

ASSESSMENT OF RAINFALL VARIABILITY IN A HUMID TROPICAL ENVIRONMENT OF NIGERIA

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DOI: <https://doi.org/10.5281/zenodo.15700159>

Abstract

This study analysed rainfall variability over Port Harcourt. A 60-year annual rainfall data was obtained from the Nigeria Meteorological Agency (NIMET) from 1963 – 2022 to examine the reliability of rainfall variability. Using the Kruskal Wallis test and T-test, it was revealed that there is no significant variability in rainfall pattern over Port Harcourt. Results showed that 1.3% variability was accounted for during the period reviewed. The year 1966 recorded the highest average rainfall of about 2,940mm followed by 2007 with average 2,899mm. The least rainfall year was in 1983 with an average of 1,632mm. While about 90 % and 33 % of annual average was above 2,000mm and 2,500mm respectively, 10 % of annual values was below 2,000mm. The average annual rainfall amount for the period was 2,336 mm. Further analysis showed an average of 6, 500.5mm and - 6,329.8mm rainfall amount gained and in deficit respectively during the successive years leading to a surplus of 170.7mm for the 60 years reviewed. This shows that there is a slight balance of rainfall trend over the years. The year 2008 recorded the highest deficit of -865.8mm from the previous year (2007) while 1993 had the highest gains of 580.2mm from the previous year (1992). Rainfall pattern for Port Harcourt showed that recent flood experience is significantly due to incessant built-up areas with increasing population without adequate plans for evacuation of rainfall induced flood. It is recommended that Policy Makers make provisions for adequate drainage for quicker flood discharge in Port Harcourt.

Keywords: Rainfall, Variability, Kruskal-Wallis, Reliability, Flood, Port Harcourt

INTRODUCTION

Rainfall is one of the most significant climate change parameters that affects environmental processes, and its variability and trends have great impacts on socioeconomic development (Akinbobola et al., 2023; Edokpa et al., 2023). The variability of rainfall is an important consideration in the tropics where rainfall not only tends to be more variable than in the temperate domains, but is also more seasonal in its incidence within the year (Ayoade, 2004). The less variable rainfall is, the more reliable it is and any change in the variation of rainfall features impacts water use productivity and thus affect water resource planning and management practices (Akinbobola et al., 2023). Rainfall variability is small in humid regions of the wet tropics and most variable in dry and sub-humid areas. The sub-humid areas are the most vulnerable since small negative deviations from the mean rainfall may cause widespread crop failure and famine as frequently happens in the sub-humid tropics. Low variability implies that the mean rainfall at a given location is reliable while high variability implies wide fluctuations about the mean value. A given amount of rainfall may be termed reliable if it can be expected to be equalled or exceeded at some chosen probability level. According to Adejunwo (2018), rainfall variability has been the attention of many previous climate studies, but inadequate quantitative analysis of variability has been

undertaken for tropical areas. It has been stated that some expanses have experienced a change towards more extreme rainfall pattern in recent decades in Sub-Saharan Africa. Close investigation discloses that rainfall variability has experienced significant modifications, especially in the recent decades. Deviations in rainfall stem from geographical factors, the interface of geographical landscapes and atmospheric elements and motions (Edokpa, 2018).

Some influences are responsible for the deviations in distribution of rainfall pattern over Port Harcourt. These influences are anthropogenic related such as releases of greenhouse gases that enhances global warming, urban modification which increases heat island, deforestation and from domain geographical features which has to do with closeness to large water bodies and source region of rain bearing air mass (Ayoade, 2004). Rainfall pattern for any expanse is a determinant factor for the sustainable development of such domain. The investigation of rainfall trend is key in proffering solution to hydrological problems. Chinago (2020) emphasised that extreme ecological events, such as floods, droughts, rainstorms, and high winds, have severe consequences for human society. Therefore, adequate forecasting and preparation for weather-related disasters such as extreme rainfall is

required for design and management of infrastructures for enduring sustainability. This study investigated the trend in rainfall over Port Harcourt and the decadal reliability over the years. The core reason of assessing rainfall variability in any location is to relate to climate change mitigation and adaptation in order to maximise water resource management and efficiency.

