This could be by testing whether their variations are periodic or not. This type of assessment will help in taking long term measures such as opening up of waterways, dredging of canals and building of even dams in the flood prone areas.[13]

Many factors are responsible for the changes in distribution and characteristics of the climatic variable (Rainfall) over Port Harcourt. These include anthropogenic activities and natural incidences, however, the general dispersion of climate variable are not just fluctuation (being primary characteristics of natural system) but a steady and slowly changing due to human inadvertent incursions into nature by ways of socio-economic activities that result to development initiatives, Population growth, agricultural activities as well as growth in science and technology. The gaseous and material injections that the above activities have injected into the atmosphere, the continuous clearing of the green vegetal cover for other land use purpose particularly inhabits transpiration and evaporation from land and vegetal surfaces. Such vicinity after decades or centuries of such human interventions.[14–16]

RF variability refers to variation in the mean state and other RF statistics on spatial and temporal scales beyond that of individual precipitation events. The importance of RF on a given area depends on how it affects the people's life and what the researcher seeks to achieve. The study could be to address problem at hand or for just an academic exercise. It could also be a research to address an identified problem. Many scholars have worked on RF and its related field within and outside Nigeria. Nieuwolt[17] stated that the amount of RF that is normally received in an area determines which type of agriculture that can be carried out and which crops can be cultivated in a region. RF is an important limiting factor in food production in many regions of the world.[18] RF as an element of climate is vital because a reasonable shift from the mean can lead to a change in the climate of the region.[19–21] Most of the scholars focused on RF trend, for instance. Abaje et al,[12] Ifabiyi et al.,[6] Imo, et al.,[22] talked on trend. RF trend according to Alexander[7] gives a picture of RF pattern annually. It is important in the study of hydrologic cycle and water resources; however, it is not very vital for agriculture and in understanding seasonal distribution of RF. It does not also explain the facts on drought and flood. It is actually an illusion to the true distribution of RF. Studies also abound in seasonal and seasonality of RF.[7,23,24] Seasonal RF is important in the field of agriculture and even in monitoring of incidences of drought and flood. The usefulness of seasonal RF is the ability to use result for prediction which most scholars has not done. So, seasonal RF is very useful in the field of climatology.[7]

The study is limited to only rainfall as against other climatic variables

The present work tend to study the trend in RF over Port Harcourt and to see if there is major dispersion over years. It will also investigate the seasonal RF distribution over the study area. Finally this work shall seek to establish the true characteristics of RF over the study area. This work is based on a long data record. The study will check if RF characteristics and pattern has change in the study area or not, among other things to achieve.

Study area

Port Harcourt is located on latitude 04° 45'N to 04°60'N and longitude 06° 50'E to 08°0'E. It is situated 15.0 metre above sea level; it is a relatively low land area. Port Harcourt is the capital of Rivers State and the entire South – South states of Nigeria. It is generally a low land area. It is the only city or mega city in Rivers State (with the idea of greater PORT HARCOURT). Rivers State has a population of 5.2 million and a population density of 190 persons per km^2 during Nigeria Population Census of 2005.[25] As at 2006 the population of the city of Port Harcourt was 1,382,592, and in 2016 the population has reach 1,865,500.

Port Harcourt has a humid semi hot equatorial climate.[26] The temperature is moderately high and would have been higher if not for her closeness to Atlantic Ocean. The mean temperature is about 28°C, with a range of about 3–5°C. The mean relative humidity is about 85%, but in the wet months, especially July and September it stood at over 95%. During the few dry months, especially December and January relative humidity is about 80%. Generally RF is recorded in almost all the months following the mean record. However, in some few years there are months without RF. The mean annual RF is about 2500mm per year. Rainy season starts in March and terminates in October, the few dry months sometimes records reasonable RF in February and November.

Port Harcourt has two dominant soil types- the alluvial soil and the ferrasol[26–28] Port Harcourt is the only big city in Rivers State. It is host to many multinational companies, though some are moving their head offices outside Port Harcourt as a result of militant activities. It has a Sea Port and three Universities, a Polytechnic and a College of Health Technology, with other higher institutions. The road network in the study area of recent has improved. The study area is shown in Figure 1.

