Modelling Rainfall Series in the Geo-Political Zones of Nigeria

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Abstract
This paper applied time series analysis techniques to rainfall series in selected states of Nigeria geo-political zones. The preliminary analysis of the series showed that the mean annual rainfall for the selected states in North West, North central, North East, South West, South South and South East were 225.395, 269.938, 300.794, 323.634, 737.836 and 442.360 millimeters respectively. The correlogram of each series showed a positive autocorrelation and partial autocorrelation value at every seasonal, hence the inclusion of seasonal autoregressive in the model. On the basis that d=D=0, seasonal ARMA model was fitted to each series using AIC and SIC model selection criteria. The performance of the two criteria in selecting optimal model was found to be alike.
Keywords: Time series, correlogram, autocorrelation, seasonal, autoregressive

1. INTRODUCTION
The changing in the statistical properties of the climate system when considered over long periods of time, regardless of cause, is referred to as climate change. Climate changing or global warming has become a global phenomenon with deleterious effects. The challenge posed by climate change is noticed in disruption of seasonal cycles and ecosystems. In addition, agriculture, water needs and supply, and food production are all adversely affected. Climate change also leads to sea-level rise with its attendant consequences, and it includes fiercer weather, increased frequency and intensity of storms, floods, hurricanes, droughts, increased frequency of fires, poverty, malnutrition and series of health and socio-economic consequences. It has a cumulative effect on natural resources and the balance of nature.

Nigeria is part of the global community and therefore not immune to the impacts of climate change. The impact of climate change can be vast in Nigeria. This implies that some stable ecosystems such as the Sahel savanna may become vulnerable because warming will reinforce existing patterns of water scarcity and increasing the risk of drought in Nigeria and indeed most countries in West African. Also, the country aquatic ecosystems, wetlands and other habitats will create overwhelming problems for an already impoverished populace. Preliminary studies on the vulnerability of various sectors of Nigeria economy to climate change were conducted by NEST. The sectors evaluated were based on seven natural and human systems as identified by the IPCC, and condensed into five. They are: Human settlements and health; Water resources, wetlands, and freshwater ecosystems; Energy, industry, commence, and financial services; Agriculture, food security, land degradation, forestry, and biodiversity; and coastal zone and marine ecosystem.

The study determined that most of the sectors analysed manifested some evidence of vulnerability to climate change. None were unaffected, nor will remain unaffected in the future by changes in the climatic conditions. In fact, in more recent assessment, although in regional or global scale, not only corroborate the patterns established by IPCC but captured more disturbing scenarios.

1.1 RESEARCH MOTIVATION
According to Obioha (2009), the sustainability of the environment to provide all life support systems and the materials for fulfilling all developmental aspirations of man and animal is dependent on the suitability of the climate which is undergoing constant changes. Thus, understanding the spatial and temporary variations in climate within a zone or region, and their relationships with other factors, is important in activities related to climate change and the management of the natural resources, such as environmental planning, land-use planning, watershed management and territorial ordering (Zuviría, 2011).

1. LANDSCAPE OF NIGERIA
Nigeria is a country covering an area of about 923,770 square kilometers. Her immense natural water resources are evident in heavy annual rainfall, numerous large rivers, and abundant ground water reserves. The mean annual rainfall distribution ranges from about 3000mm at the coast and diminishes inland towards the northern border to about 500mm and an average annual mean of 1200mm for the whole country. Surface sources of water include the River Niger, the third largest river in Africa. The country spans the greater section of the river, which with the River Benue divides the' country into three ideal geographical regions. In addition to these two rivers,

Cross River, Imo, Sokoto, Ogun, Anambra, Kaduna rivers together with several streams and channels, lakes and, ponds, provide a nation wide web of drainage basins. The quantities of runoff from the drainage basins vary widely and depend upon a large number of factors, the most important of which are the topographical features of the area.

2.1 RAINFALL EXTREMITY AND ITS CHALLENGES

Rainfall as one of the climatic elements has been studied more than any other climatic element. The reason is that rainfall affects every facet of human life, and its variability, seasonality and extremity has lot of consequences on humans. According to Gwary (2008) and Adeoti (2010), heavy rainfall coupled with bad human activities is one the major cause of flooding in most Nigerian cities that has left hundreds of people distressed and homeless.

The findings of these authors was buttress by Agbonkhese et al (2011) where they reported that thirteen state in Nigeria were affected by incidents of flood in August, 2011. The affected states were Benue, Borno, Delta, Ebonyi, Lagos, Imo, Jigawa, Kano, Katsina, Oyo, Sokoto, Taraba and Yobe. Out of these thirteen states, nine (Zamfara, Oyo, Delta, Ebonyi, Borno, Imo, Taraba, Yobe and Benue) were the worst hit having higher number of casualties as reported in the National Early Warning System (NEWS). The flood claimed about one hundred and forty lives with thousands displaced and properties worth millions of Naira destroyed, sadly children and the elderly accounted for a larger percentage of the dead from the flood. Most of the affected states recorded over 60% increase in the volume of rainfall in the period.

Apart from this, 2010 climate review prepared by Nigeria metrological station as well gave socioeconomic impact of rainfall extremity. It was reported that reduction in rainfall amount in August of the year reviewed led to a drop in millet, sorghum and cowpea production by about 10% in northern states of Borno and Yobe. Reports also indicated that Sokoto, Kebbi and Jigawa states had a reduction in rice production by 50% due to excessive flooding in September as compared to the same period in 2009.Fishing activities were affected particularly in the coastal states of Bayelsa and Rivers due to rise in water levels and flooding caused by above normal rainfall. All these and many more, suggest that a unified study that will give a clear picture of rainfall pattern in Nigeria geo-political zones is highly demanded.