MATERIALS AND METHODS

Study Area

Port Harcourt, the state capital of Rivers state is situated in the Niger delta area of Nigeria and borders within Latitudes 4° 45¹ – 4°60¹ N and Longitudes 6° 55¹ – 7°56¹E (Figure 1). Rivers state is bounded in the north by Imo state, east by Abia and Akwa-Ibom states, south by the Atlantic Ocean and in the west by Bayelsa state. The domain is positioned around the coastal region subjugated by low laying coastal plains of sedimentary formations. The area has a tropical humid monsoon climate influenced by its nearness to the Atlantic Ocean. Two main air masses controls rainfall duration across the area: wet and warm tropical maritime air from the Ocean and the dry and warm tropical

continental air from the Saharan desert. The rainfall periods last from March to November while the dry periods last from December to February. As a result of the robust presence of the warm moist air mass, the area receives an average rainfall amount of roughly 2300mm (Dammo et al., 2016). The bi-modal rainfall regime observed in the areas attains its peaks in July and September. The average high and low temperature values are 32°C and 26°C observed in January and July respectively (Muir, 2004). The average relative humidity for the area ranges from 66%-96% throughout the year (Edokpa, 2018) with high and low values during the wet and dry seasons respectively. Due to the massive water vapour in the atmosphere as a result of nearby water bodies, cloud cover pattern in the area is constantly being enhanced with monthly average of over 5oktas (Edokpa, 2018). This impact on the mean daily sunshine duration where less than 4 hours is observed in July and about 4-6 hours observed in January and December. Average monthly wind speed ranges from 0-4m/s with high and low peaks during the day and periods respectively (Edokpa, 2018).