Methodology

The data for this work is secondary; it is extracted from the Central Bank of Nigeria quarterly series culled from Nigeria Meteorological Agency RF Record. The study period is eighty four years (84) from 1931–2014. Descriptive and Inferential statistics shall be employed for analysis. The descriptive statistics used among others include graphs, tables, mean, and standard deviation, coefficient of variation, true mean and percentage. These shall describe the trend and seasonal occurrence of RF over the study period. C.V shall analyse the variation in RF, and the true mean explains the ideal RF distribution variation over the months or years. The true mean is the statistical mean divided by the number of years of study (Duration). The higher the result the more reliable the RF. True mean shows monthly mean RF during the study period. Percentage will address the seasonal contribution of the months RF to the total RF of Port Harcourt.

The inferential statistics used among others include Kruskal Wallis et al.,[29] test for several treatment[29] which shall be used to examine relationship in RF distribution over time. To achieve this, the 84 years RF data shall be exclusively grouped into four, with each group having a 21 years record. Exclusive grouping is favoured in this work because in real live years does not repeat itself. It is lack of data that forces some scholars to use inclusive data.

Kruskal-Wallis[29] Test is given below as

$$\mathcal{X}^2 = = 12/N\left(N+1\right)\left(C_1^{2/}/n_1 + C^2_{\,2}/n_2 + C^2_{\,3}/n_3 + \dots\dots\dots + C_C^{\,2}/n_C\right) - 3\left(N+1\right) \quad (1)$$

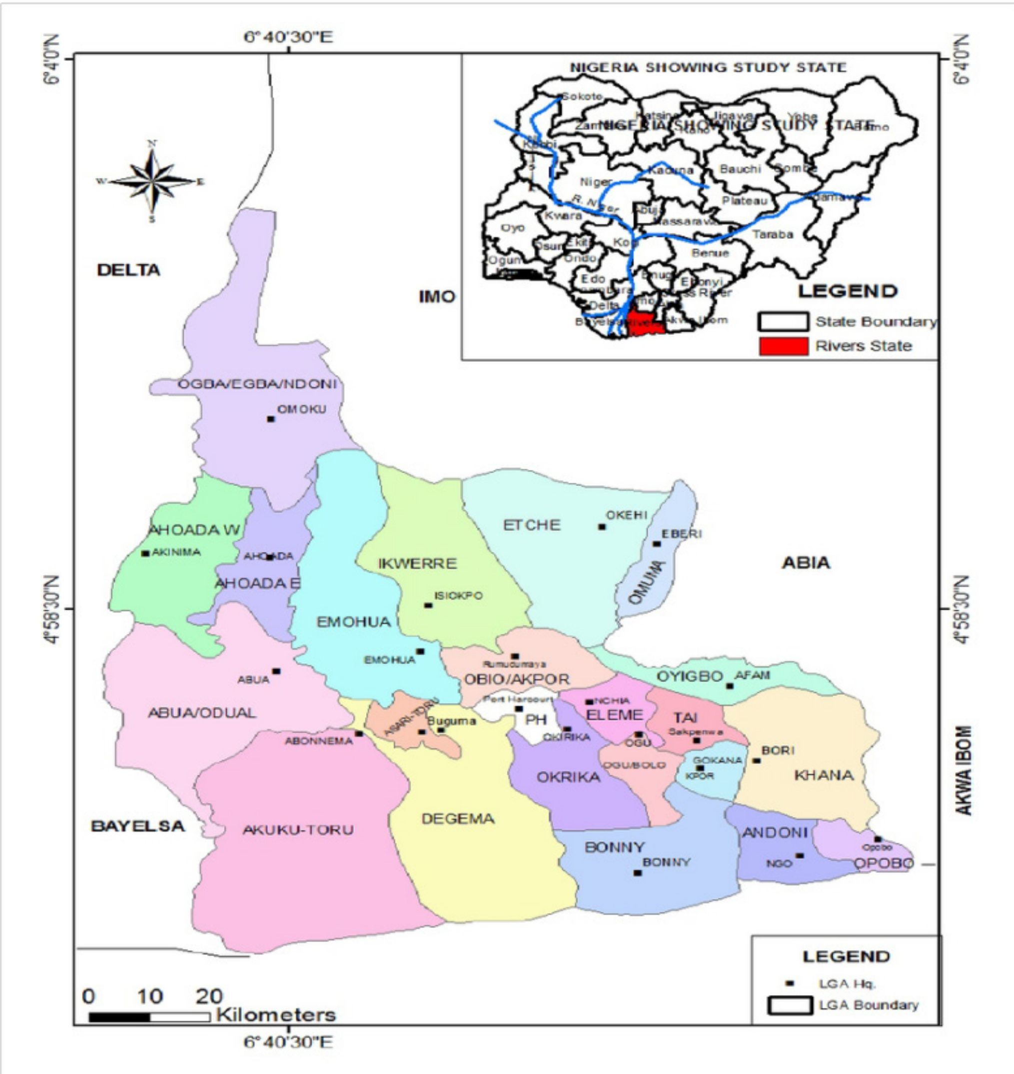

Figure 1 Map of rivers state showing Port Harcourt, the study area.