2.2THE NEED FOR THE STUDY

Our Vision 20: 2020 may also be at risk, just like the MDGs, if Climate Change adaptation and mitigation strategies are not put in place. Hence, there is need for adequate understanding of past, present and future climate trends in Nigeria so as to enable policy makers manage our changing climate and mainstream climate information into our national and global development plans. This implies that climate risk information derived from analyses of Nigerian climate data need to be integrated into our national planning and decision-making. Thus, the focus of the study is to examine rainfall trend in a randomly selected state in Nigeria geo-political zones. The study will also provide appropriate descriptive features of the series and derive an appropriate model for each series using time series technique. This study is rank different from exiting work on rainfall in that it gives overview of rainfall pattern in each geo-political zones and as well as allow for comparison among the zones. Apart from this, updated data used in the study and methodological approaches are also justification for the study. In addition, a study like this will help to understand rainfall pattern in each of the geo-political zones and in a way assist policy makers in developing strategies to combat future challenges of rainfall extremities.

2.3 POPULATION AND SAMPLE SELECTION

The study is a case study of Nigeria. In order to select sample for the research work, all the 36 states of the federation were divided into 6 clusters based on the geo-political zones (see figure 1 for detail). In each geo-political zone a state is randomly selected and rainfall data was obtained for the selected states from central bank of Nigeria statistical bulletin 2011 and 2013.

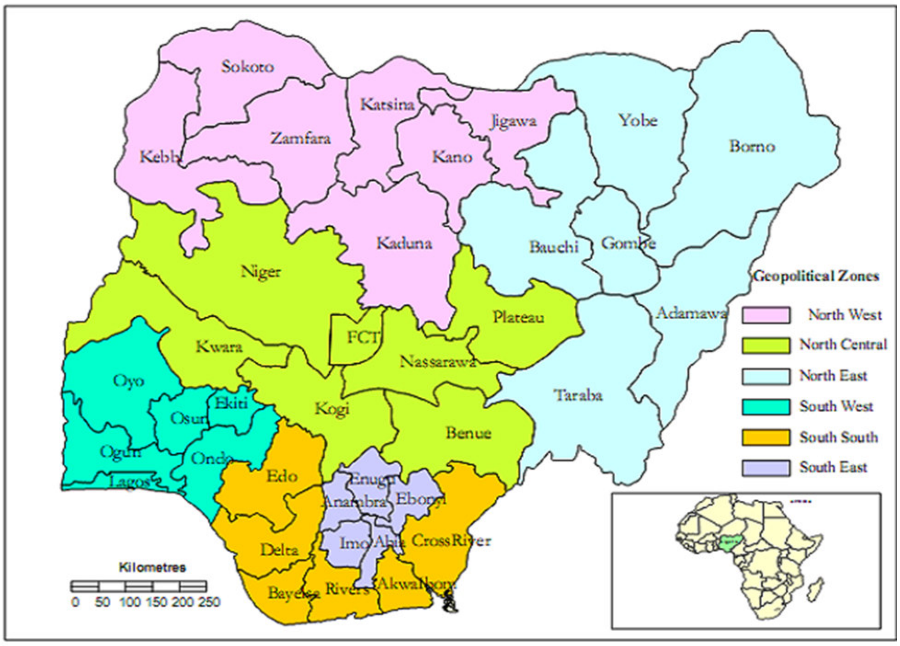

Figure 1. Nigeria map Showing 36 States/FCT and 6 Geo-political Zones

3. METHOD OF ANALYSIS

As earlier mentioned, time series analysis technique will be the method of analysis in the study. However, in order to have background information on the data, the descriptive features of the data was examined using measures of central tendency, dispersion and partition such as mean, standard deviation, skewness and kurtosis. In addition, estimate of proportion of total rainfall was computed for each states and bar chart was used to depict some of these descriptive features of the data.

3.1 Unit Root Test

In practice, stationarity is the first fundamental statistical property tested in time series analysis. A time series is "stationary" if all of its statistical properties i.e. mean, variance, autocorrelations, etc. are time invariant. Thus, it has no trend, no heteroscedasticity, and a constant degree of wiggliness. The most commonly used standard tests of stationarity are Augmented Dickey Fuller (ADF) and Phillips Perron (P-P) tests.

3.1.1 The Augmented Dickey-Fuller Test: The standard DF test applied three distinct models to check for presence of unit root. These are pure random model, random walk with intercept or drift term drift model and model that include a drift and linear trend regression. They are shown in equations 1-3.

$$\Delta y_t = (\rho - 1) y_{t-1} + \sum_{j=1}^{j} \beta_j \Delta y_{t-j} + \varepsilon_t \qquad 1$$

$$\Delta y_t = \alpha + (\rho - 1) y_{t-1} + \sum_{j=1}^{j} \beta_j \Delta y_{t-j} + \varepsilon_t \qquad 2$$

$$\Delta y_t = \alpha + \delta_t (\rho - 1) y_{t-1} + \sum_{j=1}^{j} \beta_j \Delta y_{t-j} + \varepsilon_t \qquad 3$$

These are testing:

H_0:	$\rho = 1$	against	H_1:	$\rho \neq 1$
	$\alpha = 0$	against		$\alpha \neq 0$

δ = 0 against δ ≠ 0

Using the test statistic

$$T_\rho = \frac{\hat{\rho} - 1}{S.E\left(\hat{\rho}\right)} \qquad \approx \text{ADF (I, n, } \alpha)$$

or $$T_\alpha = \frac{\hat{\alpha} - 1}{S.E\left(\hat{\alpha}\right)} \qquad \approx \text{ADF (II, n, } \alpha)$$

or $$T_\delta = \frac{\hat{\delta} - 0}{S.E\left(\hat{\delta}\right)} \qquad \approx \text{ADF (III, n, } \alpha)$$

The standard Dickey-Fuller unit root test described above is valid only if the series is an AR (1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances ε_t is violated. The Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the *y* series follows an AR (*P*) process and adding *P* lagged difference terms of the dependent variable *y* to the right-hand side of the test regression:

$$\Delta y_t = \alpha y_{t-1} + x_t^{'}\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \ldots \beta_p \Delta y_{t-p} v_t \qquad 4$$

