Extreme Rainfall Forecast and Flood Prediction in Equatorial Zone of West Africa: Port Harcourt, Nigeria in Focus

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Abstract

Purpose: Rainfall is the most important element of climate in the tropics, it dictate human outdoor activities, recharge underground water and streams, dictate agricultural calendar and many cultural activities. More recently the incidence of extreme rainfall leading to urban flood in the city of Port Harcourt is increasingly becoming a looming disaster. Despite the importance of rainfall in the tropic, the fact that it varies significantly is worrisome to both scholars and the stakeholders. This study focused on extreme rainfall forecast and flood prediction in equatorial zone of West Africa especially in a humid tropic environment like Port Harcourt.

Methodology: Statistical Time Series Model performed very well in rainfall forecast, but did better in flood prediction. Secondary data extracted from Nigeria Meteorological Agency, Oshodi, Lagos form 100/3 of the agency record servers as main source of data for this work. Descriptive statistics and inferential statistics were used, among which are mean, standard deviation, and coefficient of variation; Pearson product moment correlation and structural time series model.

Findings: The study discovered that rainfall distribution has reduced over the years, besides the dry spell in the month of August has deduced gradually but steadily over the years. It also shown that flood cannot occur in the first 6 months of the year. Rainfall distribution varies significantly over the climatic period.

Conclusion: There is a significant variation in rainfall distribution over Port Harcourt. August dry spell is steadily disappearing, giving raise to excessive run-off that triggers flood during late September to October. Flood will likely occur whenever the forecasted rainfall exceeds the generated level output during the seasonal peak. Structural Time Series Model performed well in flood prediction than in rainfall forecast.

Recommendations: Extreme RF forecast by the authorities should be taken serious by inhabitants and warning be given and adhered to by residences. Also, structural time series model should be used for long time forecast since it performed very well, but this should be done with large data.

Keywords: Climate change, Dry spell, Extreme rainfall, Flood, Forecast and Rainfall distribution
INTRODUCTION

Weather forecast is the use of scientific ideas, art and technology to predict or prognosticate the future atmospheric condition of a given location at a given point in time (Dirmeyer et al., 2009). Prediction is the ability to foretell the certainty or the likely occurrence of an event not yet occurred. It is the art and science of foretelling the outcome or result of an event that has not happened with a degree of confidence.

The view of Dirmeyer et al. (2009) is that weather forecast is the ability to predict the outcome and occurrence of an event or element of climate as to address the challenges or harness the gain from such events or elements. The importance of forecasting cannot be overemphasized. Weather forecasts, both for the next couple of hours and for the next couple of days, are issued daily. Apart from forewarning people on the variability of weather it also forearm them. For example, even in a small matter as inviting friends to a party. It help people decide when they should invite their neighbour for a barbecue, weather forecasts provide vital information for a wide range of occupational categories such as farmers, pilots, sailors and soldiers. Furthermore, forecast has help and equipped people to be less likely surprised by severe weather; and people suffering from hay fever or any other weather triggered illness like pneumonia for example can time their outdoor activities according to weather forecasts.

Weather forecasting is a very competitive and successive business, especially in United State of America. This can be seen when the number of people that watches weather report is compared to the number of people watching programmes before and after the weather report (Bethge et al., 2000). Forecasting of weather and atmospheric variables is regarded as divine or heavens will in the ancient time, therefore ancient civilizations appeals to the gods of sky for accurate forecast. The Egyptians looked to Ra, the sun god. The Greek sought out the all-powerful Zeus, and then the Nordic looked onto Thor, the god of thunder. The Africans looked to rain doctor. Those with the ability to predict the weather or seemed to influence its predictions were held in highest esteem and reverend among his people (Goldstein, 2002).

The first recorded weather forecast related case was penned down about 1520BCE (Gen. 7:4). The art of weather prediction began long ago as a result of studying reoccurring astronomical and meteorological events; these enable forecasters to observers’ seasonal changes in weather (NASA, 2002). As early as 650BCE the Babylonians had started predicting short-term weather changes based on the appearance of clouds and optical phenomena such as haloes. The account of (I Kings 17:1; 18:41-45 and Matt 16:2-3) are also recorded weather prediction recorded about 590BCE and 1CE. Similarly, a Greek scholar Aristotle in 340BCE published meteorological, a philosophical treatise that include theories about the formation of rain, cloud, hail, wind, thunder, lightning and hurricane. The Chinese also developed a calendar during 300BC that divided the years into 24 festivals, each of which was associated with different type of weather (NASA, 2002).