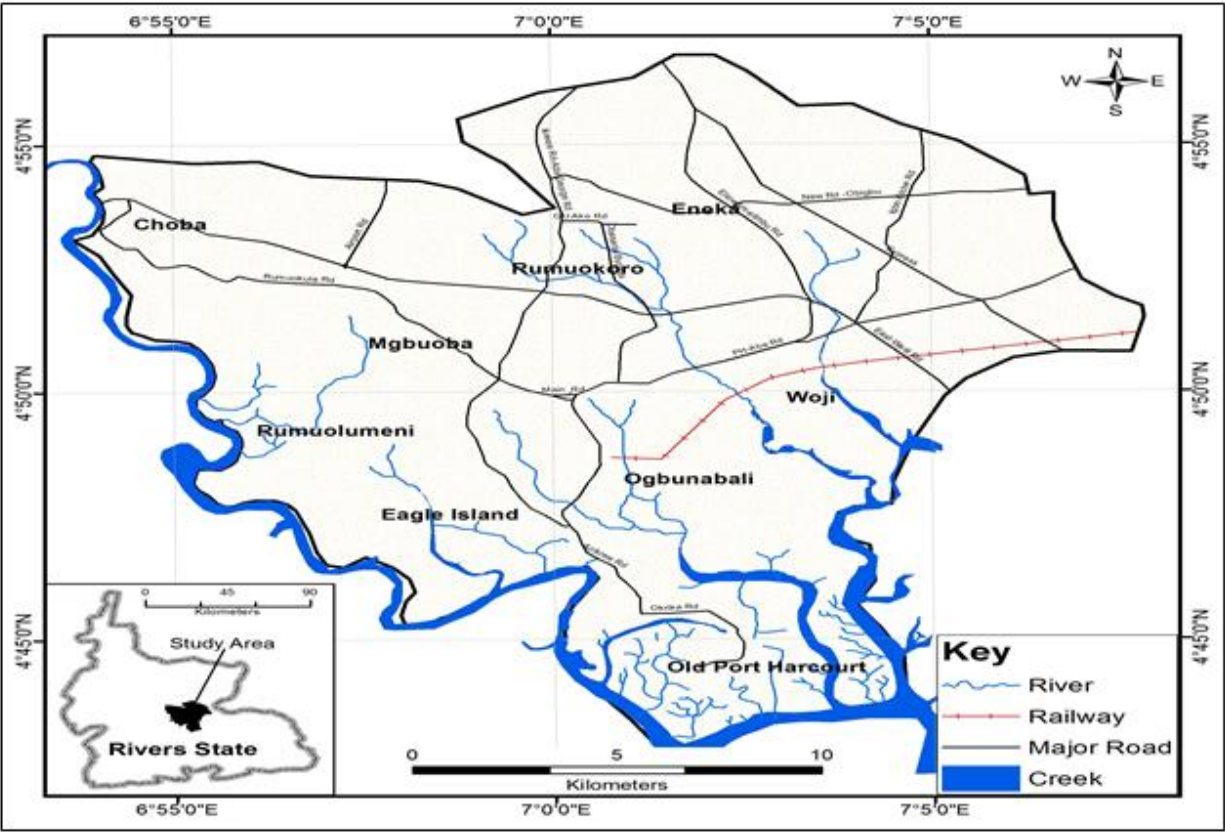


Figure 1: Study Area
Source: Ministry of Lands and Survey, Rivers State

Methods

Average annual rainfall data for this study were obtained from the Nigerian Meteorological Agency, Abuja from 1963-2022. The Kruskal Wallis test for

several treatments was used to examine relationship in rainfall distribution over time. To achieve this, the 60 years' rainfall data was grouped into three, with

each group having a 20-year record. This test is to check the significant variability within the three groups. The Kruskal Wallis test is given below:

$$X^2 = \frac{12}{N} (N + 1) \left\{ \frac{C_1^2}{n_1} + \frac{C_2^2}{n_2} + \frac{C_3^2}{n_3} + \dots \dots \dots \frac{C_c^2}{n_c} \right\} - \frac{3(N + 1)}{3(n - 1)} \dots \dots \dots \text{(Eqn. 1)}$$

Where N = summation of the all-observed outcomes or occurrences (C₁ + C₂ + C₃ + 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.

X² = Chi square symbol.

Pearson Product-Moment Correlation Coefficient (PPMCC) is used to analyse a longer duration of 30 years (i.e. the 60 years was group into two to find longer time effect. PPMC is given as

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{n\sigma_x\sigma_y} \dots \dots \dots \text{(Eqn. 2)}$$

r = Coefficient of correlation

n = number of pairs or sample size

Σ = summation and σ = standard deviation

The coefficient of determination is used to measure of the strength of relationships and Student test is used to test the validity of the result or otherwise.

$$\text{Coefficient of determination (CD)} = r^2 * 100 \dots \dots \dots \text{(Eqn. 3)}$$

Where:

r² = coefficient of correlation square

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

$$t' = r\sqrt{n - 2} / \sqrt{1 - r^2} \dots \dots \dots \text{(Eqn. 4)}$$

Where:

‘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.

RESULTS AND DISCUSSION

Figure 2 shows the rainfall trend of Port Harcourt for the period under review. Result analysis shows that the highest and lowest average annual rainfall recorded was in 1966 and 1983 i.e. 2,940.3 mm and 1,632 respectively. It was revealed that about 90 % of the average annual values for the 60 years was above 2,000 mm while 10 % was below it. Also, about 33 % of rainfall values was above 2,500 mm. As at the year 2022, the average value was 2,345.1 mm. The almost uniform pattern of rainfall in Port Harcourt as shown in Figure 2 reveals steady trend with fluctuations over the years. The fluctuations persist due to the seasonal variations in rainfall amount from January – December (Orji et al., 2022 and Johnson et al., 2021). The season variations are influenced by the interplay of two major pressure wind system with the moist southwesterly dominating due to it closer source region to the study environment. The 5-year moving average trend as shown in Figure 2 exhibited a near similar pattern for the rainfall trend investigation.