3.1.2 Phillips-Perron (P-P) Test: Phillips and Perron proposed a non-parametric alternative method of controlling for serial correlation when testing for a unit root. The P-P method estimates the non-augmented DF test equations, and modifies the t-ratio of the α coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic. The P-P test is based on the statistic:

$$t_\alpha = t_\alpha \left(\frac{\gamma_0}{f_0}\right)^{\frac{1}{2}} - \frac{T(f_0 - \gamma_0)(se(\hat{\alpha}))}{2 f_0^{\frac{1}{2}} s} \qquad 5$$

Where $\hat{\alpha}$ is the estimate, and t_α is the t-ratio of α, $se(\hat{\alpha})$ is the coefficient standard error, and *s* is the standard error of the test regression. In addition, γ_0 is a consistent estimate of the error variance in any of equations (1-3) and it is calculated as $(T - K)s^2$ (where *k* is the number of regressors). The remaining term, f_0, is an estimator of the residual spectrum at frequency zero. Therefore, both equation (4) and (5) are used to test for the stationarity of the variables.

The study will employ the two methods and in a situation where ADF results differ from P-P, P-P result will be used to decide on the level of integration of the variable in question. This is because it is a non parametric method and in way not tied to distribution assumption unlike ADF where normality assumption is given prominence.

3.2 SEASONAL AUTOREGRESSIVE INTEGRATED MOVING AVERAGE (SARIMA)

The generalized seasonal autoregressive integrated moving average (SARIMA) model is expressed as:

$$\Phi_P\left(B^s\right)\phi_p(B)(1-B)^d(1-B^s)^D X_t = \theta_q(B)\Theta_Q\left(B^s\right)\varepsilon_t \qquad 6$$

where d=1 and $\phi_p(B)$ and $\theta_q(B)$ are the autoregressive and moving average polynomials given as,

$$\phi_p(B) = 1 - \phi_1(B) - \phi_2 B^2 - \ldots - \phi_p B^p \qquad 7$$

$$\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q \qquad 8$$

and $\Phi_P(B^s)$ and $\Theta_Q(B^s)$ are the seasonal autoregressive moving average polynomials given as,

$$\Phi_P(B^s) = 1 - \Phi_1 B^s - \Phi_2 B^{2s} - \ldots - \Phi_P B^{Ps} \qquad 9$$

$$\Theta_Q(B^s) = 1 - \Theta_1 B^s - \Theta_2 B^{2s} - \ldots - \Theta_Q B^{Qs} \qquad 10$$

The residual ε_t is a white noise process. The model defined in (6) is often expressed as $ARIMA(p,d,q) \times (P,D,Q)_S$ where s is the seasonal period, p,d,q are the autoregressive, differencing and moving average orders in the nonseasonal part of the model; the P,D,Q are the autoregressive (SAR), differencing and moving average (SMA) orders in the seasonal part of the model. An SAR signature usually occurs when the autocorrelation at the seasonal period is positive, whereas an SMA signature usually occurs when the seasonal autocorrelation is negative.

With $d=D=1$, the model reduces to $SARIMA(p,1,q) \times (P,1,Q)_S$ process given as

$$\Phi_P(B^s)\phi_p(B)(1-B)(1-B^s)X_t = \theta_q(B)\Theta_Q(B^s)\varepsilon_t \qquad 11$$

Also, with $d=D=0$, the model reduces to $SARMA(p,q) \times (P,Q)_S$ process given as

$$\Phi_P(B^s)\phi_p(B)X_t = \theta_q(B)\Theta_Q(B^s)\varepsilon_t \qquad 12$$

It is very common to have time series with period s=4 and 12 for quarterly and monthly data respectively. The current study uses a quarterly series, hence s=4

3.3 ORDER OR MODEL SELECTION

Model comparison tests-such as the likelihood ratio, Lagrange multiplier, or Wald test-are only appropriate for comparing nested models. In contrast, information criteria are model selection tools that can be used to compare any models fit to the same data. That is, the models being compared do not need to be nested.

These criteria were developed for pure AR models but have been extended for $ARMA$ models. It is assumed that the degree of differencing had been decided and that the object of the criterion is to determine the most appropriate values p and q. The more applied model selection criteria are the Akaike Information Criterion (AIC), (Akaike; 1974) and the Schwarz Information Criterion (SIC), (Schwarz; 1978) given by:

$$AIC = \ln(\hat{\sigma}_\varepsilon^2) + \frac{2k}{T} \qquad 13$$

$$SIC = \ln(\hat{\sigma}_\varepsilon^2) + \frac{k}{T}\ln(T) \qquad 14$$

Where k is the number of the estimated $ARMA$ parameters $(p+q)$ and is the number of observations used for estimation. Both criteria share the same goodness-of-fit term and are based on the estimated variance $\hat{\sigma}_\varepsilon^2$ plus a penalty adjustment depending on the number of estimated parameters. However, the penalty term of SIC $(k \ln T)$ is potentially much more stringent than the penalty term of AIC $(2k)$.Thus, SIC tends to choose fitted models that are more parsimonious than those favoured by AIC. In practical work, both criteria are usually examined and if they do not select the same model, many authors tend to recommend the use SIC.

4. DATA ANALYSIS

This section deals with application of time series techniques discussed in the previous section on the rainfall series of selected states in Nigeria geo-political zones. The section is subdivided into five. They are: descriptive analysis, trend analysis, testing for presence of unit root, model building and selection and model parameterization.