Extreme rainfall is among the commonest factor responsible for flood occurrence in tropical humid environment. Factors like terrain, soil types and anthropogenic factors are contributory agent in flood incidents, but rainfall remain and independent factor responsible for flooding in most tropical region of the world and Port Harcourt in particular. Therefore, a spot on accurate and target rainfall forecast is vital, and adequate for reservoir operation and flood prediction and mitigation, because it can provide an extension of lead-time on the flow forecast (Chau & Wu, 2010). Sumi, Zaamna and Hirose (2012) stated that accurate forecasting of rainfall is the most important issue in hydrology research, because early warning of severe weather can
prevent causalities and damages caused by natural disasters if it is timely and accurately forecasted.

Rainfall is a natural climatic phenomenon whose prediction is challenging and demanding. It is a form of precipitation common in the subequatorial climate. It is liquid water dropping from the atmosphere to the surface of the ground, ranging from 1 – 5mm in diameter (Mayhew, 2004). Rainfall is a complex atmosphere process which depends upon many weather related features. Accurate and timely prediction of rainfall can be helpful in many ways. Such as planning the water resources management, issuance of early flood warnings, managing of flight operations, limiting transport and construction activities and Agriculture and other outdoor activities (Chau et al., 2010; Wu et al., 2008; Wu, Long & Liu, 2015; Somvanshi et al., 2006). The importance of rainfall in the tropics cannot be underestimated. Rainfall determines the agricultural calendar, recharge the aquifer, recharge streams, causes flood and lack of it results to drought, affects outdoor activities social and economic. In fact, rainfall forecast is of relevance to all sectors in the tropics.

Flood is caused by extreme rainfall; its impact on tropical environment is disastrous. Excessive rainfall (extreme) is caused by natural phenomenon; the major causes of heavy rainfall are convective and frontal forces. Adetunji and Oyeleye (2013) opined that rainfall is the major force that triggers flooding in the tropical environment, unlike in the temperate and polar regions of the world, where ice melting and snow causes flood. Flood can lead to water borne diseases and can negatively affect the soil though chemical leakages.

Water, especially rivers may be polluted from flood water resulting to disease epidemics especially in tropical developing nations that depends on stream and well water for domestic uses. Besides, animals are also dislodged from their normal habitat, thereby forcing them to move into human inhabited areas. This can cause a lot of problem to both human and the animals. Most plants are at risk, since most of them cannot survive underwater for a long time. Loss of lives and property, mass migration, impact on the economy, destruction of natural habitat for animals, destruction of farmlands, destruction of some mineral resources (limestone, tin and columbite mines) closing of schools and work, restriction of movement, destruction of infrastructures such as bridges road canal etc. are some of the impact of flood. (Douglas et al., (2005).

Flood is one of the oldest consequences of extreme rainfall. It has a positive and negative effect on the people. Flood occurs when rivers over flow its bank and encroaches on dry land. When water occupies areas that used to be dry land for a long period of time then flood is said to occur. Flood is a situation where water/river moves beyond its confirmed area (bank or channel) to dry land. This natural disaster can affect lot of activities. For instance, the agriculture, transportation, construction, and other human outdoor activities suffer. From ancient Egypt and Babylon to date, scholar have summed up characteristics of flood as triggering factor, spatial occurrence, duration, frequency, magnitude and secondary events (https://www.mnestudies.com).

Lot of scholars home and abroad have contributed to solving the problem of extreme rainfall and flooding, through forecast and predictions. For instance, Ibrahim and Afandi (2014) stated that one of the most likely options to improve accuracy of rainfall forecasts is to enhance and improve numerical weather prediction (NWP) models using data assimilation and ensemble forecasting. This gives the opportunity to provide an early warning of even over the twelve-hour period before the rainfall event. This method requires lot of manipulations and readings confusing to beginners and besides the result achieved over the years are short time results of...
few hours and days. Note few hours (12) forecast can hardly address the problem of farmers. It is very inadequate to enable movement of properties, persons and structures.

