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Analysis of Annual Maximum Rainfall Series using Method of L-Moments in Some Selected Sites in South-South Geographical Zone, Nigeria

I. R. Ilaboya [a, *], E. A. Otuaro [b]

[a] Department of Civil Engineering, University of Benin, P.M.B. 1154, Benin City, Nigeria
[b] Department of Civil Engineering, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria

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ABSTRACT

Determination of the extent of peak rainfall for different return periods is an essential ingredient for the accurate design of hydraulic structures such as drains, dams and culverts as well as detection of flood risk areas. The focus of this study is to analyze annual maximum daily rainfall series in some selected sites within the coastal region of Nigeria using three parameter probability distribution models, namely, Generalized Logistics (GLO), Generalized Extreme Value (GEV) and Generalized Pareto (GPA) with the view of identifying the best fit probability distribution model per station that can be employed to estimate the rainfall magnitude for selected return periods. Specific time series analysis test, namely, detection of outlier and homogeneity test were performed to certify that the data utilized are adequate and suitable. Descriptive statistics such as sample mean, variance, standard deviation, kurtosis, skewness, and coefficient of variation were computed using basic statistical equations. The probability weighted moment parameters (b_0, b_1, b_2 and b_3), L-moment values (λ_1, λ_2, λ_3 and λ_4) and ratios (τ_2, τ_3 and τ_4) including the distribution parameters, namely, shape (k), scale (α) and location (ξ) parameters were computed based on L-moments procedures. To select the best-fit probability distribution model per station, carefully chosen goodness-of-fit statistics, namely, root mean square error, relative root mean square error, maximum absolute deviation index, maximum absolute error and probability plot correlation coefficient were employed since they can adequately assess the fitted distribution at a site. Results obtained indicate that the GLO is the best fit distribution for analyzing annual maximum daily rainfall series from Warri and Calabar while GPA for Port Harcourt and Uyo.

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1. Introduction

In many countries of the world, flood arising from high precipitations are causing damages to properties and agricultural lands resulting in huge economic losses including loss of lives within the affected areas [1]. Precipitations can be estimated through the use of different techniques depending upon the structure being analyzed or designed, and size of watershed. Methodologies to precipitation hydrology include

* Corresponding author
E-mail address: rudolph.ilaboya@uniben.edu

probabilistic, deterministic, conceptual or parametric analysis [2]. The reasonable valuation of precipitation has remained a main challenging concern where hydrological data and information are inadequate. This is the typical case in many gauging stations in Nigeria where most of the sites are poorly gauged or not gauged at all. Estimation of precipitations must be fairly accurate not only to prevent catastrophes, but also to avoid excessive costs due to overestimation of precipitation magnitude, or excessive damage while underestimating the precipitation potential. Determination and accurate analysis of extreme flood discharge requires the utilization of statistical frequency analysis or fitting of probability distribution to the series of observed annual maximum discharge [3]-[5]. Univariate statistics is one of the mostly used statistical techniques employed for rainfall frequency analysis. Apart from this, univariate statistics has also find used in characterizing rainfall, analysis of peak discharge series including low flow record of observations [6].

Numerous probability distribution models needed for precipitation frequency analysis exist in the literature of hydrology. Examples of such probability distribution models include; Generalized Logistics (GLO), Generalized Pareto (GPA), Generalized Extreme Value (GEV), Normal distribution and Gumbel distribution [7]. To apply any probability distribution model for precipitation frequency analysis, the parameters of such probability distribution model must first be approximated. To predict the parameters of a specific probability distribution model, different methods applied, namely, Least Square Regression (LSR), Method of Moments (MoM), Maximum Likelihood Estimation (MLE) and method of L-moments (LMO). Owing to the limitations of LSR, MLE and MoM, LMO was proposed to precisely estimate the parameters of probability distributions. L-Moment is an enhanced advancement over typical product moment statistics for characterizing the shape of a probability distribution and estimating the distribution parameters, particularly for environmental data where sample sizes are commonly very small [1],[8]-[10].