Where N = summation of the all observed outcomes or occurrences ($C_1 + C_2 + C_3 + \dots C_C$)

n = number of occurrences in a column.

C = summation of the observed items in each column.

12, 3 and +1 are constant in the equation.

$\mathcal{X}^2$ = Chi square symbol.

Pearson Product-Moment Coefficient of Correlation (PPMCC) is used to analyse a longer duration of 42 years (i.e. the 84 years was group into two to find longer time effect.

PPMC is given as

$$r = \sum xy - n\sigma\bar{y} \,/\, n\sigma x^{*}\sigma y \qquad (2)$$

r = Coefficient of correlation

n = number of pairs or sample size

Σ = summation and σ = standard deviation

Other test like coefficient of determination and Student test shall he used to test the validity of the result or otherwise.

Coefficient of determination (CD) = r^2*100 (3)

r^2 = coefficient of correlation square

Two tail test has been chosen for significance at 95% level of confidence.

$$'t' = r\sqrt{n} - 2/\sqrt{1} - r^2 \qquad (4)$$

't' is the student test.

n = number of pairs or sample size.

r = coefficient of correlation, while n is the number of pairs or the sample size.

Analysis and discussion

Seasonal distribution of rainfall

From Table 1 December has the highest coefficient of variation (CV) of 133.57%. It is followed by January with 80.97%, February 73.94%, November has 65.52% and March with 51.21%. The high CV months accounted for 15.84% of RF occurrences during the study period. This represented 31,521.81mm of the total RF over Port Harcourt. This implies that about 375.26mm of RF per year is expected from the five high CV months. The high CV months are the dry season months. These months are the most unreliable RF months in Port Harcourt.

June, September, October, May, and July are months with low CV. The five months with lowest CV accounted for 63.85% of the RF over Port Harcourt during the period of study. This represented 127,062.33mm of RF during the 84 years of study. It means that these months are responsible for at least 1512.65mm of RF annually. The low CV months are the wet months.

Table 1 Rainfall distribution, mean, standard deviation and coefficient of variation over Port Harcourt

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TOTAL	2887.83	5734.46	10968.5	15483.4	19602.9	24477.5	29183.4	24939.3	31453	22335.5	8767.64	3167.79
MEAN	34.79	68.27	130.58	184.33	233.67	291.4	347.42	296.9	374.44		104.38	37.71
STD	27.84	50.48	66.87	77.21	76.56	89.88	115.47	130.23	120.28	85.73	68.39	50.37
CV	80.97	73.94	51.21	41.89	32.81	30.84	33.24	43.86	32.12	32.24	65.52	133.57
%	1.45	2.88	5.51	7.78	9.85	12.3	14.67	12.53	15.81	11.22	4.41	1.59

August had a CV of 43.86%, though it is among the wettest months. August accounted for 12.53% of RF during the study period, The reason for the relative high CV is as a result of the seasonal dry spell on West Africa known as August break.

The mean seasonal CV of RF is 40.49%, and the mean seasonal RF is 16,583.44mm, but the true mean is 2369.06mm. The mean of mean RF is 197.422mm. This is the mean monthly RF over the study period. In seasonal rainfall (RF) we look at RF characteristic base on months. Figure 2.0 shows the general characteristics of RF over the years. From figure 2.0 September had the highest rainfall. The mean rainfall for September is 374.44mm. July had a seasonal average RF of 347.42mm. Between September and July, was an abrupt fall in RF distribution in August. The fall is the august break. August mean RF is 296.90mm. The two peaks in RF in July and September and a sudden fall in August is rainfall pattern for most of the sub equatorial climate.

The seasonal pattern of RF for the four climatic regimes is shown below as Figures 2.1–2.4.