Mathematicians and Physicists approach weather forecast using return period method. Rakhecha and Singh (2009) defined return period as a reoccurrence interval which is an estimate of the interval of time between events like an earthquake, flood or river discharge flow of a certain intensity or size. It is a Statistical measurement denoting the mean reoccurrence interval over an extended period of time and to dimension structure so that they are capable of withstanding an event of a certain return period (with its associated intensity) (Deraman et al., 2017). However, the factor affecting rainfall is not just natural factors; therefore incorporating the human factor is a great challenge to return period method.

Seckin et al. (2009) studied flood frequency analysis in Ceyhan River basin; they compared the Probability Weighted Moments (PWM) method in estimating the parameters. It was discovered that the longer the period of the observed flood peak series, the more realistic the result of the flood frequency analysis, because the parameters of the probability distribution function estimated from longer sample series tend to be close to their population value. This method is purely statistical in nature and can be very helpful. However, flood is dependent on rainfall, therefore the best way to address flood related problem is to understand the rainfall pattern and characteristics.

Orupabo et al. (2019) studied flood prediction using Rainfall-Runoff spatial variation over Port Harcourt in Rives State. The study observed that the use of ANN provided a significant improvement in the flood prediction accuracy in comparison to the use of simple prediction approaches, which are often applied hydrological practice. However, the work make prediction based on few years annual records. The annual rainfall of an area does not adequately explain the incidence of flood in an area.

Chu et al. (2010) used hybrid model integrating artificial neural network (ANN) and support vector Regression for daily rainfall forecast. In the modelling process, singular spectrum analysis was first adopted to decompose the raw rainfall data; then Fuzzy C-mean clustering was used to split the training set into three crisp subsets which may be associated with over medium and high-intensity rainfall. The findings among other things shows that ANN did not perform well, however, support vector regression model performed the best in forecast. But the work is based on a very short term daily forecast. The work is useful only for academic purpose, or for daily purposes. This cannot help framers; the common people and it is difficult to use daily rainfall for urban flood prediction.

As stated earlier, most of the forecasting works available are mostly short-term in nature, ranging from some hours to about three months. Short-term predictions cannot address attendant problems of flood, drought, water shortages, or famine. A month or three months’ prediction cannot stop crop destruction by flood or drought. The evacuations of flood victims are just temporary measures, but the hardship that awaits the survivors remains unimaginable. The present meteorological predictions are temporary measures that focus on human life. Only long-term climatological predictions will fore-armed the people on rainfall related issues. This will enable farmers to plant corps that mature faster in flood return period years, or plant drought resistant crops on the year of scanty rainfall. It could also help event planners to fix dates at the convenient period of the year. This work will address the aforementioned problems since it is using reliable historical data for long-term prediction using tested statistical model Structural time series model.
To predict and successfully mitigate consequences of flood, there must be an accurate understanding of rainfall characteristics and pattern. This gives clear view of when flood is most likely to occur and the extent of it. This is important especially in a humid tropic environment like Port Harcourt.

METHODOLOGY

The research was carried out using secondary data and Statistical model. The acquired data were homogenized into annual and seasonal rainfall data. Analysis of the entire data set was taken as a check for two climatic periods. Descriptive and inferential methods were adopted in this work so that full analysis of the subject matter will be achieved. Among the descriptive statistics employed were total, mean, standard deviation, coefficient variation, graphs, tables, etc. That data for this work was extracted from Nigeria Meteorological Agency (NIMET) Oshodi, Lagos form 100/3 of the agency record. The rainfall data for this work (Monthly and Yearly) were collected from 1931 – 2014 (84 years). Rainfalls was arranged from the month of January to December. Records are taken based on monthly and yearly availability. Vertical records represent monthly rainfall, while horizontal records are yearly rainfall distribution. The single climate data for this work is rainfall. Rainfall for months and years were collected from the archive of Nigeria Meteorological Agency (NIMET), Oshodi, Lagos for 84 years (1931 – 2014). Missing data shall be replaced using 15-years (fifteen) mean.

Structural Time Series Model (STSM) will be used for forecast. Coefficient of variation (C.V) or Relative Standard Deviation (STD) is a standardized measure of dispersion of a probability distribution or frequency distribution (ratio of STD to mean). It have been observed that the higher the coefficient of variation the greater the level of dispersion around the mean. The lower the coefficient of variation value the more precise the estimate. It is generally expressed in percentage. It is reliable method of calculating rainfall variability.