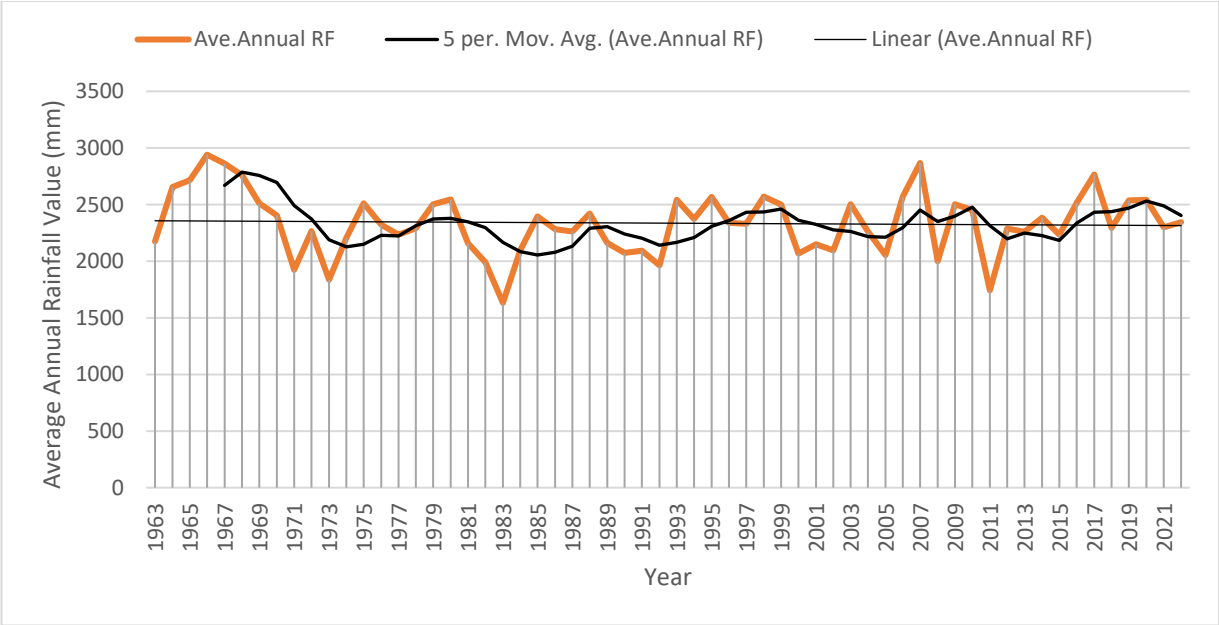


Figure 2: Average Annual Rainfall Trend of Port Harcourt from 1963 – 2022.
Source: Author’s Work (2024)

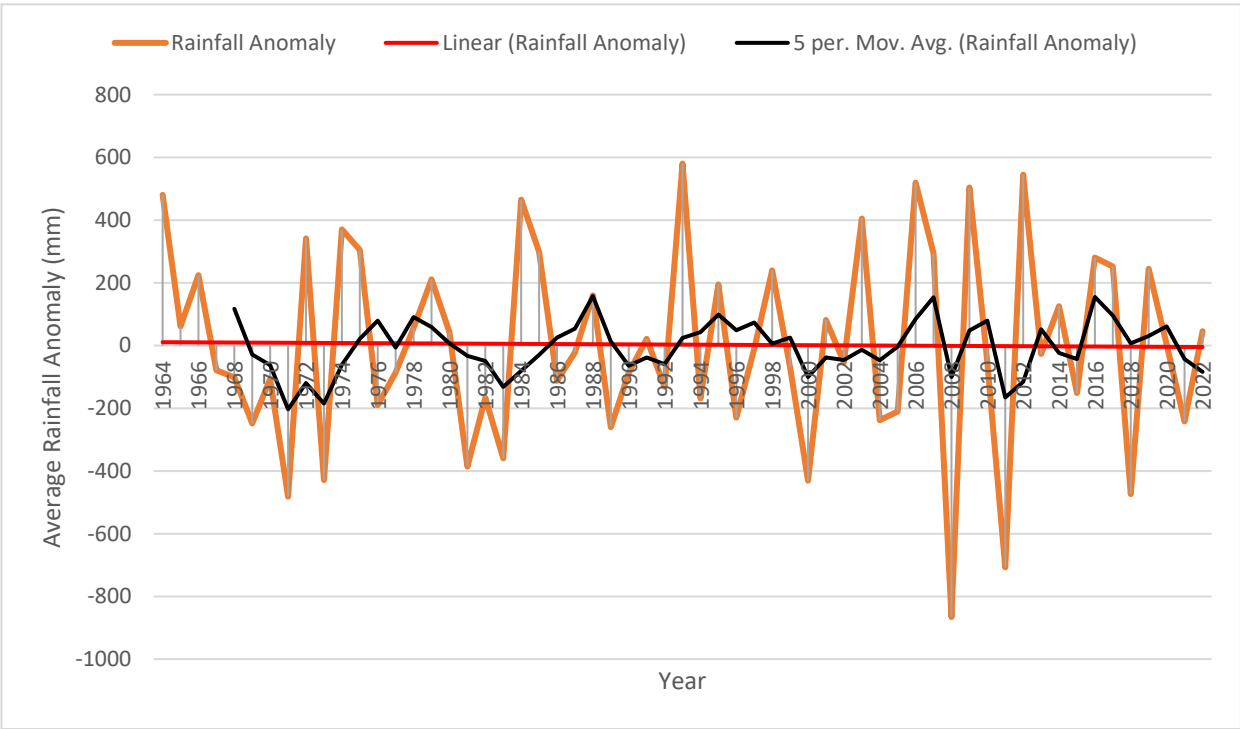
In the Port Harcourt environment, rainfall could be observed almost throughout the year with marked prolong rainy periods and shorter dry season. According to Johnson et al. (2021), only the months of December and January actually qualifies as dry season months. Furthermore, it has been observed that the heaviest rainfall periods for the study area are in July and September which averages over 350 mm.