4.1 DESCRIPTIVE ANALYSIS

Table 1: Descriptive features of the underlying variables (mm)

	ZAMFARA	KOG1	BAUCHI	OYO	CROSS RIVER	ENUGU
Mean	225.395	269.938	300.794	323.634	737.836	442.360
Median	143.900	173.350	275.650	263.700	667.650	399.250
Maximum	1099.800	1528.800	955.200	1168.300	2111.500	1183.300
Minimum	0.000	0.000	0.000	0.000	26.200	1.000
Std. Dev.	269.820	321.885	245.098	221.886	439.352	317.952
Skewness	1.170	1.217	0.513	0.705	0.426	0.283
Kurtosis	3.497	3.860	2.254	3.211	2.403	1.823

Source: Authors' construct 2015

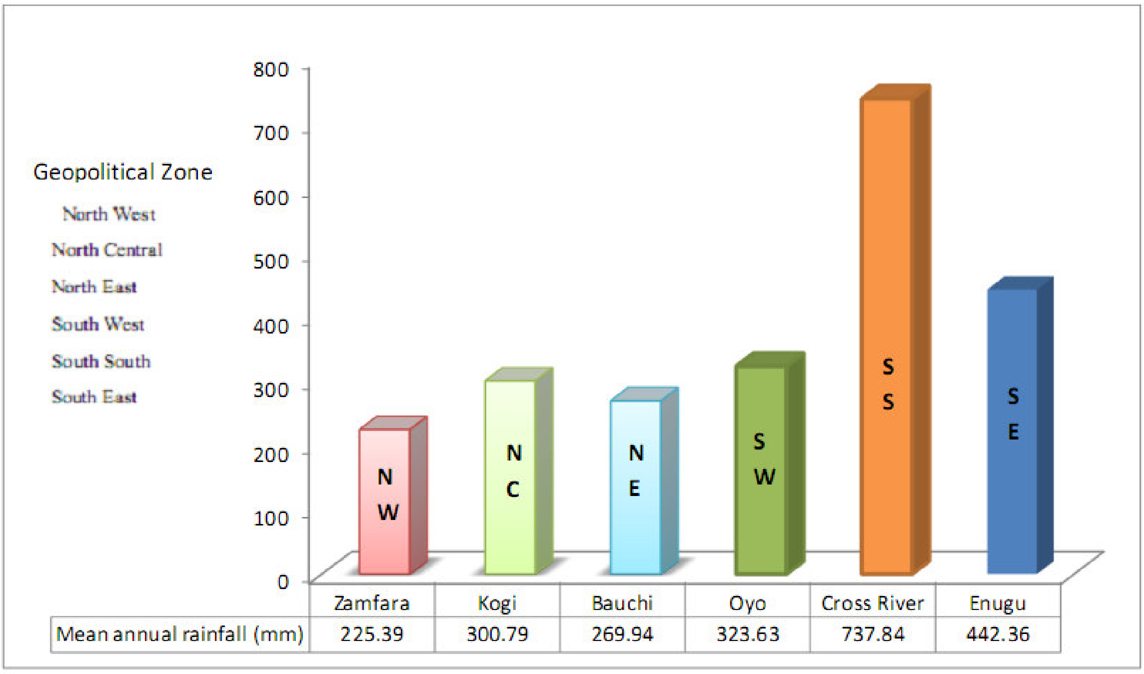

Figure 2: Mean annual rainfall of Nigeria geo-political Zones

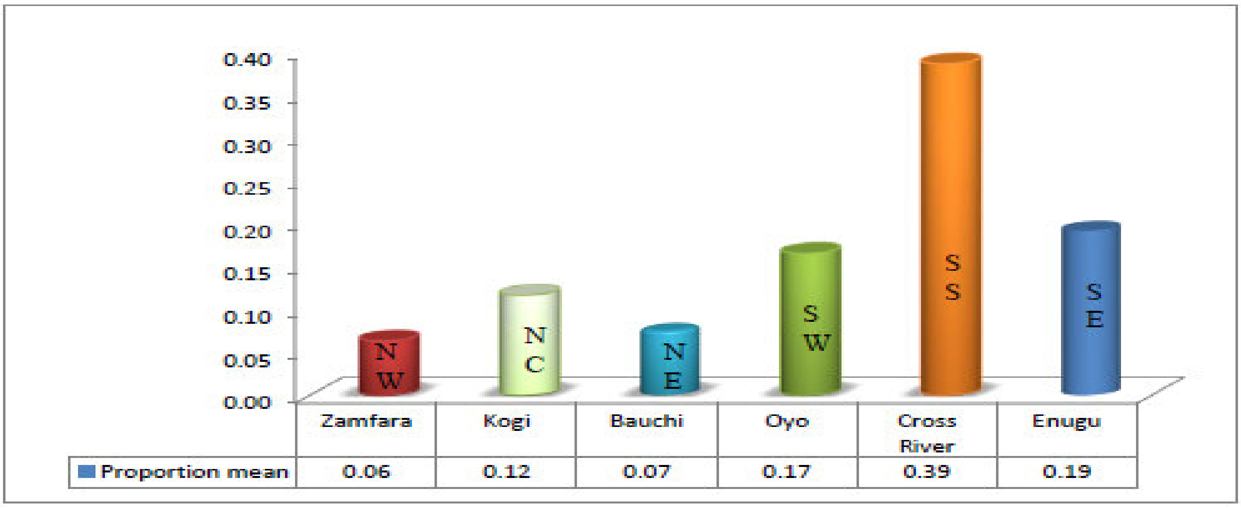

Figure 3: Proportion of total rainfall in the geo-political Zones

4.2. TREND ANALYSIS

In general, the series showed an increasing trend. The rate of change with time is highest in Cross river state and this is followed by Oyo state while it is least in Enugu state.