Coefficient of variation = \( \frac{\sigma}{\bar{x}} \times 100 \) ................................................................. (1)

Where \( \sigma \) is the standard deviation of rainfall, and \( \bar{x} \) is the mean rainfall

Microsoft excel was used for graphs and calculation based on descriptive statistics. The inferential statistics employed in this work includes Pearson Product Moment Correlation and regression analysis.

\[ r = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}} \] ................................................................. (2)

Where \( x \) and \( y \) are individual variables (individual rainfall captured) and \( \bar{x} \) and \( \bar{y} \) are mean of individual set of variables respectively. Pearson product moment correlation coefficient is used in testing the relationship between the rainfall distributions between the climatic regimes. Similarly, the regression analysis shall be used also to examine the trend and extreme rainfall pattern in Port Harcourt. This task will be performed using excel Microsoft. Structural time series models are formulated directly in terms of unobserved components, such as trends, cycles and seasonal, that has a natural interpretation and represents the salient features of the series under investigation.

\[ y_t = \mu_t + \epsilon_t, \quad t = 1, 2, ..., T, \quad \epsilon_t \sim NID(0, \sigma^2_\epsilon) \] eqn. .................................................. (3)

\[ \mu_t + 1 = \mu_t + \eta_t, \quad \eta_t \sim NID(0, \sigma^2_\eta). \] ................................................................. (4)

Where, NID denotes normally and independently distributed variables. This is known as the local level model (LLM) and is a straightforward generalisation of the constant level model: \( y_t = \mu_t + \epsilon_t \) arising when \( \sigma^2_\eta = 0 \). On the other hand, when \( \sigma^2_\epsilon = 0 \), (1) reduces to a pure random
walk and the trend coincides with the observations. \( \eta_t, \epsilon_t \) are independent of each other, and \( \sigma^2 \) is the standard deviation.

The Study Area

The main city of Port Harcourt is the Port Harcourt City in the Port Harcourt local government area, consisting of the former European quarters now called Old GRA and New Layout areas. The urban area (Port Harcourt metropolis) on the other hand is made up of the local government area itself and parts of Obio-Akpor and Eleme accordingly. According to Ogbonna et al. (2007), Port Harcourt, the current capital of Rivers State, is highly congested as it is the only major city of the state.

Port Harcourt is the capital of Rivers State. It is the main city in the state and has one of the largest seaports in the Niger Delta region of Nigeria. It is the hub of industrial, commercial, administration and other activities in the state. The city lies between latitude 04° 45'N to 04° 60'N and longitude 06° 50'E to 08° 0'E. It covers an estimated area of 1811.6 square kilometres. The city is bounded in the north by Imo and Abia States, East by Akwa-Ibom State, West by Bayelsa State and south by the Atlantic Ocean.

Figure 1: Rivers State showing Port Harcourt metropolis

Source: Adapted from Akukwe T.I., and Ogbodo C. (2015)

One of the most striking features of the region within which Port Harcourt is located is the uniqueness of its surface drainage. Areola (1983), described the drainage of the area as poor, essentially due to a combination of low relief, high water table and high rainfall. The low relief of the region results in strikingly gentle slopes which have the effect of making the flow velocities of the rivers very low. This situation results in the formation of well-developed river
meanders. Aisuebeogun (1995) argued that meandering rivers in this region are irregular or even tortuous with sinuosity value exceeding 1.9. At the southwest and making a convex bend is the Bonny River, which obviously, is the largest river in the area with an average width of 0.5km.

To a large extent, the drainage network in Port Harcourt region is structurally controlled on the coastal lowlands and it is mainly dendritic in pattern on the shore zone. Anabranching and anastomosed channels characterize the lower reaches of most of the stream channels. Some ancient river courses constitute poor drainage sites retaining large pools of water during the rainy season. Beneath these sites are gradational lithological compositions consisting of profiles of white fine sand/silt; medium/coarse sand (brownish yellow) and fine grave. This profile sequence, down to 12 m in places, strongly suggests that these valleys were once ancient river courses.

Port Harcourt is endowed with abundant sunshine by virtue of its geographical location near the equator hence; the sun is vertically overhead throughout the year. Daylight hours are longer because of the long duration of solar radiation. However, the amount of solar radiation received at the surface is substantially reduced mainly due to cloudiness consequent upon its coastal location. These moderating influences induce slight diurnal, monthly and annual variation in temperature over the region. Other influences aside cloud cover; include the harmattan and the influence of vegetation.

