ANALYSIS OF NIGERIAN HYDROMETEOROLOGICAL DATA

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ABSTRACT
Rainfall and runoff like most hydrologic events are governed by the laws of chance; hence, their predictions cannot be done in absolute terms. Since there is no universally accepted method for determining the likelihood of a certain magnitude of rainfall or runoff, common probabilistic models were used in this research to predict the magnitude and frequency of their occurrence. Missing records were determined by the mass curve analysis for rainfall and regression analysis for runoff involving runoff data at neighbouring site. Tests on time homogeneity, showed that the annual rainfall records at Port Harcourt, Enugu and Lokoja were stationary and random, the annual runoff records of River Niger at Onitsha, Lokoja and Baro were non-stationary, showing a decreasing trend of mean annual runoff. Various models were tested for suitability in predictions of annual rainfall at Port Harcourt, Enugu and Lokoja, also for annual runoff of River Niger at Onitsha, Lokoja and Baro. The mean annual rainfall was found to diminish from the coast to inland with values' of 2, 400, 1, 700, and 1,200mm for Port Harcourt, Enugu and Lokoja respectively. The mean annual runoff for River Niger at Onitsha, Lokoja and Baro were 117, 000, 169, 300, and 60, 525 Mm^3 respectively. The application of the models showed that the lognormal distribution should be adopted for predictions of annual rainfall at Port Harcourt and Lokoja and annual runoff of River Niger at Onitsha and Lokoja, The normal distribution should be adopted for predictions of annual rainfall at Enugu and annual runoff of River Niger at Baro. However, for a return period of 5 years, the annual rainfall appear to be best described by the Pearson type III and log Pearson type III distributions.

INTRODUCTION
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.

In most of the developing countries like Nigeria, the long-term data required for the planning and design of water resources projects are not available. The only recourse before the hydrologist is to extend the short-term data or else generate the data with properties of historically observed data. However, the first and foremost requisite for the planning of water resources development is the determination of the risks associated with proposed designs or anticipated operating schemes. Hydrologic phenomena are mostly random in nature, the predictions cannot be done in absolute terms and since there is no universally accepted method for determining the likelihood of a certain magnitude of rainfall or runoff, statistical and probabilistic analysis is made to predict the frequency of desired events or occurrences.

Frequency studies have been carried out by several researchers (Chow, 1951; Haan, 1977; Lettenmaier and Burges, 1982; Oyebande and Longe, 1990). The work are mainly on the application of some distributions and determination of some of the distribution parameters. For instance, Oyebande and Longe (1990) obtained an empirical formula for determination of rainfall intensity by using Gumbel Extreme Value Distribution.

A summary of the common distributions is given in Table 1. While they have been used by several researchers to predict the frequency of hydrologic events, little or no work has been done in the area of comparing the applicability of these distributions to Nigerian hydrologic events. The process of doing this is often hampered by lack of complete runoff and rainfall data. The study is therefore aimed at:

(i) Prediction of rainfall and runoff magnitude for various return periods using common probabilistic models like the Normal, Lognormal, Pearson type III, Log Pearson type III and Gumbel distributions.

(ii) Test for homogeneity of annual rainfall records' at Port Harcourt, Enugu and Lokoja and annual runoff record of River Niger at Onitsha, Lokoja and Baro.

(iii) Determination of the partial variation of mean annual rainfall at Port Harcourt, Enugu and Lokoja; and mean annual runoff of River Niger at Onitsha, Lokoja and Baro.

(iv) Determination of the model with the best fit to annual rainfall and runoff records at the various locations.

MATERIAL AND MATHODS

Data:

Daily rainfall in millimeters for Enugu, Port Harcourt and Lokoja for forty years (1953 - 1992) were obtained from the Meteorological Services Department of the Federal Ministry of Aviation at Oshodi, Lagos State. Monthly runoff in million cubic meters (M.m^3) for River Niger at Onitsha, Lokoja, and Baro for thirty years (1960 - 1989) were obtained from the Niger River Basin Development Authority through the Anambra / Imo River Basin Development Authority Owerri, Imo State.

Determination of missing rainfall records using mass curve analysis.

The accumulated depth of rainfall for any year starting from the first year of record was plotted as ordinate against time as abscissa. The plot was extrapolated to periods of no record and accumulated depth at the extrapolated time read off from the graph. The depth of rainfall for year $t_2$was obtained by subtracting the depth at time $t_2$from that at time t_2.