Port Harcourt Rainfall Variability

The 60 years average annual rainfall amount was classified into three groups of 20 years and the distribution ranked in ascending order. The Kruskal-Wallis test was used to validate the stated Null and Alternate hypotheses given as:

- H₀: There is no significant difference in rainfall trend and variability over Port Harcourt.
- H₁: There is significant difference in rainfall trend and variability over Port Harcourt.

variability in the trend of rainfall over Port Harcourt area for the reviewed 60 years. The tests showed that $K-W_{cal} < X^2_{table}$ i.e. (2.922<5.991) and $T-test_{cal} < T_{table}$ i.e. (0.278<2.048). A study conducted by Chinago (2020) for rainfall anomaly in Port Harcourt from 1931 to 2014 showed similar trend. Result analysis from this study showed that about 1.3 % rainfall variability was accounted for during the periods under review. The year 1966 recorded the highest average rainfall of over 2900 mm followed by year 2007 with average 2,899mm. The least rainfall year recorded was in 1983 with an average of 1,632 mm. While about 90 % of annual average were above 2,000 mm and 33 % were above 2,500 mm, 10 % of annual average were below 2,000 mm. The annual average for the reviewed period was 2,336 mm. A Coefficient of Variation (CV) of 11.5 indicates a moderate variability of the yearly annual average rainfall values around the central average. Figure 3 shows the annual rainfall anomaly in the study environment for the period reviewed.



From the Kruskal-Wallis test ($K-W_{test}$) and T-test, it was revealed that there is no significant difference or
Figure 3: Average Annual Rainfall Anomaly of Port Harcourt from 1963 – 2022.
Source: Author’s Work (2024)

Further analysis showed that an average of about 6, 500.5 mm and -6,329.8 mm rainfall amount was gained and in deficit during the successive years from 1963 leading to a surplus of 170.7 mm for the 60 years under review. This shows that there is a slight balance of rainfall trend over the years. The year 2008 recorded

the highest deficit of -865.8mm from the previous year (2007) while 1993 had the highest gains of 580.2 mm from the previous year (1992). Figure 3 shows the rainfall anomaly trend with almost stable trend line for the rainfall periods considered. Table 1 shows the extent of rainfall anomaly for the period reviewed.