Port Harcourt and its environs lie very close to the ocean but have no orographic advantage, which by far outweighs the moderating influence of the sea. Consequently, mean annual temperature is only high but has a spatial sequence of slight increase with latitude. For instance, Port Harcourt records a mean annual temperature of 28°C. Onne, which is further inland, records at temperature of 28.2°C, while Bonny, on the coast records a mean annual temperature of 27°C. This is a very important aspect of temperature distribution as it affects tourism. It shows the daily temperature rhythm, which coincides nicely with the net radiation within the 24 hours of the day. In the Port Harcourt region, the morning hours are cold. Temperature rises gradually and peaks around 2pm; between 4pm and 5pm, it becomes warm and peters to a cold situation again at night. The months of February, March and April record the highest temperatures. This gradually slopes down through May, June and more deeply in July and August.

Consequently, July and August record the lowest mean monthly temperatures. Again, temperature rises through September, October and November. These months are periods of weather instability, with November marking the end of the rainy season. At this period cloud cover also reduces. The value of temperature is considerably reduced in the months of November and December (26.5°C – 26.2°C) because of the influence of the hamattan. The seasonal variations in relative humidity are mainly due to the seasonal variation in the amount of insolation received at any given location on the globe. The apparent movement of the sun through the region creates two periods of low relative humidity separated by a period of high relative humidity. Generally, relative humidity is high over the entire region with mean annual figures at 85%. The rainy season months of June, July, August, September and October record the highest values. These months are very cloudy due to the strong presence of the south-westerly wind. Comparatively, the more northerly town of Onne, taking lower values both in annual amounts and seasonal march, revealing spatial variation even within short distances because of the nearness of the region to the sea. Like temperatures, monthly and annual relative humidity variations are very low.
Hamattarn, which is a dry cold wind, embedded in the North East trade wind blows over Port Harcourt region from December to February. A study on hamattarn, observed that February recorded the highest intensity (5.68%) followed by January (5.60%) and December with (5.50%). Generally, these intensities are very low when compared to other places, mainly due to the proximity of the area to the moderating influence of the sea (Atlantic Ocean). Another plausible reason is the fact that after its long trajectory, the hamattarn weakens as it reaches Port Harcourt. Its persistence, duration and reliability are very low with values at 12.48% for the month of January (Ede, 1999). It is erroneous to believe that the hamattarn has a moderating and soothing effect on the sultry weather conditions of Port Harcourt as per human comfort. Ede (1999), calculated the effective temperature index (ET) and wind chill index for the hamattan months. No month had less than 27°C (mean ET). Consequently, Port Harcourt is uncomfortable and stressful during the hamattan months. The mean wind chill figures viz: (20.29k, 33.45k, 63.21k and 68.94k) in January, February, November and December respectively, reveal relatively low wind chill which has a small soothing effect on the high ET., of December to February which show slightly higher variations. This low temporal variation is consistent with the low seasonality and low variability in most climatic elements of the humid tropics.

It needs to be stated that the factor which controls the temporal pattern of rainfall in Port Harcourt is the position of the Inter Tropical Discontinuity (ITD) at various locations during the course of the year. For example, the Inter Tropical discontinuity is in its maximum location of 22°N during July – August, and Port Harcourt during this period is completely under the strong influence of the ITD. During the months of January and February, the ITD is off the country, but over Atlantic Ocean, with the dominance of the North East trades. Though there might be rain during the months of December, January and February, most of the rains received are unreliable and spotty due to the convective overturning of the southwest wind. Generally speaking, rainfall starts early in Port Harcourt and ends late. The mean onset date for Port Harcourt is 27th February. This temporal situation falls in line with the situation of the rain belt at this period (Chinago, 2020).

The retreat of the rains begins generally from the middle of November. By this time, the maximum location of the Inter tropical discontinuity is about 16°N at which time, most of the northern and middle belt parts of the country are already under the influence of the dry subsiding north – east trade winds. It should be noted that the southward retreat of the rains is faster than their northward advance. The mean decadal end of the rains in Port Harcourt is 26th November. In terms of the length of the rainy season which is also taken as the length of the period (in days) between the date of onset and date of end of the rainy season, the literature shows that there is no year when the length of the rainy season falls below 250 days. The mean length of the rainy season in the Port Harcourt region is 272 days (Chinago, 2020).