Determination of missing runoff records using regression analysis

A microcomputer Spreadsheet (Lotus 1, 2, 3) was used for the regression analysis. The missing annual runoff records were obtained by taking X_i as the annual runoff of River Niger at Lokoja since Lokoja has complete records and Y_i as the annual runoff of River Niger at Onitsha Regression analysis wasused to determine annual runoff at Onitshafor known annual runoff at Lokoja at any time. Similarly, the missing runoff at Baro was obtained from that of River Niger at Lokoja.]

Table 1: summary of common distributions

Distribution	Probability density function	Range	Mean	Variance
Rectangular	$p(x)=\frac{1}{b-a}$	$a \le x \le b$	$(b+a)/2$	$(b-a)^2/12$
Binomial	$p(x)=C_X^N p^X q^{N-x}$	$0 \le x \le N$	PN	pqN
Poisson	$p(x)=\frac{m^x e^{-m}}{x!}$	$0 \le x \le ...$	m	m
Normal	$p(x)=\frac{1}{\sigma\sqrt{2\Pi}}e^{-(X-\mu)^2/2\sigma^2}$	$-\infty \le x \le \infty$	μ	σ^2
Lognormal (y = Inx)	$p(y)=\frac{1}{\sigma y e^y\sqrt{2\Pi}}e^{-(y-\sigma y)^2/2\sigma_y^2}$	$-\infty \le x \le \infty$	μy	σ^2
Pearson type III	$p(x)=Po\left(1+\frac{x}{a}\right)^c e^{\frac{-cx}{a}}$	$0 \le x \le \infty$	mode $-\mu 3/2\mu_2$	μ_2
Logpearson type III (y = Inx)	$p(y)=Po\left(1+\frac{y}{a}\right)^c e^{\frac{cy}{a}}$	$0 \le x \le \infty$ mode	$-\mu 3/2\mu_2$	μ_2
Gumbel (Extreme value type I)	$p(x)=\frac{1}{c}e^{-(a+x)/c-e^{-(a+x)/c}}$	$-\infty \le x \le$	$yc-a$	$\frac{\Pi c}{\sqrt{6}}$

Theoretical probabilistic models with frequency factors

A computer programme was written to vary the size of the data of annual rainfall into subsets of ten, twenty & forty while that of annual runoff was in subsets of ten, fifteen and thirty. Five common probabilistic models namely normal, lognormal, pearson type III, log pearson type III and Gumbel's Extreme value type I distributions were applied using frequency factors. For every set of data of annual rainfall or annual runoff, the mean $\bar{X}$ standard deviations, coefficient of skewness Cs_I and adjusted coefficient of skewness Cs_2 were computed. The logarithm of annual rainfall or annual runoff to base ten was computed. The mean $\overline{X}_1^1$, standard deviation S^1 coefficient of Cs_1^1skewness CS1 and adjusted coefficient of skewness Cs_2^1 of the logarithmic values were also computed. For a given return period T, the cumulative probability function CDF was computed as 1 – l /T. Let K_1, K_2, K_3, K_4, and K_5, represent the frequency factors for normal, lognormal, pearson, logpearson and Gumbel distributions. From the table of frequency factors for normal probability distribution, K_1 and K_2 were read off as functions of return period or CDF only (Bedient and Hurber, 1992). K_3 and K_4 were read off from Pearson's- type III distribution table as functions of adjusted skewness Cs_2 or Cs_2^1 and return period T (Haan, 1977). K_5 was read off from Gumbel's distribution table as function of return period and number of years of record (WMO, 1983).

Chow's general equation (Chow, 1951) for frequency analysis was applied to each distribution. Let XPAR represent the predicted annual rainfall or runoff for a particular distribution, the following relationships were used for the predictions

$$Normal\ XPAR = \bar{X} + K_1 S \ldots 1$$

$$\text{lognorrmal: XPAR} = 10(\bar{X}^1 + K_2 S^1) \quad \ldots 2$$

$$\text{pearson typeIII: XPAR} = \overline{X} + K_3 S \ldots 3$$

$$\text{Logpearson type III: XPAR} = 10^{(X^1 + K_4 S^1)} \quad (4)$$

$$Gumbel's\ type\ I: XP\ AR = \overline{X} + K_3 S \ldots 5$$

Empirical normal probalistic model using Weibull's plotting position formula

For each set of annual rainfall or annual runoff record, the data was rearranged in order of decreasing magnitude with rank number m assigned to each value. m= 1 for the largest value of the set of data. The return period was computed as (N+1)/m where N is the number of years of record. The CDF was computed as (l-l/T). The magnitude of annual rainfall or runoff was plotted as ordinate and the CDF as the abscissa on a normal probability plotting paper. A line of best fit' was drawn on the plot and the annual rainfall and runoffs corresponding to various return periods were read off.