2. L-Moment Theory and Statistics

The basic steps involved in the analysis of rainfall frequency by method of L-Moment as prescribed by [1], [11] are described in this paper.

2.1. Computation of Probability Weighted Moments

PWM is essential for LMO computations. To compute the PWM, the data employed must be ranked in ascending order of magnitude. The basic equations involved are:

$$b_0 = \frac{1}{N}\sum_{j=1}^{n} X_{(j\ :n)}. \tag{1}$$

$$b_1 = \frac{1}{N}\sum_{j=2}^{n} X_{(j\ :\mathrm{n})}\ [(j-1)\,/(n-1)]. \tag{2}$$

$$b_2 = \frac{1}{N}\sum_{j=3}^{n} X_{(j\ :\mathrm{n})}\ [\text{(j-1)(j-2)}]/[\text{(n-1)(n-2)}]. \tag{3}$$

$$b_3 = \frac{1}{N}\sum_{j=4}^{n} X_{(j\ :\mathrm{n})}\ [\text{(j-1)(j-2)(j-3)}]/[\text{(n-1)(n-2)(n-3)}]. \tag{4}$$

Where; $X_{(j)}$ is the ranked annual maximum series, $X_{(1)}$ is the smallest precipitation or stream flow data and $X_{(n)}$ is the largest.

2.2. Computation of L-Moment Values

LMOs are normally calculated in terms of PWMs. The following equations define the first four L-moment values [1]:

$$\lambda_1 = L_1 = b_0. \tag{5}$$

$$\lambda_2 = L_2 = (2b_1 - b_0). \tag{6}$$

$$\lambda_3 = L_3 = (6b_2 - 6b_1 + b_0). \tag{7}$$

$$\lambda_4 = L_4 = (20b_3 - 30b_2 + 12b_1 - b_0). \tag{8}$$

2.3. Computation of L-Moment Ratio

To compute the LMO ratios, the following equations prescribed by [1] applies:

$$L - CV \text{ (Coefficient of variability) } = (\tau_2) \tag{9}$$

$$L - \text{ Skewness } = (\tau_3) \tag{10}$$

$$L\text{ - Kurtosis } = (\tau_4) \tag{11}$$

L-CV is a measure of variability, which is usually in the range of 0 < | *L-CV* | < 1. According to [12], [13], negative values of *L-CV* are only possible if the at-site mean has a negative value. It is a dimensionless quantity. L-Skewness is a measure of asymmetry, which may take positive or negative values. It is in the range 0 < | L-Skewness | < 1 according to [14].

L-kurtosis is a measure of the "peakedness" of the probability distribution of a real-valued random variable. To compute the parameters (τ_2 τ_3 andτ_4), the equations proposed by [1], [15] apply:

$$\tau_2 = \frac{\lambda_2}{\lambda_1} = \frac{L_2}{L_1}. \quad (12)$$

$$\tau_3 = \frac{\lambda_3}{\lambda_2} = \frac{L_3}{L_2}. \quad (13)$$

$$\tau_4 = \frac{\lambda_4}{\lambda_3} = \frac{L_4}{L_3}. \quad (14)$$

3. Materials and Methods

3.1. Description of Study Area

The six geopolitical zones in Nigeria are major divisions in modern Nigeria, which were not created based on geopolitical location, but rather, they were created on the bases of states with similar cultural characteristics, ethnic diversity and historical background. The south-south geopolitical zone comprises six states, as shown in Fig. 1. The entire south-south geopolitical zone occupies a land mass of approximately 85,303 km^2. The 2006 National Population Census put the population of the region at 21,014,655 according to [16]. With reference to Fig. 1, the region is strategically positioned at the point where the 'Y' tail of the river Niger joins the Atlantic Ocean through the Gulf of Guinea. For this study, four selected states within the south-south region were used and they include Akwa-Ibom, Cross River, Delta and Rivers. The states were selected on the bases of data availability.