In Figure 2.1 the double maxima is clearly shown. September, July, June and October recorded higher RF than August. The least rainy months are January and December, with mean RF of 34.79mm and 37.71mm respectively.

In Figure 2.2 representing 1952-1972, the double maxima pattern is still there, however, March RF has exceeded that of November. Showing fluctuation of variables as a –natural phenomena. Figure 2.3 show very slight double maxima. June rainfall is higher than October RF. An emerging trend is that May RF is closing up on October.

From the entire graph, it shows that September recorded the highest RF flowed by the month of July, then June and October. The only shift from this pattern is Figure 2.2.

In Figure 2.4 the month of august recorded higher RF than June and October. Figures 2.1&2.4 resemble the general distribution Figure 2 in outlook. The graphs show that much variability has not taken place.

Trend and temporal distribution of rainfall

The rainfall (RF) of Port Harcourt for the study period is represented in Figure 3. It shows that the highest rainfall recorded was in 1935, 3162.3mm of rainfall. 1962, 2006 and 1960 followed closely with annual rainfall of 3004.8, 2969.1 and 2934.3 respectively.

1950 recorded the least rainfall with 1539.6mm of annual RF; other years of low RF includes 1958 with 1733.2mm, 2010 recorded 1775.7mm and 1953 recorded 1860.1mm of RF.

From the Figure 3, it shows that 70 years of the 84 years under review recorded annual RF above 2000mm, and only 14 years had RF below 2000mm annually. This implies that 83% of the years recorded RF above 2000mm annually. The remaining 16.67 accounted for years with 2000 or less RF. The period of low RF coincided with notable drought period. Figure 2 shows that rainfall is gently decreasing. The mean RF of Port Harcourt is 2369.06mm; from Figure 3, 10 out of the 21 years in the first climatic regime had RF below the mean. The second regime had 9 years below the station mean RF. But the third and fourth regimes had 12 years with RF below the station climatic record. In addition Figure 3 show that the first 42 year had more RF distribution over the 2800 minor gridline than the last 42 year. The finding agreed with Alexander[2] which stated that Port Harcourt RF is gradually decreasing over years. However, the finding does not agree with Odjugo et al.,[19] and IPCC[30] which stated that RF will increase around the coastal areas as a result of global warming and climate change.[31–34]

The 10 years running mean also shows that rainfall in Port Harcourt is slowly but steadily decreasing over the years. However, the last 8 years shows that rainfall occurrence in increasing. Almost 200mm of RF will be lost by the 10 years projection when compared with 1931 when RF recording started in Port Harcourt.

Figure 3 shows that the amount of RF is decreasing over years.

The CV for the years is moderate. That explains the cluster of the scatter gram in Figure 3.

Analysis of rainfall variability

Kruskal-Wallis[29] test for several Treatments was use for analysis. First, rainfall was grouped in years as shown in Table 2 below. Each group contained 21 years for this study as a climate. This was subjected to analysis using Kruskal-Wallis test.[29] All the rainfall distributions were classified or rank in an ascending order. We had items from 1 – 84(first year of the study to the last year of the study).

The null hypotheses for this work are.

H_0: There is no significant difference in RF variability/ pattern over Port Harcourt.

H_1: There is significant difference in RF variability/ pattern over Port Harcourt.