The climatic condition experience in Port Harcourt is common and almost the same as experienced in other parts of West Africa. The effect of the Ocean is also the same, especially as Atlantic Ocean lies south of West Africa.

RESULTS
The rainfall characteristics of the study area is shown in table 1 and explained in figure 2.
The implication is that only January and December with 34.38mm and 37.71mm of rainfall respectively are qualified to be called dry season since they were the only months with rainfall distributions of less than 51mm. Accordingly Walter (1979) stated that onset of rainfall starts with a monthly accumulation of or more than 51mm of rainfall as shown in February a month with relative low seasonal rainfall (68.27mm). The highest rainfalls occurred during September and July with mean rainfall of 374.44mm and 350.24mm respectively. Other high rainfall months include August, June, October and May with 298.60mm, 291.40mm, 265.56mm and 233.37mm respectively. The high rainfall months with mean rainfall over 200mm accounted for 76.44% of the rainfall during the study period. The low rainfall months accounted for 23.56% of the rainfall over Port Harcourt during the study period.

Table 1 shows that the mean rainfall during the study period is 2375.23mm that means that if rainfall were to be distributed evenly, each year will have about 2375.23mm of rainfall. A great deviation from the mean will signal abnormality, depending on the direction of the deviation. Figure 3 show the seasonal distribution of rainfall during the study period.

![Figure 2: Mean seasonal rainfall Distribution in the study Area. (1931-2014).](https://doi.org/10.58425/jegs.v1i1.82)
Figure 2 shows that rainfall occurrence in the study area increases from January to July, but there was a fall in August (between the month of July and September) a dry spell which occurs as a result of brief dryness for about 15 days. This rainfall characteristic gives rise to double maxima.

From figure 2, extreme rainfall does not occur till the Month of May, and since May is the first month with extreme rainfall, it is most unlikely that flood will occur in the first five month of the year. It was also observed that the first half of the years (first 6 months) recorded lesser rainfall than the last 6 months of the years. The first half of the years accounted for 39.7% of the total rainfall during the study period, while 60.3% of the rainfall occurs during the second half of the years. This implies that it is difficult for flood to occur during the first half of the year in in the West African subcontinent.

Generally, Rainfall variability and reliability in the study area is relatively moderate. June is the most reliable and the least variable in terms of rainfall fluctuation. The coefficient of variation is 31.03% and it is followed by October, July and September with 31.47%, 32.05% and 32.32 respectively. The most variability or unreliable month is December and January, with CV of 133.6% and 81% respectively. The standard deviation is another way of identifying variation. From Table 1, it was observed that the rainy reason months have higher standard deviations this implies that the probability of having rainfall of the same or higher magnitude is high. It was observed from figure 2, that for the 84 years of study the rainy months have consistently experienced extreme and reliable rainfall.

Table 1 shows that the mean monthly rainfall (the mean of mean) is 197.9mm; May to October has mean rainfall greater than 197.9mm, and from November to April has rainfall less than 197.9mm. This implies that months with rainfall less than 197.9mm can hardly produce extreme rainfall that can cause flood, the best such could produce are flash flood that last for few hours. The extreme rainfalls from the month of May and the previous accumulated rainfall are pointer to flooding incidence. Observations have shown that seasonal streams rejuvenate around June and middle of July, with the little dry spell that follows in August, it follows that extreme rainfall (RF) from September which is key to flooding incidence in the study area starts from mid-September to October, even to early November. However, when extreme rainfall started early from late April and early May it can trigger early flood in early July. This work observed that no matter the runoff experienced in the study area, extreme rainfall induce flood may likely not occur earlier than late June.

The dry spell in August, which is a check to extreme rainfall and flood occurrence previously, is seriously reducing. From 1931-1958, the August dry spell, locally called August break is well pronounce. June and October recorded more rainfall than August, but since 1959-2014, August rainfall has exceeded that of June and October, and it is closing up with July. This explains insistent flood incidence of late in the study area.