3.2. Data Collection/Preliminary Analysis

The data utilized for this study, which include daily precipitation datasets for 40 years spanning between 1974 and 2013 was collected from the Nigerian Meteorological Agency, Oshodi, Nigeria. To analyze the data and obtain the annual maximum daily precipitation records, Microsoft excel program was employed. To ascertain the data quality, selected preliminary analysis were done. Some of the preliminary analysis includes; outlier detection and test of homogeneity. For frequency analysis, it is expected that the data be homogeneous and independent. Homogeneity test, which is based on the cumulative deviation from the mean was carried out to establish that the data used are from the same population distribution. The following equations were employed to define the assumption of homogeneity [17]:

$$S_k = \sum_{i=1}^{k} \left(X_i - \bar{X} \right) \quad k = 1, \ldots, n. \quad (15)$$

Where, X_i represents the record for the series X_1, X_2 …, X_n; $\bar{X}$ is the mean while S_{ks} is the residual mass curve.

For a homogeneous record, one may expect that the S_{ks} fluctuate around zero in the residual mass curve since there is no systematic pattern in the deviation of X_i. To perform the homogeneity test, a software package (Rainbow) for analyzing hydrological data was employed.

3.3. Fitting of Probability Distribution Models

The three probability distribution models employed for this analysis are GEV, GLO and GPA. The fundamental equations of the selected probability distribution model are presented in Table 1.

Table 1 Basic Equations of selected probability distribution models [1]

Distribution	Parameters/Range	Probability density function f(x)	Cumulative distribution function F(x)	Quantile function (x_p)
GEV	Parameters: ξ (location), α (scale), k(shape) Range: α > 0, ξ + α/k ≤ x < ∞ for k < 0, -∞ ≤ x ≤ ξ + α/k for k > 0	$f(x)=\frac{1}{\alpha}\left[1-\frac{k(x-\xi)}{\alpha}\right]^{1/k-1}\exp\left\langle-\left[1-\frac{k(x-\xi)}{\alpha}\right]^{1/k}\right\rangle$	$F(x)=exp\left(-\left[1-\frac{k(x-\xi)}{\alpha}\right]^{1/k}\right)$	$x_p=\xi+\frac{\alpha}{k}(1-[-ln(F)]^k)$
GPA	Parameters: ξ (location), α (scale), k(shape) Range: α > 0, ξ ≤ x < ∞ for k < 0, ξ ≤ x ≤ ξ + α/k for k > 0	$f(x)=\frac{1}{\alpha}\left[1-k\frac{x-\xi}{\alpha}\right]^{1/k-1}$	$F(x)=1-\left[1-k\frac{x-\xi}{\alpha}\right]^{1/k}$	$x_p=\xi+\frac{\alpha}{k}[1-(1-F)^k]$
GLO	Parameters: ξ (location), α (scale), k(shape) Range: α > 0, ξ + α/k ≤ x < ∞ for k < 0, -∞ ≤ x ≤ ξ + α/k for k > 0	$\gamma=\left[1-\frac{k(x-\xi}{\alpha}\right]^{\frac{1}{K}}$ for k ≠ 0 $f_x=(\frac{1}{\alpha})\left[\frac{\gamma^{(1-x)}}{(1+\gamma)}\right]^2$	$F_x(x)=\frac{1}{1+\gamma}$	$x_p=\xi+\frac{\alpha}{k}\left[1-\left(\frac{1-F}{F}\right)^k\right]$

Fig. 1 Map of South-South Geopolitical Zone in Nigeria.

3.4. Selection of Best Fit Probability Distribution Model

The probability distribution model that best fit the annual maximum daily rainfall data was selected based on five Goodness-of-Fit (GoF) statistics presented in Table 2. The GoF was selected based on their potential to summarize the deviation between observed and estimated precipitation. Also, they are able to adequately evaluate the fitted distribution at a station.