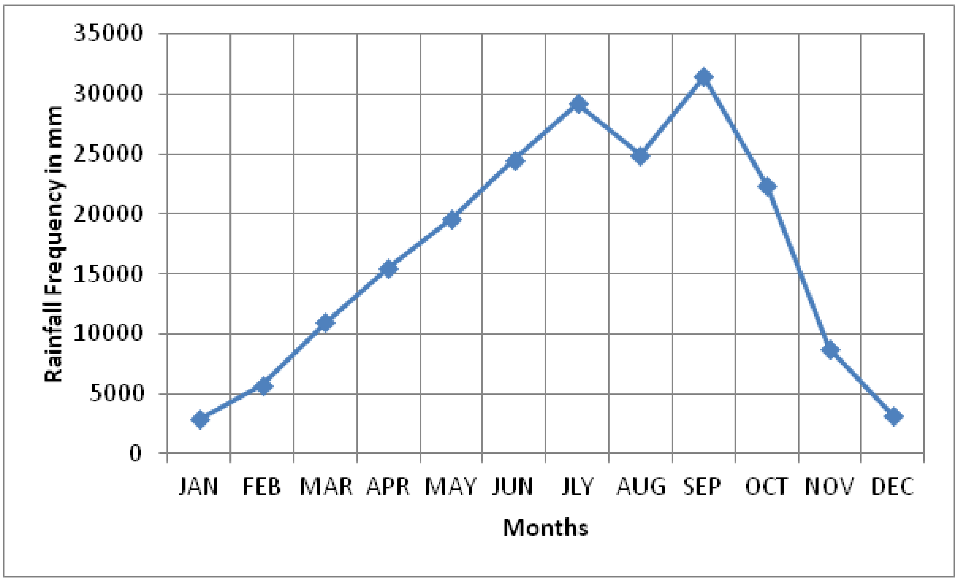

Figure 2 Seasonal distribution of rainfall over Port Harcourt

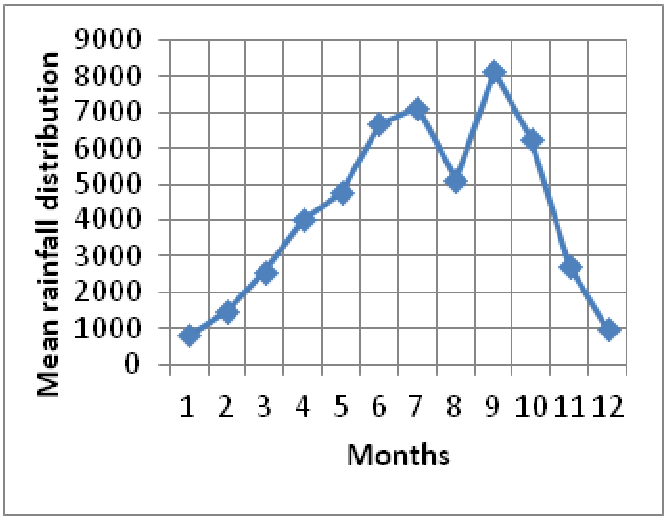

Figure 2.1 Seasonal RF (1931-1951).

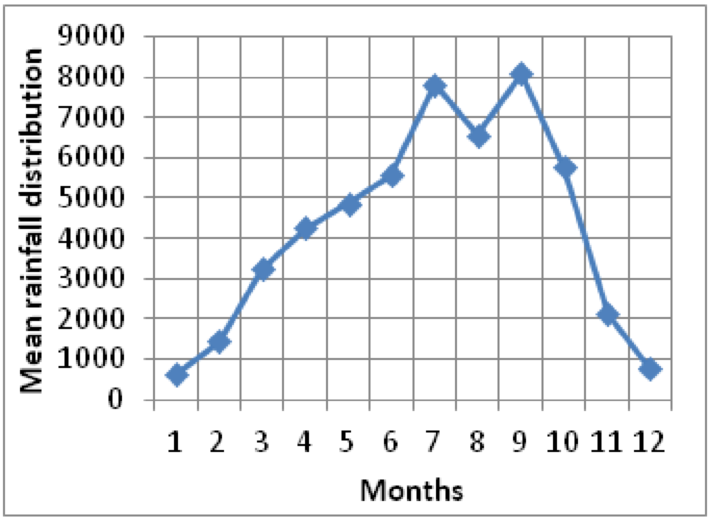

Figure 2.2 Seasonal RF (1952-1972).

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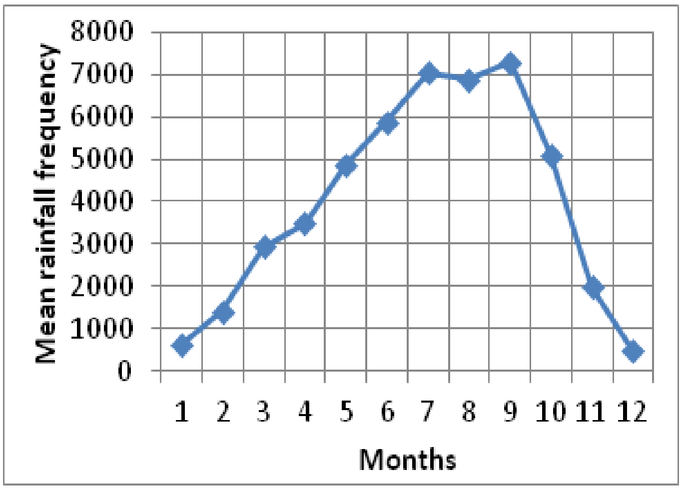

Figure 2.3 Seasonal RF (1973-1993).