Annual Rainfall Pattern

The mean annual RF for the 84 years of study is 2375.23mm. The annual rainfall explains the fluctuations, variations and trend of rainfall in the study area. The annual rainfall, especially the amount does not explain whether flood will occur or not. Figure 3 show that rainfall is decreasing over time in the study area, but rainfall characteristics over the station remain almost the same. The highest rainfall occurrence was recorded in 1935 (3163mm) followed by 1962 (2969mm), 1960 (2991mm), 2006 (2969mm) and 1966 (2966mm) respectively, while the least rainfall was recorded during 1950 (1582mm), 1958 (1733mm) and 2010 (1776mm). Annual rainfall shows how wet or dry a year may be. Series of extreme rainfalls in a year will however
result to high rainfall distribution and flood. This is because majority of the storms that accounted for the high rainfall distribution come from the rainy season. Figure 3 shows the trend, 5 years moving average and annual frequencies of rainfall over the study area.

![Figure 3: The trend and annual fluctuation of rainfall over the study area (1931-2014)](image)

**Source:** Nigeria Meteorological Agency, Lagos (2021).

The black line shows the five years running mean. The red line denotes the trend, while the blue line is the yearly fluctuation of rainfall over the study period. Using Pearson Moment Correlation Coefficient for analysis (Comparing variation in rainfall distributions from 1931-1972 and 1973-2014). H₀: There is no significant variation in rainfall distribution over years in the study area

H₁: There is significant relationship in rainfall distribution in the study area.

\[ r = 0.09 \]

Coefficient of determination (CD) = \( r^2 \times 100 = 0.81 \) approximately 1%, this implies that the variation in rainfall distribution over time can only be explained by 1%. The variation that occurs is by chance, the chance is climate change.

\[ t_{\text{calculated}} = 1.30, \text{ and } t_{\text{critical}} = 2.02 \]

Since \( t_{\text{calculated}} < t_{\text{critical}} \), therefore H₀ is rejected and H₁ accepted at 95% level of confidence under one tail test. This shows that there is significant variation in distribution of rainfall over the years in Port Harcourt.

**Extreme Rainfall Forecast and its Relationship to Flooding**

This section is concern with the forecasting of extreme rainfall and flood. This will be achieved using structural time series model, which is capable of forecasting extreme rainfall and urban flood occurrence.

**Structural Time Series Model- Interpolation of inputted RF data**

The algorithm used for the analysis is BFGS (Wessa, 2016), it trained 66 years data. The training is to see the reliability and validity of the model in comparison with the actual rainfall. The result of the first training is shown in figure 4 structural time series model scored 13/18*100 (72.22%) in extreme rainfall forecast, but did better in flood prediction during the
period of study. Note that extreme rainfall and flood is said to occur whenever the predicted observe RF is above the predicted level rainfall.

![Figure 4: Actual Rainfall and Structural Time Series Model forecast RF from 1997-2014.](image)


The observed is the model forecast output; the level and seasonal data are the machines hidden manipulations gotten from several statistics. The analytic computer centre used Broyden-Flect; Goldfarb-Shanno (BFGS) algorithm for training and prediction. Autocorrelation function (ACF), Spectral analysis, Frequencies, Standardizes residual and Kernel density were part of the computer manipulations. The result gives level that can be compared with the observed rainfall to determine when extreme rainfall is likely to occur and by implication flood predictions.

![Figure 5: Observed and level trained RF data1931-2014.](image)


Figure 5 shows the period of extreme rainfall and when flood is most likely to occur in the study area. It was observed that whenever the observed rainfall is above the level, it is likely a
The difference between the observed when above the level will determine the extremity of the rainfall and by implication the volume of flood that will occur. Based on the performance of the structural time series model, a further forecast for 18 years (2015-2032) was carried out using the entire 84 years data (1931-2014). The result of the prediction was recorded in Table 2 and Figure 6. Three components were analysis- the observed, level and seasonal.

The result was compared to actual extreme rainfall and incidence of flooding in the study area during the period of 2015-2021. The result was spot on. It performed over 98% in prediction of extreme rainfall and incidence of flooding in Port Harcourt metropolis in particular and the equatorial West Africa in general. For instance, as predicted there was extreme rainfall and flood in 2015, 2018, 2019 and 2021. This show that structural time series model perform better with larger data than short term data in predictions. It better in climatological predictions with large database and should be used in climatological predictions.