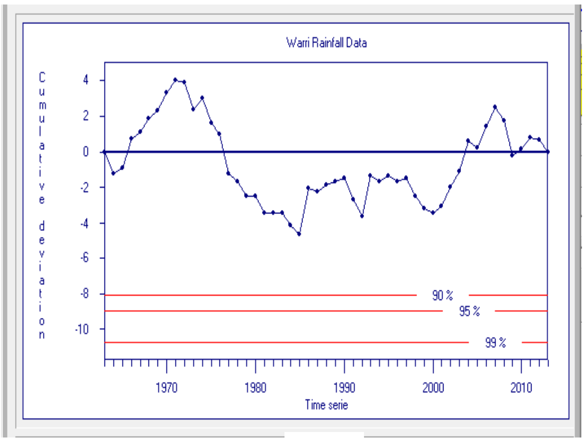
Table 2 Selected goodness of fit statistics [1].

Statistics	Equation
Root Mean Squared Error (RMSE)	$RMSE = \left(\frac{\sum(x_i - y_i)^2}{n-m}\right)^{1/2}$
Relative Root Mean Squared Error (RRMSE)	$RRMSE = \left(\frac{\sum\left(\frac{x_i - y_i}{x_i}\right)^2}{n-m}\right)^{1/2}$
Mean Absolute Deviation Index (MADI)	$MADI = \frac{1}{N}\sum_{i=1}^{N} \lvert \frac{x_i - y_i}{x_i} \rvert$
Maximum Absolute Error (MAE)	MAE = max ($\lvert x_i - y_i \rvert$)
Probability Plot Correlation Coefficient (PPCC)	PPCC = $\frac{\sum[(x_i - \bar{x})(y_i - \bar{y})]}{\left[\sum(x_i - x)^2 \sum(y_i - \bar{y})^2\right]^{1/2}}$

4. Results and Discussion

Results of homogeneity test, which was employed to justify that the data used for this study and the results are presented in Fig. 2. Results of Fig 2, showed that the data used are statistically homogeneous since the data points fluctuate around the center line of the residual mass curve. This result agrees with the findings presented in [6], [8]. The descriptive and LMO statistics, which includes; the PWM statistics (b_0, b_1, b_2 and b_3), computed L-moment values (λ_1, λ_2, λ_3 and λ_4,) and the LMO ratio values for the selected stations are presented in Table 3.

The LMO parameters λ_1 and λ_2 their ratio ($\tau = \lambda_2/\lambda_1$) termed L-CV, and L-moment ratios λ_3 and λ_4 are the most valuable quantities for summarizing probability distribution [18]. The parameters of location (ξ), scale (α) and shape (k) for the selected probability distribution models are given in Table 4.



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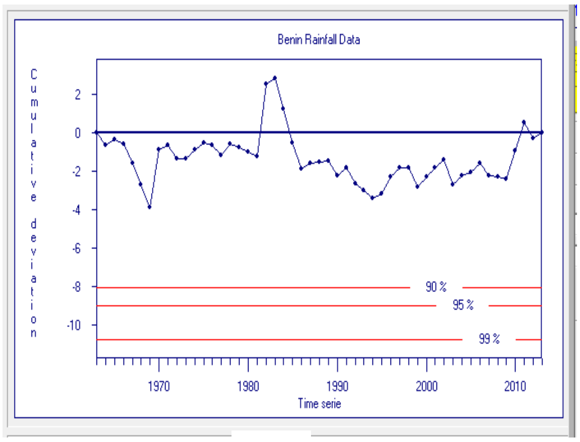