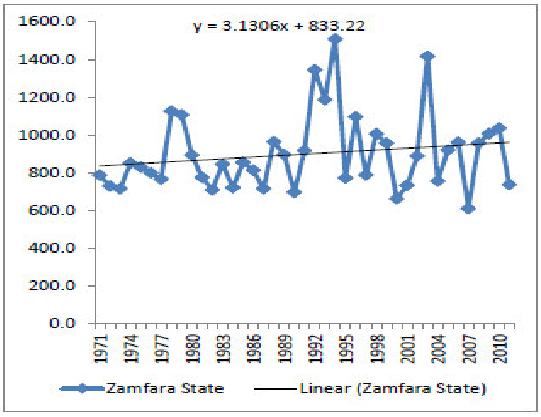

Figure 4: Zamfara rainfall trend

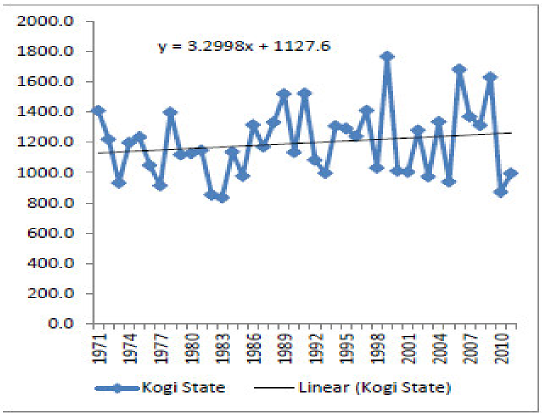

Figure 5: Kogi rainfall trend

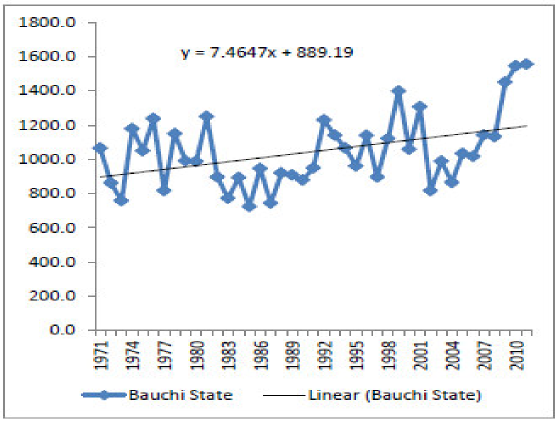

Figure 6: Bauchi rainfall trend

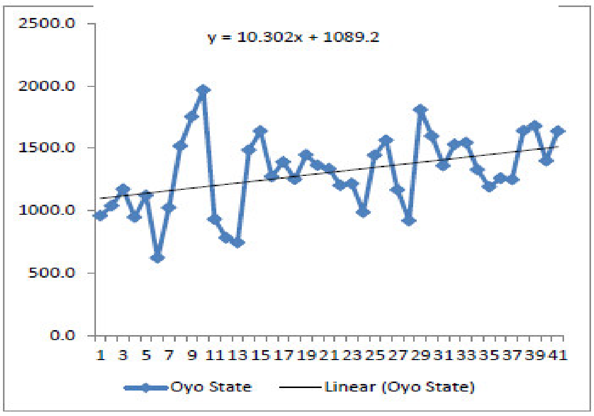

Figure 7: Oyo rainfall trend

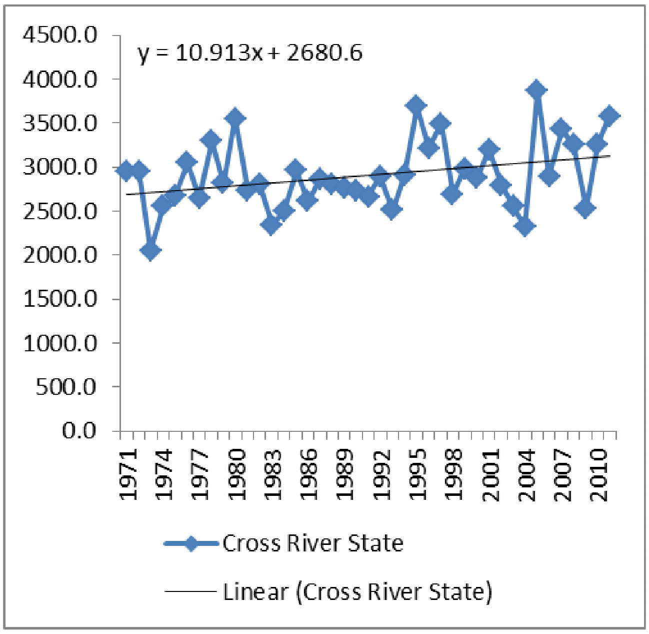

Figure 8: Cross River rainfall trend

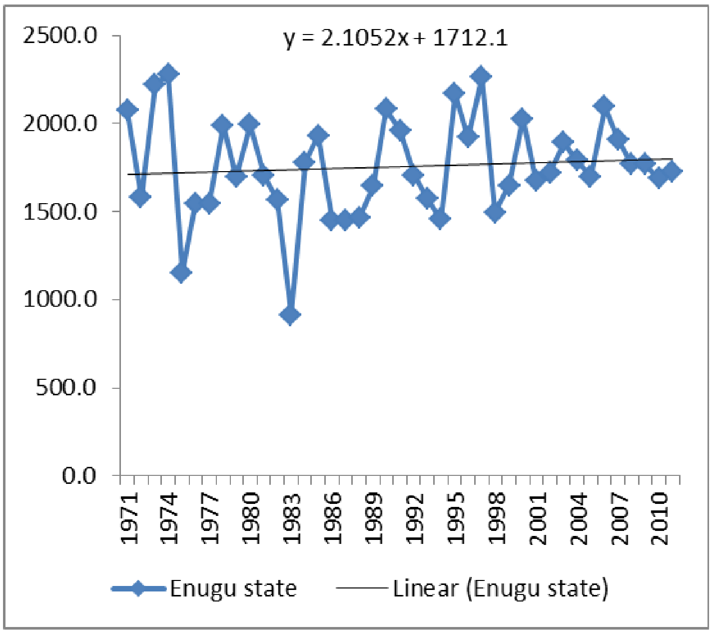

Figure 9: Enugu rainfall trend

4.3. TESTING FOR PRESENCE OF UNIT ROOT

The table shows that all the series are stationary at level and this implies d=D=0.Based on this, we proceed to estimate SARMA model in the next section.