Test for time homogeneity

The subset mean of annual rainfall and runoff were compared to the long-term mean by calculating the deviation of the subset mean from the long-term mean and expressed in percentage. The fallowing relation was used.

Deviation from mean (%) = (subset mean- long-term mean)/ long - term mean ... (6).

Test for goodness of fit

The goodness of fit of each of the models at each return period for all the data was tested by checking the model which has the least absolute value of deviation from the mean. The mean at a return period was taken as the average of the predicted annual rainfall or runoff of all the models at that return period. The deviation from the mean for any model was computed as:

Deviation from mean (%) =

$$\left(\frac{predicted\ rainfall\ (or\ runoff) - mean}{mean}\right) \times 100 \qquad (7)$$

RESULTS AND ANALYSIS

Spartial Variation of Mean Annual Rainfall

The mean annual rainfall decreases from the coast inland with values of about 2,400, 1,700 and 1,200 for Port Harcourt, Enugu and Lokoja. Enugu falls between the isohyetal line of 1,500mm and 2,00Omm while Lokoja is slightly below the isohyetal line of 1250mm mean annual rainfall.

Test for homogeneity of mean annual rainfall

Table 2 shows the long-term mean and subset means of annual rainfall at Port Harcourt, Enugu and Lokoja. The deviation mean expressed in percentages are in bracket. The subsets of 20 years show that the rainfall at these locations are time homogenous and time homogenous series are purely random and stationary. The subsets of 10 years are equally consistent with a maximum deviation of 7% from the long-term mean.

Table 2: Comparison of subset means with long term mean of annual rainfall

Term	Mean annual rainfall (mm)		
	Port Harcourt	**Enugu**	**Lokoja**
Long term	2383	1689	1192
1st 20years	2494(4.6%)	1688(-0.06%)	1226(2.9%)
2nd 20 years	2272(-4.6%)	1689(0%)	1157(-2.9%)
1st10 years	2492(4.6%)	1674(-0.9%)	1191(0.05%)
2nd10 years	2493(4.6%)	1701(0.7%)	1262(5.9%)
3rd 10 yeas	2315(-2.9%)	1741(3.0%)	1108(-7.0%)
4th 10 years	2230(-6.4%)	1638(-3.0%)	1206(1.2%)

Spartial Variation of Mean Runoff of River Niger

The mean annual runoff of River Niger increases downstream with values of 60, 525; 169,279; 176, 875 for Baro, Lokoja and Onitsha. This may be due to contributing flows from other rivers (such as River Benue at Lokoja), streams, lakes etc. as we move down the latitude.

Test for homogeneity of mean annual runoff of river Niger

Table 3 shows the subset means of annual runoff of River Niger in million cubic meters at Onitsha, Lokoja and Baro. The subset means of annual rainfall at Port Harcourt, Enugu and Lokoja. The deviation of the subset means from the long-term mean expressed in percentages are given in bracket. The subsets of 20 years show that the rainfalls at these locations are time homogeneous and time homogeneous series are purely random and stationary. The subsets of 10 years are equally consistent with a maximum deviation of 7% from the long-term mean deviation of the subset means from the long- term mean expressed in percentage are given in bracket. The subsets of 15 years show the record as being consistent or stationary. However, the subset means of 1 0 years show a trend decreasing down the subsequent sets. This shows that the annual runoff of River Niger at these locations is not stationary. This non-stationary may not be unconnected with man's activities in the river basin or nature's large accidental or slow modifications of the rainfall and runoff conditions.

Table 3: Comparison of subset means with long-term mean of annual runoff of River Niger.