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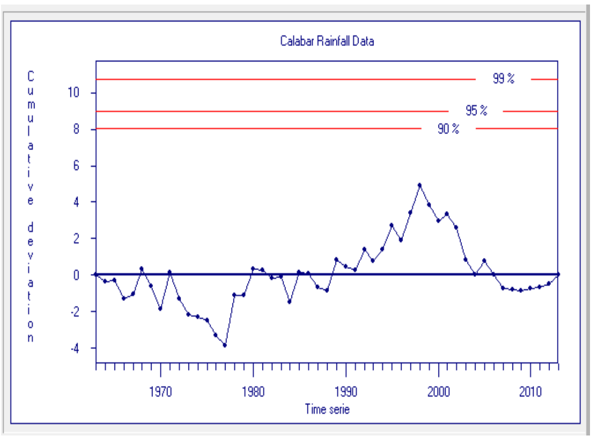

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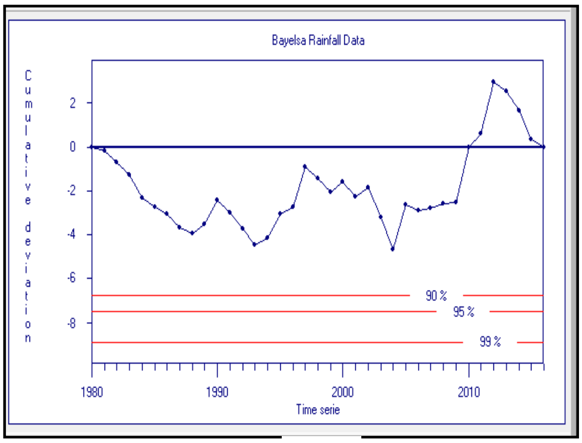

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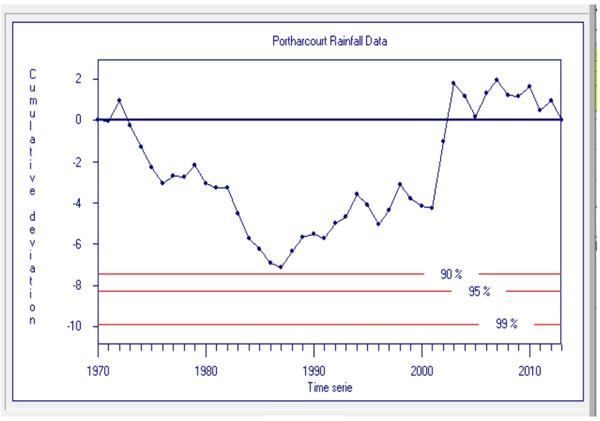

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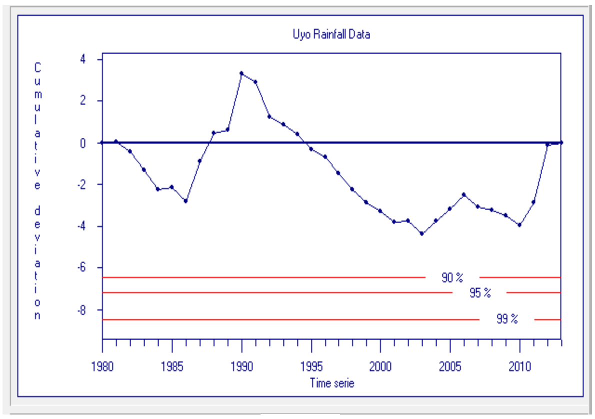

(f)

Fig. 2 Homogeneity test for (a) Warri Data (b) Benin Data (c) Calabar Data (d) Bayelsa data (e) PHC Data (f) Uyo Data.

Table 3 Descriptive and L-moment statistics for study area.