Table 2: Test statistic value resulting from stationarity test at level

	Augmented Dickey Fuller Test (ADF)			Phillips-Perron Test (P-P)	
	Non constant regression	Trend regression	Drift regression	Non constant regression	Trend regression
Zamfara State	-0.671	-4.688	-4.584	-9.489	-17.910
Kogi State	-0.978	-5.848	-5.525	-6.290	-14.519
Bauchi State	0.190	-3.084	-2.067	-9.273	-17.425
Oyo State	-0.788	-3.480	-3.538	-5.083	-12.750
Cross river State	-0.312	-4.260	-3.582	-4.453	-14.459
Enugu State	-0.727	-4.760	-4.604	-5.551	-14.370
Critical values	1%=-2.591 5%=-1.950 10%=-1.614	1%=-4.018 5%=-3.441 10%=-3.141	1%.=-2.350 5%=-1.654 10%=-1.287	1%=-2.591 5%=-1.950 10%=- 1.615	1%.=-4.016 5%=- 3.441 10%=- 3.141

Note: The more negative value or the absolute value of both ADF and P-P tests statistic greater than the critical value at level indicates rejection of null hypothesis that the series is not stationary.
P-P is given preference in deciding level of integration

Source: Authors' construct from underlying data

4.4 MODEL BUILDING AND SELECTION

The AIC and SIC values resulting from the fitted models are presented in table 3. These values are charted in figure 10 and it shows that the minimum AIC and SIC values of the fitted models are recorded at model 4 for Zamfara, Kogi, Bauchi, Cross River and Enugu while these values are minimum for Oyo at model 3.Hence , the optimal models for five of the selected states (Zamfara, Kogi, Bauchi, Cross River and Enugu) and Oyo state are SARMA(4,4)$(1,0)_4$ and SARMA(3,3)$(1,0)_4$ respectively.

Table 3: AIC and SIC values of the fitted models

sn	Model	Criteria	Zamfara	Kogi	Bauchi	Oyo	Cross River	Enugu
1	SARMA $(1,1)(1,0)_4$	AIC	12.460	12.301	12.586	12.730	13.651	13.145
		SIC	12.535	12.375	12.661	12.804	13.725	13.201
2	SARMA $(2,2)(1,0)_4$	AIC	12.362	12.264	12.417	12.706	13.686	13.018
		SIC	12.475	12.377	12.529	12.819	13.798	13.112
3	SARMA $(3,3)(1,0)_4$	AIC	12.334	12.228	12.441	12.542	13.724	12.802
		SIC	12.485	12.378	12.591	12.693	13.875	12.934
4	SARMA $(4,4)(1,0)_4$	AIC	12.035	12.037	12.330	12.699	13.351	12.676
		SIC	12.224	12.226	12.519	12.888	13.540	12.846

Source: Authors' construct from underlying data

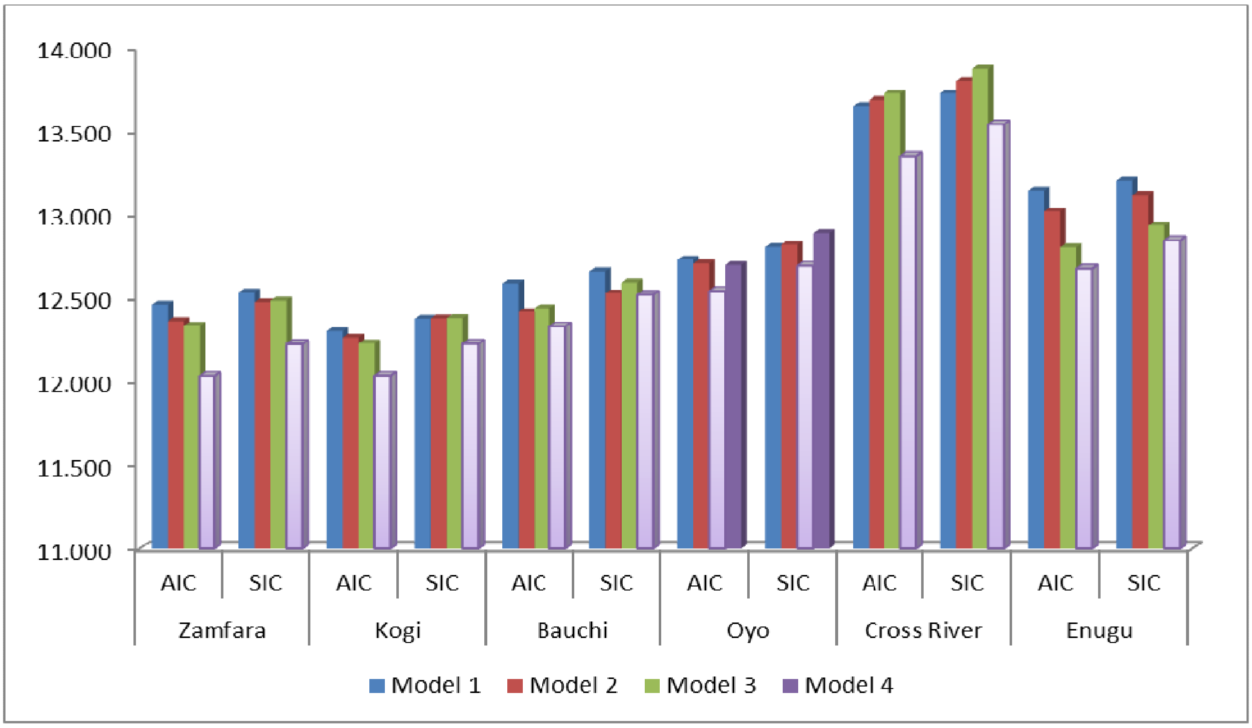

Figure 10: AIC and SIC values of the fitted models

SUMMARY AND CONCLUSION

The subject matter of this study is to model rainfall series in selected states of Nigeria geo-political zones using time series data analysis techniques. This section of the study provides summary of findings obtained from the study and draws conclusion based on the results.