Term	Mean annual runoff of River Niger		
	Onitsha	**Lokoja**	**Baro**
Long term	176, 875	169, 297	60,525
1st 15 years	195,875 (10.6%)	188, 447 (11.3%)	70,175 (15.9%)
2nd 15 years	158, 163 (-10.6%)	150,147 (-11.3%)	50,880(-15.9%)
1st 10 years	212,050 (19.9%)	204,214 (20.6%)	76632 (26.6%)
2nd 10 years	171, 591 (-3.0%)	165, 768 (-2.1%)	570997 (-5.7%)
3rd 10 years	146,984 (-16.9%)	137,909 (-18.5%)	47,847 (-20.9%)

Test of Best Fit To Annual Rainfall

Table 4 shows the predicted annual rainfall at Port Harcourt using the different probabilistic models at various return periods. The mean predicted annual rainfall of all the models for each return period is the average predicted annual rainfall with the six models. In brackets are the deviations from the mean expressed in percentage. The lognormal distribution has the least deviation from the mean for an return periods except for T = 5 with least mean deviation given by logPearson distribution. The lognormal probabilistic model should be adopted for prediction of annual rainfall in Port Harcourt.

Table 4: Determination of the best fit of the models to annual rainfall at port-Harcourt(1953-1992)

T	Normal	Lognormal	Pearson	Logpearson	Gumbel	Graphical	Mean
100	3197.11	3342.82	3197.11	3197.02	3627.02	3650	3368.5
(-5.1%)	(0.8%)	(-5.1%)	(-5.1%)	(7.7%)	(8.3%)		
50	3101.9	3209.04	3101.9	3104.8	3412.9	3440	3228.4
	(-3.9%)	(-0.6%)	(-3.9%)	(-3.8%)	(5.7%)	(6.6%)	
25	2995.9	3066.3	2995.9	3000.3	3197.2	3240	3082.6
	(-2.8%)	(-0.5%)	(-2.8%)	(-2.7%)	(3.7%)	(5.1%)	
10	2831.7	2857.8	2831.7	2836	2906.4	2950	2868.9
	(-1.3%)	(-0.4%)	(-1.3%)	(-1.1%)	(1.3%)	(2.8%)	
5	2677.7	2675.1	2677.7	2680.3	2676.3	2710	3082.6
	(-0.2%)	(-0.3%)	(-0.2%)	(-0.1%)	(0.2%)	(1.0%)	
2	2383.0	2357.4	2383.0	2380.9	2323.7	2350	3082.6
	(0.8%)	(-0.2%)	(0.8%)	(0.8%)	(-1.7%)	(-0.6%)	

Table 5 show the predicted annual rainfall at Enugu for various return periods using six different probabilistic models. The normal distribution has the least deviation from the mean and should be used in the prediction of annual rainfall in Enugu. However at T=5 the least mean deviation is given by the Pearson distribution

Table 5: Determination of the best of the models to annual rainfall at Enugu (1953-1992)

T	Normal	Lognormal	Pearson	Logpearson	Gumbel	Graphical	Mean
100	2520.34	2520.34	2073.5	1986.4	2632.32	2450	2328.1
	(-0.9%)	(8.3%)	(-10.9%)	(-14.7%)	(13.1%)	(5.2%)	
50	2234.1	2401.1	2054.9	1982.9	2469.9	2320	2243.8
	(-0.4%)	(7.0%)	(-8.4%)	(-11.6%)	(10.1%)	(3.4%)	
25	2153.7	2274.9	2029.2	1975.5	2306.3	2210	2158.3
	(0.2%)	(5.4%)	(6.0%)	(-8.5%)	(6.9%)	(2.4%)	
10	2029.2	2029.5	1977.2	1953.1	2085.8	2040	2019.1
	(0.5%)	(0.5%)	(-2.1%)	(-3.3%)	(3.3%)	(1.0%)	
5	1912.4	1934.7	1912.9	1912.5	1911.3	1910	1915.6
	(0.2%)	(-1.0%)	(-0.1%)	(-0.2%)	(-0.2%)	(-0.3%)	
2	1688.9	1665.2	1740.7	1758.8	1647.7	1700	1700.2
	(-0.7%)	(-2.1%)	(2.4%)	(3.4%)	(-3.1%)	(-0.01%)	

Table 6 shows the corresponding predicted annual rainfall at lokoja. The lognormal distribution has the least deviation from the mean the mean except at T =5, which has the least mean deviation given by the pearson distribution. Hence, the lognormal distribution should be used for predictions of annual rainfall at Lokoja.