Table 1: Extent of Annual Rainfall Deficit and Surplus

Year	Rainfall Anomaly (mm)		Year	Rainfall Anomaly (mm)	
	Deficit	Surplus		Deficit	Surplus
1964	-	480.7	1994	-168.2	-
1965	-	60.6	1995	-	195
1966	-	224.6	1996	-229.5	-
1967	-78.7	-	1997	-10.3	-
1968	-101.6	-	1998	-	239.9
1969	-248.2	-	1999	-69.7	-
1970	-106.8	-	2000	-430.7	-
1971	-481.7	-	2001	-	81.1
1972	-	341.9	2002	-53	-
1973	-429.2	-	2003	-	404.6
1974	-	370.2	2004	-238.3	-
1975	-	305.3	2005	-210.3	-
1976	-189.7	-	2006	-	519
1977	-86.3	-	2007	-	294
1978	-	55.7	2008	-865.8	-
1979	-	211.1	2009	-	504
1980	-	42.6	2010	-53.6	-
1981	-386.6	-	2011	-707.5	-
1982	-166.8	-	2012	544.3	-
1983	-359.5	-	2013	-27.1	-
1984	-	464.8	2014	125.1	-
1985	-	298.8	2015	-151.1	-
1986	-112.5	-	2016	-	280.6
1987	-21.8	-	2017	-	252.1
1988	159.6	-	2018	-473.6	-
1989	-260.7	-	2019	-	244.4
1990	-86.9	-	2020	-	3.6
1991	21.1	-	2021	-242	-
1992	-132.2	-	2022	-	45.7
1993	-	580.2	-	-	-

Source: Author’s Work (2024)

Rainfall Variability Implication to Climate Change Impact in Port Harcourt

Chinago (2020) highlighted that climate variation and fluctuation are normal natural occurrences, but a change from the mean climate over the years is a vital concern to researchers as its significance to the environment is unfavourable. This study has revealed that rainfall pattern swings over the years in Port Harcourt indicating a balanced variability. In recent years, Port Harcourt metropolis has experience series of flooding that ravaged the city during and after moderate to heavy rainfall level. Chinazor (2016) noted that rainfall is used as measure of climate variability and change, and stressing that the high rainfall intensity and duration periods observed in Port Harcourt during wet season always culminate into enormous perennial flood incidents across the metropolis. This rainfall intensity-induced flooding

also hampers agricultural crops production such as maize, cassava and yam. It was noted that the availability of adequate water drains as well as avoiding building on dammed areas be enhanced to alleviate the increasing flood issues in the metropolis. A qualitative and quantitative study of flooding in Port Harcourt was conducted by Akukwe (2014). It was disclosed that increasing flood incidents in Port Harcourt arises from identified glitches of this order: Absence of/inadequate drainage facilities; heavy rainfall; blocked drainage systems; impervious surfaces; inadequate town planning/uncontrolled urbanization; poor drainage network; flat terrain; climate change; unplanned development on flood plains. These glitches constituted: 15.74%, 15.59%, 14.97%, 14.35%, 12.19%, 11.88%, 7.10%, 4.48% and 3.70% respectively. It was highlighted that the effect of rainfall intensity arises from the impact of

West African monsoon rainfall augmented by continentality effects.

CONCLUSION

This study evaluates the reliability of rainfall variability and trend over Port Harcourt. The study covers rainfall distribution from 1963 – 2022 (60) years which is two climatic periods. Findings showed that there is no significant variability in rainfall trend over Port Harcourt. An average of about 6,500.5 mm and -6,329.8 mm rainfall amount was gained and in deficit during the periods under review indicating a slightly balanced trend. While about 90 % and 33 % of annual average was above 2,000 mm and 2,500mm respectively, 10 % of annual values was below 2,000 mm. A Coefficient of Variation (CV) of 11.5 indicates a moderate variability of the yearly annual average rainfall values around the central average of 2,336 mm. With the proximity of Port Harcourt to the rain bearing air mass source region, i.e. the Atlantic Ocean, it is vital to note that convectional type of rainfall will persist and be enhanced leading to high rainfall intensity in the area. This will result to ceaseless flood incidents where adequate measures are not in place to alleviate the impacts of high rainfall intensity. It is vital that Policy Makers should engaged in detailed vulnerability flood mapping and assessment of the area in order to guide on-the-spot action plan thereby re-engineering water channel designs for flood prone areas.

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