The following are the findings of the study:

- The mean annual rainfall in Nigeria geo-political zones for the period showed the ordering from highest to the least to be South South, South East, South West, North Central, North East and North West.
- About 39% of total rainfall in Nigeria is accounted for by South South zone of the country.
- All the series showed an increasing trend. However, the rate of change is highest in South South and next to it in term of rate of change with time is South West.
- All the series are stationary at level. That is they are stable over the period and do not manifest any systematic pattern.
- The two model selection criteria performed the same way. There is no variation in their decision of the optimal model for the series.
- The optimal model choosed by the two criteria for the selected states in North West, North Central,

North East, South South and South West was SARMA(4,4)(1,0) with exception of selected state in the South West zone which claimed SARMA(3,3)(1,0).

In conclusion, this study has provided valuable insight on rainfall pattern in Nigeria Geo-political zones. The study showed that rainfall amount in South South, South East and South West was considerably higher than other zones and this might be one of the likely factors while dwellers of these zones were more vulnerable to flooding in comparison to other zones. Going by this assertion, it will mean that the study in part corroborate Gwary (2008) and Adeoti (2010) statement that “heavy rainfall coupled with bad human activities is one of the major causes of flooding in most Nigerian cities that has left hundreds of people distressed and homeless”.

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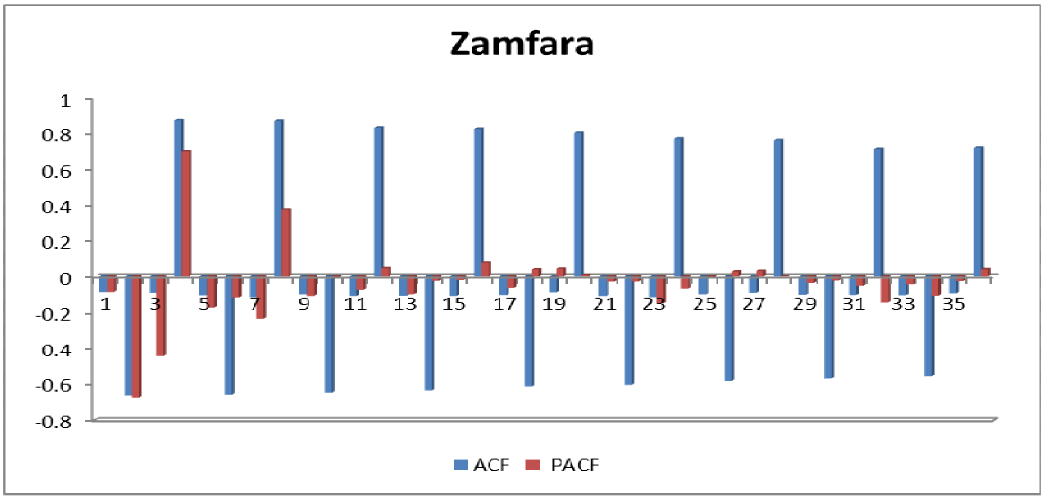
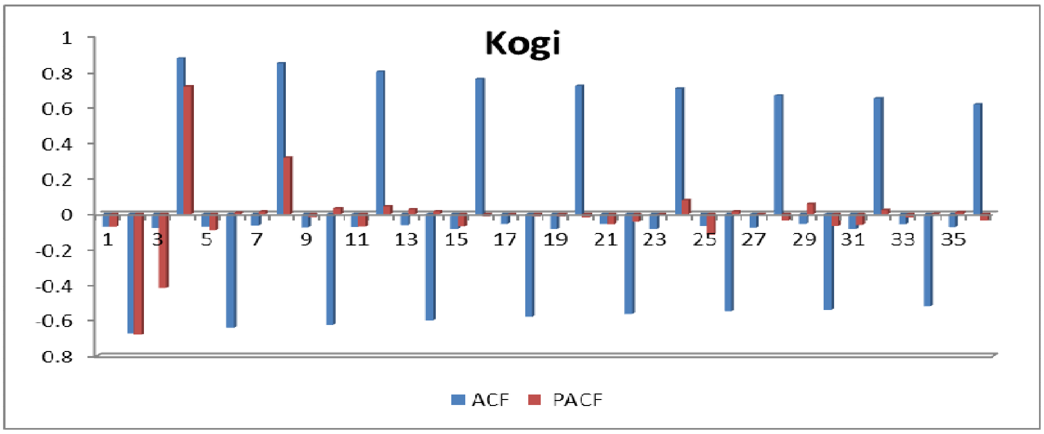
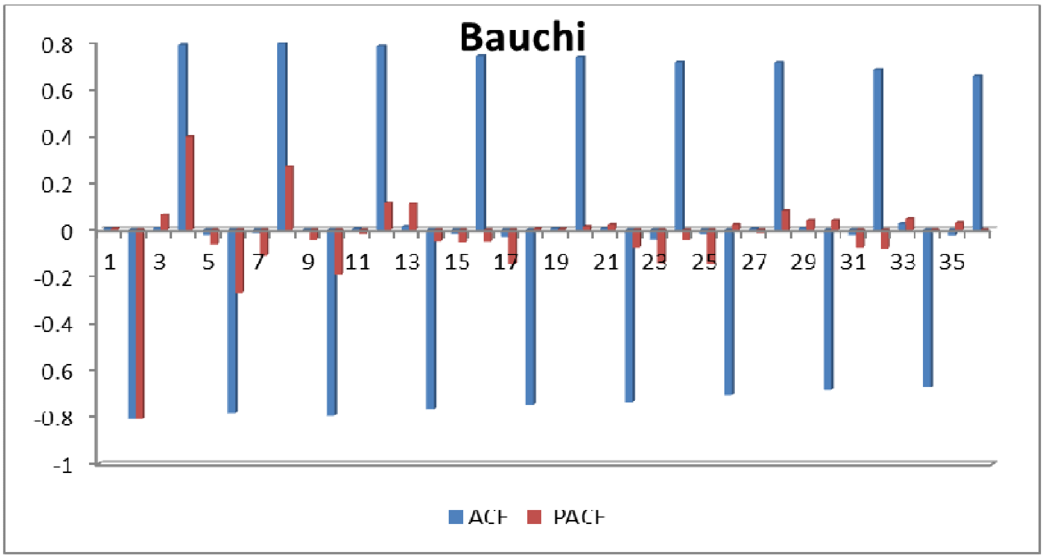
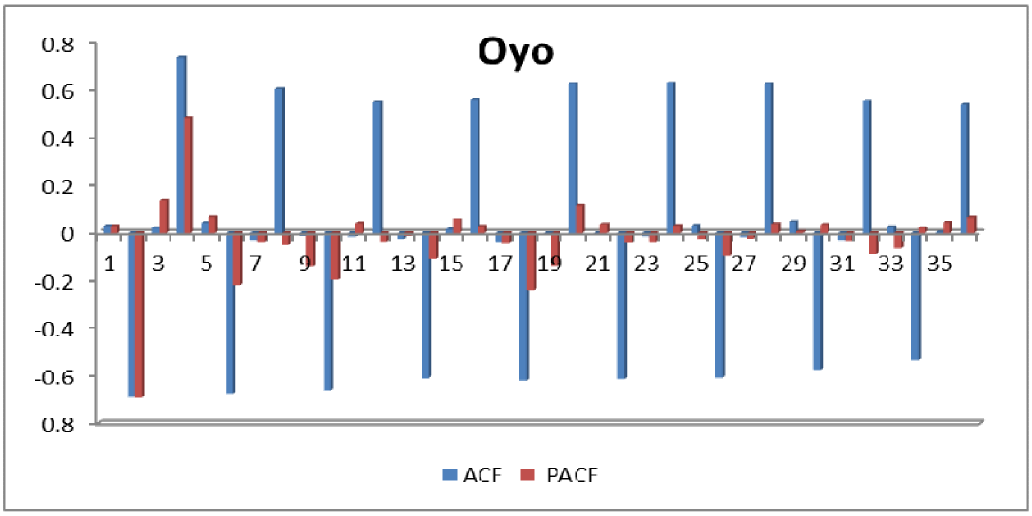
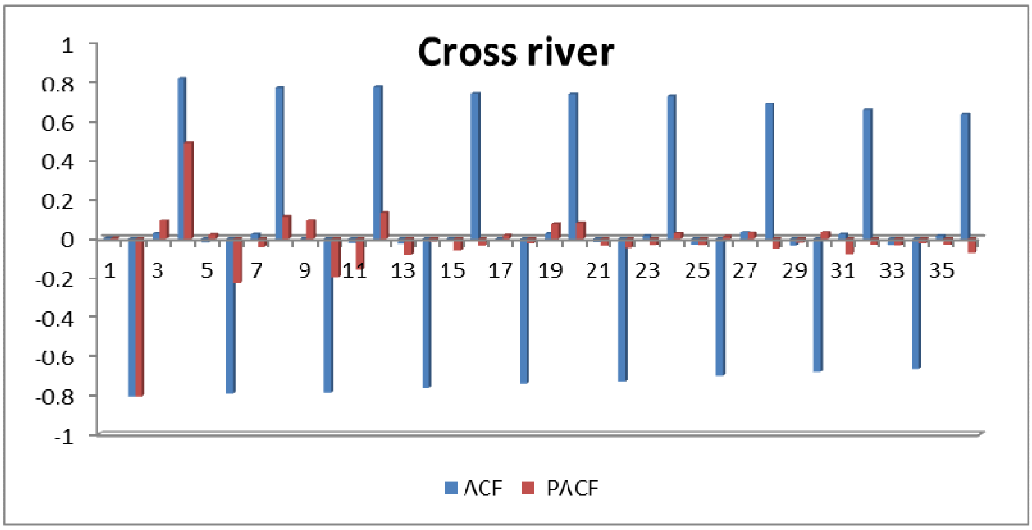
Appendix A: Correlogram