Table 6: Determination of the best fit of models to annual rainfall at Lokoja (1953-1992)

T	Normal	Lognormal	Pearson	Logpearson	Gumbel	Graphical	Mean
100	1627.8 (-5.4%)	1714.3 (-0.4%)	1618.8 (-5.9%)	1627.1 (-5.4%)	1858.0 (8.0%)	1875 (9.0%)	1720.2
50	1576.8 (-4.3%)	1640.6 (0.4%)	1570.2 (-4.7%)	1577.6 (-4.2%)	1743.3 (5.8%)	1775 (7.8%)	1647.2
25	1520.0 (-3.1%)	1562.1 (0.4%)	1515.7 (-3.4%)	1522.5 (-3.0%)	1627.8 (3.8%)	16652210 (6.1%)	1568.9
10	1432.1 (-1.4%)	1448.1 (-0.3%)	1430.6 (-1.54%)	1435.0 (-1.2%)	1472.1 (1.3%)	1500 (3.2%)	1453.0
5	1349.6 (-02%)	1348.6 (-0.3%)	1350.2 (-0.2%)	1351.5 (-5.9%)	1348.8 (-0.3%)	1365 (-0.9%)	1352.3
2	1191.8 (1.0%)	1177.0 (-0.2%)	1193.8 (1.2%)	1190.8 (1.0%)	1162.7 (-1.4%)	1160 (-1.6%)	1179.4

Test of Best fit To Annual Runoff of River Niger

Table 7 shows the predicted annual runoff of river at Onitsha with different models at various return periods, the mean and the deviation from the mean expressed in percentage. The lognormal distribution has the least deviation at higher return periods and the lowest return period of 2years. However, at T =5 and T=l0, the normal theoretical distribution and normal probability plotting paper have least deviation. On the whole, the lognormal distribution should be adopted for predictions of annual runoff of the River Niger at Onitsha. Similarly, the lognormal distribution gives the best fit for the runoff data at Lokoja (Table 8).

Table 7: Determination of the best fit of the models to annual Runoff of River Niger at Onitsha

T	Normal	Lognormal	Pearson	Log Pearson	Gumbel	Graphical	Mean
100	26843.1 (-6.3%)	298256.4 (8.3%)	262605.5 (-10.9%)	268492.9 (-14.7%)	320680.5 (13.1%)	300000 (5.2%)	286411.1
50	257724.6 (-4.9%)	279733.9 (3.2%)	253434.1 (-6.5%)	25855.4 (-4.6%)	295972.9 (9.2%)	281.000 (3.7%)	271070.2
25	245797.6 (-3.5%)	260451.6 (2.2%)	2430031 (-4.6%)	247114.7 (-3.0%)	261000 (6.4%)	271084.1 (2.5%)	254742
10	22733 7 (-1.5%)	233193 (1.08%)	226397.3 (-1.9%)	229829 (-0.9%)	237531.8 (3.0%)	231000 (0.13%)	230697.2
5	210017.6 (0.05%)	210219.4 (0.14%)	210332.5 (0.2%)	210964 (0.5%)	210978 (0.5%)	207000 (-1.4%)	209918.6
2	176874.6 (1.5%)	172376.2 (-1.1%)	178173.6 (2.2%)	176446.1 (1.2%)	170868 (-2.5%)	1 71000 (-1.9%)	174289.8

Table 8: Determination of best fit of the models to annual runoff of River Niger at Lokoja.

T	Normal	Lognormal	Pearson	Log Pearson	Gumble	Graphical	Mean
100	25175.5 (-6.3%}	293216.8 (6.0%)	252027 (-8.9%)	245-180.5 (-11.5%)	310467.5 (12.2%)	300000 (8.4%)	276677.9
50	248665.2 (8.8%)	274078.6 (19.9%)	243410 (6.5%)	239230.6 (4.7%)	28621.6 (25.2%)	280,000 (22.5%)	228599.5
25	236957 (-3.7%)	254226.3 (3.3%)	233498.6 (-5.2%)	231636.2 (-5.9%)	261779.9 (6.3%)	259000 (5.2%)	246183
10	218834.4 (-1.8%)	226295.5 (1.5%)	217655.8 (-2.4%)	218081.1 (-2.2%)	22884.4 (2.6%)	228000 (2.3%)	222951.5
5	201832.4 (-0.5%)	202888.2 (0.02%)	202218.8 (-0.3%)	203392.3 (-0.3%)	202775.2 (-0.04%)	204000 (2.3%)	202851.2
2	169296.7 (1.0%)	164631.8 (-1.8%)	170919.8 (2.0%)	171299.8 (+2.2%)	163400.1 (-2.5%)	166000 (-0.9%)	167591.3

In the case of the annual runoff of River Niger at Baro the normal distribution has the least deviation from the mean except at T=5 where the Pearson distribution has the least deviation from the mean. Hence, the normal distribution should be adopted for its prediction.