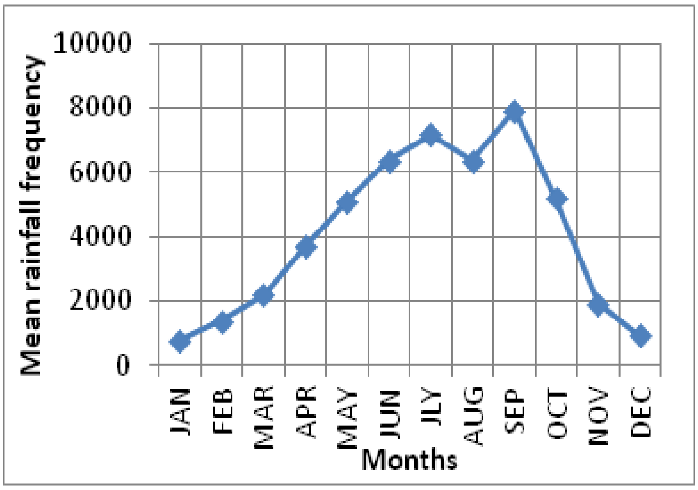

Figure 2.4 Seasonal RF (1994-2014).

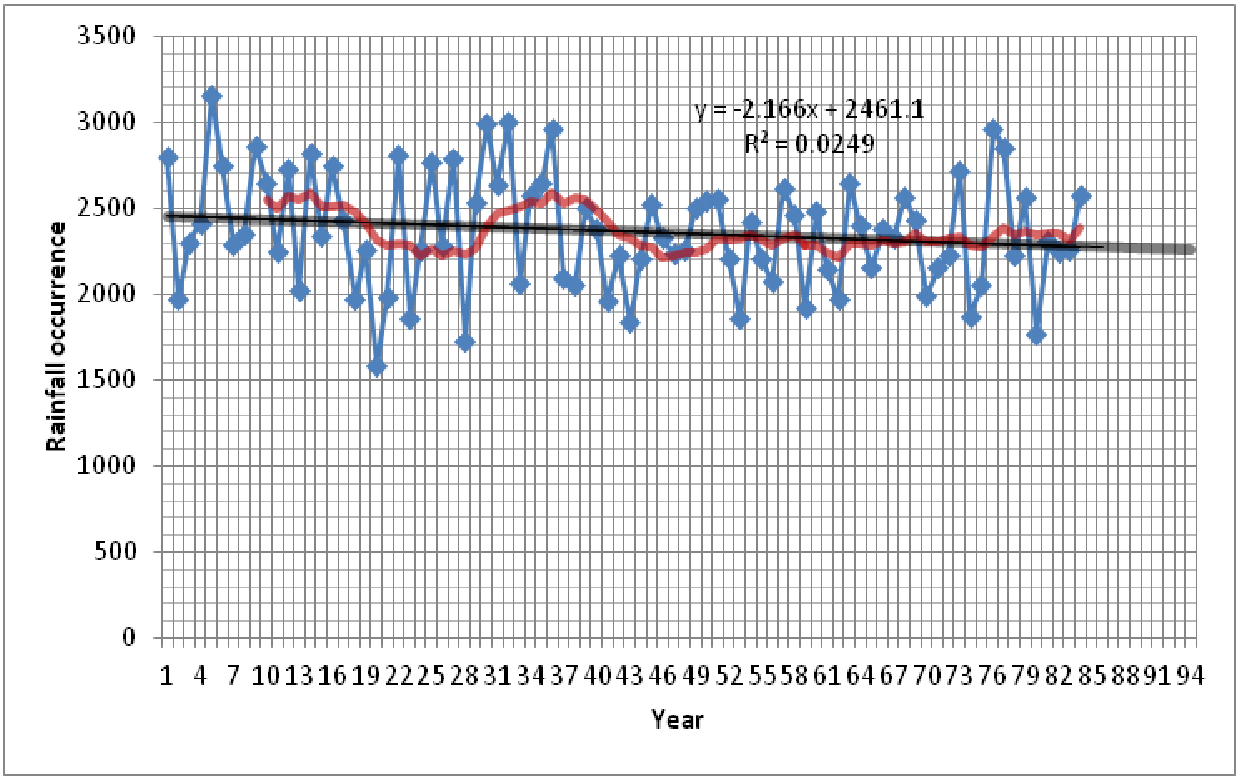

Figure 3 Rainfall fluctuation and trend (1931-2014).