Oyo
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0.8
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
ACF
PACF


Cross river
1
0.8
0.6
0.4
0.2
0
-0.2
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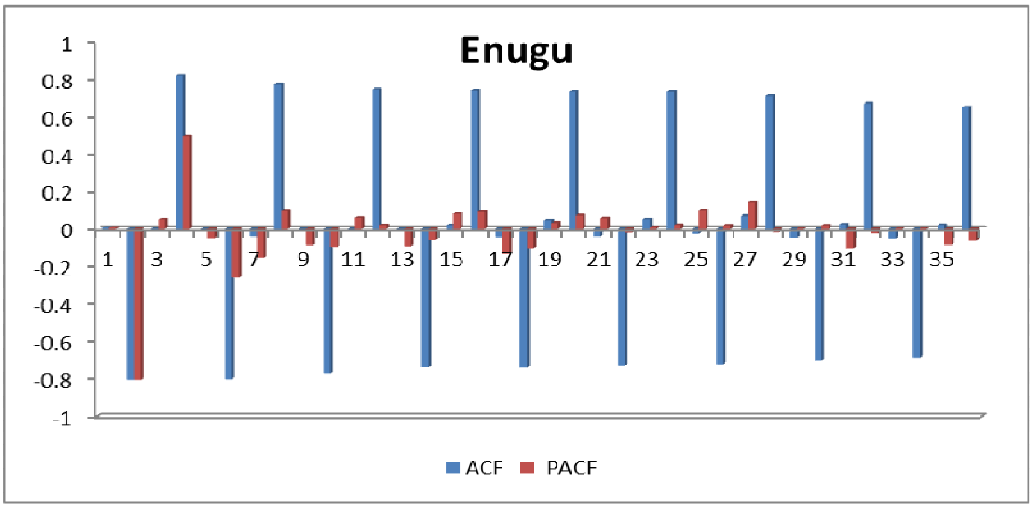
-0.6
-0.8
-1
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
ACF
PACF


Enugu
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
ACF
PACF