Table 9: Determination of the model with best fit to annual runoff of River Niger at Baro.

T	Normal	Lognormal	Pearson	Log pearson	Gumble	Graphical	Mean
100	98472.11 (6.9%}	118389.6 (11.9%)	93023.16 (-1.2%)	70510.5 (-14.4%)	120127.6 (13.6%)	114000 (7.8%)	105753.8
50	94034.4 (-5.5%)	108929.6 (9.5%)	89988.72 (-9.5%)	88591.3 (-11.0%)	109887.2 (10.5%)	105.500 (6.0%)	99488.6
25	89091.44 (-4.0%)	99278.66 (7.0%)	86415.91 (-6.9%)	85998.93 (-7.3%)	99571.69 (7.3%)	96500 (4.0%)	92809.4
10	81440.08 (-2.0%)	85998.93 (3.5%)	80493.85 (-3.1%)	80989.91 (-2.5%)	85665.46 (3.1%)	84000 (1.1%)	83098.0
5	74261.83 (-0.4%)	75159.92 (0.8%)	74490.23 (-0.1%)	15205.96 (0.9%)	74659.89 (0.2%)	73500 (-1.4%)	74546.2
2	60525.27 (1.4%)	58079.88 (-2.7%)	61748.83 (3.5%)	61653.09 (3.4%)	58035.72 (-2.7%)	58000 (-2.8%)	59673.71

CONCLUSION

The mean annual rainfall in millimeters for Port Harcourt, Enugu and Lokoja were obtained as approximately 2400, 1700, 1200 diminishing from the coast inland. The test for homogeneity of mean annual rainfall at Port Harcourt, Enugu and Lokoja showed that the rainfall records were homogenous hence random and stationary. For stationary records, the general structure statistical parameters representing the series such as mean do not change from one segment of the series to another.

The mean annual runoff of River Niger in million cubic meters at Onitsha, Lokoja and Baro are approximately 17700,169300 and 60525 respectively. The mean annual runoff of River Niger increases downstream and may be as a result of contributing flows from other rivers, streams, lakes, etc. The test for homogeneity of the runoff records showed that it is non- stationary having a decreasing trend down the subset of 10 years. The application of the six models namely normal, lognormal, Pearson type III, logPearson type III, Gumbel's extreme value type I, and the graphical plot on normal probability plotting paper showed that the lognormal distribution should be used in the prediction of annual rainfall at Port Harcourt and Lokoja annual runoff of River Niger at Onitsha and Lokoja. On the other hand, the normal distribution should be used in the predictions of annual rainfall at Enugu and annual runoff of River Niger at Baro.

This can be justified, since annual rainfall and runoff can be conceptualized as the sum of individual processes (daily rainfall and monthly runoff). From central limit theorem, as the number of variables in the sum becomes large, the distribution of the sum of a large number of random variables will approach the normal distribution regardless of the underlying distribution (Benjamin and Cornell, 1970). Also, for most hydrologic event, the logarithms of the variables obey the central limit theorem and are distributed normally (Bedient and Huber, 1992).

The records of annual of 7 Port Harcourt, Enugu and Lokoja (1953-1992) are stationary whereas the annual runoff of River Niger (1960-1989) at Onitsha, Lokoja and Baro are non-stationary having a decreasing trend.

Recommendation for Future Studies

The effect of the length of record on predicted annual rainfall at Port Harcourt Enugu and Lokoja, and the predicted annual runoff of River Niger at Onitsha, lokoja and Baro should be investigated. Analysis should be carried out to explain why the Pearson distribution is a good estimator at a return period of 5 years. Lastly, the non-stationarity of River Niger showing a decreasing mean annual runoff is a signal to future danger and should be investigated.

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