$$\chi^2 = \frac{12}{N(N+1)}\left(\frac{C_1^{\ 2}}{n1}\ \frac{C_2^{\ 1}}{n1}\ \frac{C_2^{\ 2}}{n2}\ \frac{C_3^{\ 2}}{n3}\ldots\frac{C_c^{\ 2}}{nc}\right) - 3(n+1)$$

$$\chi^2 = \frac{12}{84X85}\left(\frac{973^2}{21} + \frac{991^2}{21} + \frac{762^2}{21} + \frac{856^2}{21}\right) - 3*85$$

0.00168 * 45082.33+46766.9+27649.71 +34892.19-255

0.00168 * 154390.13 – 255

χ^2 = 259.5298-255 = 4.5298

χ^2 = 4.5298

At 95% level of confidence, with the degree of freedom Df. = C-1 = 3

χ^2 Critical = 7.81

χ^2 Calculated < χ^2 critical.

Since χ^2 Calculated is < the χ^2 critical value

H_0 is accepted and H_1 is rejected.

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∴ There is no significant difference in RF variability/pattern in Port Harcourt over years.

In Figure 3, a regression line of best fit was drawn from the scattergram; the result is shown on the black line. More than 100mm of rainfall is shaded off. This implies that intensity of RF or amount has dropped, but the pattern remains the same.

Further analysis using PPMC, was achieved by grouping the RF data into two groups 1931–1972 and 1973–2014.

r = 0.1053.

Coefficient of determination = r^2*100, 0.10532 * 100 = 1.12% this implies that time accounted for just 1.12% of RF variability over the study period. Base on the result there is no likelihood that time affects RF variability.

To test for significance we use the aforementioned null hypothesis at 95% level of confidence. The degree of freedom = n -2 =40,

't'Calculated = 0.671 and 't'critical = 2.02

't'Calculated'< 't'critical at 95% confidence level therefore H_0 is accepted. This confirms that RF variability has not changed significantly over years in Port Harcourt.

Table 2 Ranked rainfall distribution

S/N	1931 - 1951	1952 - 1972	1973 - 1993	1994 - 2014
1	75	76	4	47
2	10	6	24	23
3	39	36	56	45
4	48	73	41	42
5	84	37	30	61
6	72	74	34	51
7	38	2	54	14
8	44	57	58	22
9	79	82	59	29
10	66	65	26	69
11	32	83	5	7
12	70	18	49	16
13	15	63	25	81
14	77	67	19	78
15	43	80	64	27
16	71	20	52	60
17	50	17	8	3
18	11	52	53	55
19	35	46	21	31
20	1	9	12	33
21	13	28	68	62
	973	991	762	856

Conclusion

This study tends to address the issue of rainfall variability and pattern over Port Harcourt and indeed the Niger Delta region of Nigeria. This will enable readers and stakeholders to know if the climate is actually changing within the study area or not. The general fluctuations observed in this work is just up and downs of natural system, but of serious note is the fact that flooding has increase in the area and rainfall intensity has also increase. The present study is limited to Port Harcourt and just one element of climate (Rainfall) is considered. In future studies, temperature, sunshine duration and rainfall should be study together for a dependable generalization of climatic variability and pattern of weather in Port Harcourt. This study covers rainfall distribution from 1931 – 2014 (84) years which is roughly four climatic season.

In the tropics, weather dictates the kind of houses and dresses people put on. Agriculture, Transport and even aviation industries relay very much on weather and its variables. This study will affect transportation in all ramifications. Over 83% of the years recorded rainfall of over 2000mm. This implies that Port Harcourt is a humid tropic region. In seasonal analysis, it was discovered that there was no major departure from the normal double maxima, August break and little dry season from December to January and early February. Indebt study of figure 3.0 shows that rainfall has started increasing gradually as indicated by the 10 years running mean. However, the general indication is obvious, that rainfall is reducing during the 84 years study period. Rainfall pattern and trend will affect underground water capacity and agriculture, it may also reduce flood in the study area. The long-time study shows a gradual but steady decrease in amount of RF, this could be an indication for climate change. The impact of such shift to agriculture and the environment is beyond the scope of this paper.

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Conflicts of interest

The author declares there are no conflicts of interest.

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