Probability Weighted Moment Values	L-Moment Values	L-Moment Ratios	Basic Statistics
Warri			
b_0 = 115.375	λ_1 = 115.375	L-CV = 0.123	n = 40
b_1 = 64.783	λ_2 = 14.191	L-Skewness = 0.095	Mean = 115.375
b_2 = 45.779	λ_3 = 1.347	L-Kurtosis = 0.195	Variance = 651.332
b_3 = 35.705	λ_4 = 2.763		Standard Dev. = 25.521
			C.V = 0.221
			Skewness = 0.508
			Kurtosis = 0.789
Benin			
b_0 = 88.125	λ_1 = 88.125	L-CV = 0.1139	n = 40
b_1 = 49.0822	λ_2 = 10.0395	L-Skewness = 0.0442	Mean = 88.125
b_2 = 34.4688	λ_3 = 0.4441	L-Kurtosis = 0.26684	Variance = 377.7855
b_3 = 26.7940	λ_4 = 2.6789		Standard Dev. = 19.4367
			C.V = 0.22056
			Skewness = 1.2796
			Kurtosis = 5.1694
Calabar			
b_0 = 126.645	λ_1 = 126.645	L-CV = 0.14058	n = 40
b_1 = 72.2247	λ_2 = 17.8044	L-Skewness = 0.16247	Mean = 126.645
b_2 = 51.5993	λ_3 = 2.8928	L-Kurtosis = 0.14656	Variance = 1024.63
b_3 = 40.5269	λ_4 = 2.6093		Standard Dev. = 32.0099
			C.V = 0.25275
			Skewness = 0.7293
			Kurtosis = 0.3654
Port Harcourt			
b_0 = 99.4925	λ_1 = 99.4925	L-CV = 0.1437	n = 40
b_1 = 56.8934	λ_2 = 14.2943	L-Skewness = 0.2116	Mean = 99.4925
b_2 = 40.8155	λ_3 = 3.0252	L-Kurtosis = 0.1315	Variance = 705.829
b_3 = 32.1558	λ_4 = 1.8796		Standard Dev. = 26.567
			C.V = 0.2670
			Skewness = 1.3296
			Kurtosis = 2.4014
Uyo			
b_0 = 100.225	λ_1 = 100.225	L-CV = 0.1691	n = 40
b_1 = 58.5865	λ_2 = 16.9479	L-Skewness = 0.2796	Mean = 100.225
b_2 = 42.6722	λ_3 = 4.7391	L-Kurtosis = 0.20799	Variance = 1162.915
b_3 = 34.0439	λ_4 = 3.5251		Standard Dev. = 34.1015
			C.V = 0.3402
			Skewness = 2.2727
			Kurtosis = 8.0068
Bayelsa			
b_0 = 87.95	λ_1 = 87.95	L-CV = 0.1987	n = 40
b_1 = 52.7109	λ_2 = 17.4717	L-Skewness = 0.4799	Mean = 87.95
b_2 = 39.4500	λ_3 = 8.3847	L-Kurtosis = 0.3670	Variance = 1686.261
b_3 = 32.2666	λ_4 = 6.4119		Standard Dev. = 41.0641
			C.V = 0.4669
			Skewness = 3.0959
			Kurtosis = 11.1832

Table 4 Estimated distribution parameters using LMO.

Location	Distribution	Shape (k)	Scale (α)	Location (ξ)
Warri	GEV	0.12086	18.8308	136.1651
	GLO	-0.09492	14.0044	113.4053
	GPA	0.65323	62.2493	77.7219
Benin	GEV	0.20673	12.74016	101.6995
	GLO	-0.044234	9.8372	83.5521
	GPA	0.83056	52.0196	59.7076
Calabar	GEV	0.011688	176.335	25.2097
	GLO	-0.16247	127.1326	17.8836
	GPA	0.44094	83.1857	62.6221
PHC	GEV	-0.064196	117.3185	21.3112
	GLO	-0.211634	101.0992	14.6343
	GPA	0.301328	66.5966	42.8083
Uyo	GEV	-0.1645	125.9911	27.3225
	GLO	-0.2796	103.9153	17.9799
	GPA	0.1259	64.1952	40.5663
Bayelsa	GEV	-0.4323	125.056	37.6603
	GLO	-0.4799	97.7998	22.1987
	GPA	0.2971	58.1976	20.9125

The parameters presented in Table 4 were applied to the relevant quantile function given in Table 1 in order to estimate the predicted annual maximum daily rainfall records based on LMO using the three-probability distributions viz., GEV, GLO and GPA. Using the observed and predicted rainfall records, five selected GoF statistics were then applied in order to determine the best fit probability distribution model. The estimated parameters of the selected GoF statistics are presented in Table 5.