Table 2: Structural time series model –extrapolation for extreme RF forecast

<table>
<thead>
<tr>
<th>t</th>
<th>Observed</th>
<th>Level</th>
<th>Seasonal</th>
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</thead>
<tbody>
<tr>
<td>2015</td>
<td>2846.79289646607</td>
<td>2541.9321027161</td>
<td>304.853686194456</td>
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<td>2016</td>
<td>2273.31375625711</td>
<td>2610.52113957609</td>
<td>-337.207383318981</td>
</tr>
<tr>
<td>2017</td>
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Source: Field work. (2022)
Note, it is not every time that the observed exceed the level that flood will occur, sometimes it could lead to flash flood that last for hours, which can happen, when it rained for some hours. However, it was observed that the seasonal peaks indicate when flood is likely to occur. That is flood will most likely occur when the observed rainfall exceeds the level at the seasonal peak. It indicates clear dispersion between observe and level. The other points where observe are greater than level outside the seasonal peak, the dispersion is very close, which is an indication of a mild flood. The study observed that flood occurred and will likely occur in the study area in 2015, 2018, 2019, 2021, 2023, 2026, 2027, 2030 and 2031. The most pronounce extreme rainfall capable of causing flood occurred in 2015, 2018 and will likely occur in 2027 and 2030. Mild flood occurred during 2019, 2021, and may likely be experienced in 2023, 2026 and 2031. 2017, 2024, 2025 and 2029 can also produce extreme rainfall that is capable of causing weak flood. The reason is due to the closeness of the observed and the level in figure 6. Figure 6 show that level data is linear in nature, that is ever increasing, but observed data fluctuates, however, it also shows a positive trend. The seasonal data has a real natural distribution. Despite the high flood incidence in Nigeria, and in Rivers State in particular, this year 2022 as the study show, Port Harcourt the study area did not experienced flooding.

DISCUSSION

From the findings it was observed that the rainy season which starts from the month of March to October is the likely time extreme rainfall and flood will occur in Port Harcourt. The rainy season accounts for about 90% of the total rainfall occurrence in the study area. Therefore whatever flood there is in the area will start to recede by Middle November. The study show that the August dry spell is reducing and that account for more runoff in the month of September, which triggers flood in the study area between late September and in the month of

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October. Besides, it was discovered that the annual rainfall is decreasing over time. All West African equatorial zone experiences the adverse harmattan weather. Pearson product moment correlation coefficient shows that there is a significant variation over the years in rainfall distribution. But the fact that just 1% of the variation can be explained shows that the variation is by chance, this chance is climate change. The study using structural time series model and as shown in figure 4 shows that the model performance rate was 72.2% for extreme rainfall forecast, and 98% for flood prediction using trained data. In figure 6 the study predicted flood years using 84 years trained data. The results up to the present (2022) shows a 100% performance. Serious flood occurs whenever the predicted rainfall (Observed) is over level at the crest of a season.

CONCLUSIONS

From the findings, it is obvious that RF distribution varies over climatic period in Port Harcourt. The rainy season still account for the greatest amount of rainfall. The slight dry spell in August and the double maxima remains a major pattern of rainfall in Port Harcourt. However, the August dry spell has reduced significantly of recent, and that is responsible to more incidence of flooding in Port Harcourt and other coastal equatorial regions of West Africa. The run-off that could have dried during the dry spell, before September heavy rainfall would not dry because August rainfall has increase and the dry spell reduce. The result is large accumulation of run-offs that will add to September rainfall to trigger flood by late September or early November. Rainfall and flood was forecasted using Structural Time Series Model, the model performed very well in extreme rainfall and even better in urban flood prediction. Flood will most likely occur whenever the forecasted rainfall occurrence is greater than the level output during a seasonal peak.

RECOMMENDATION

Based on the observed findings, the study recommends the following:

(a) Extreme RF forecast by the authorities should be taken serious by inhabitants and warning be given and adhered to by residences.

(b) For long time forecast, structural time series model should be use since it performed very well, but this should be done with large data.

(c) Since extreme RF and flood years are forecasted ahead of time using this model, drains, water channels and water ways should be cleared before flood period, especially in flood predicted years. Furthermore, farmers should cultivate hybrid crops that can mature faster on forecasted extreme RF and flood years to minimise impact of flood on food production.

(d) Building on marshy land, water channel, wetland, etc. should be discouraged and there should be legislation prohibiting it. Besides, in incidence of flood, the people should be evacuated on time and drugs and drinkable water made available for flood victims. This arrangement should be in place since likely year of flood have been predicted.

(e) Dyke and embankment should be constructed around river banks to check coastal flood.

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Availability of data and materials
All data gathered and analysed in this study are included in this article.

Competing interests
Not applicable

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