Based on the result of Table 5, the distribution with the least RMSE, least RRMSE, lowermost MADI, smallest MAE and highest PPCC was assigned a score of 3, the next was given the score 2, while the worst was given the score 1. The score of each distribution was obtained by summing the individual point scores and the distribution with the highest total point score was selected as the best fit distribution. Result of the scoring and ranking procedure is presented in Table 6.

Table 5 Computed values of GoF statistics.

Location	Distribution	RMSE	RRMSE	MADI	MAE	PPCC
Warri	GEV	31.3074	0.32105	0.27967	47.99265	0.999595
	GLO	3.86371	0.03985	0.00291	14.13908	0.999961
	GPA	6.68388	0.07187	0.00278	17.84667	0.999829
Benin	GEV	21.4954	0.28078	0.23757	31.1775	0.999602
	GLO	8,0531	0.06432	0.04035	41.331	0.999858
	GPA	9.05434	0.07893	0.00584	44.826	0.999729
Calabar	GEV	65.9314	0.5844	0.5366	77.0051	0.999729
	GLO	6.9636	0.06087	0.03959	14.40959	0.999857
	GPA	6.43119	0.06266	0.000106	18.7236	0.999832
PHC	GEV	32.1616	0.3485	0.3258	44.2466	0.999838
	GLO	7.7191	0.0791	0.0621	17.4944	0.999888
	GPA	6.2902	0.0416	0.00296	23.0373	0.999862
Uyo	GEV	47.5855	0.4973	0.4702	71.5865	0.999712
	GLO	13.8794	0.1279	0.1110	28.2935	0.999649
	GPA	11.3530	0.0598	0.00355	63.0729	0.999551
Bayelsa	GEV	88.7732	0.9017	0.8487	195.351	0.9963
	GLO	31.6674	0.3194	0.2807	69.576	0.9978
	GPA	14.9249	0.0756	0.0138	74.132	0.9993

Table 6 Scoring and ranking scheme for selected probability distribution models

Location	Test Criteria	Distribution Scoring		
		GEV	GLO	GPA
Warri	RMSE	1	3	2
	RRMSE	1	3	2
	MADI	1	2	3
	MAE	1	3	2
	PPCC	1	3	2
	Total Score/ Rank	5 (3rd)	14 (1st)	11 (2nd)
Benin	RMSE	1	3	2
	RRMSE	1	3	2
	MADI	1	2	3
	MAE	3	2	1
	PPCC	1	3	2
	Total Score/ Rank	7 (3rd)	13 (1st)	10 (2nd)
Calabar	RMSE	1	2	3
	RRMSE	1	3	2
	MADI	1	2	3
	MAE	1	3	1
	PPCC	1	3	2
	Total Score/ Rank	5 (3rd)	13 (1st)	11 (2nd)
PHC	RMSE	1	2	3
	RRMSE	1	2	3
	MADI	1	2	3
	MAE	1	3	2
	PPCC	1	3	2
	Total Score/ Rank	5 (3rd)	12 (2nd)	13 (1st)
Uyo	RMSE	1	2	3
	RRMSE	1	2	3
	MADI	1	2	3
	MAE	1	3	2
	PPCC	3	2	1
	Total Score/ Rank	7 (3rd)	11 (2nd)	12 (1st)
Bayelsa	RMSE	1	2	3
	RRMSE	1	2	3
	MADI	1	2	3
	MAE	1	3	2
	PPCC	1	2	3
	Total Score/ Rank	5 (3rd)	11 (2nd)	14 (1st)

Based on the result of Table 6, the following inferences and decisions were made:

(a) GLO with the highest total score of 14 was selected as the best probability distribution model for analyzing annual maximum daily rainfall series in Warri;

(b) GLO with the highest total score of 13 was selected as the best probability distribution model for analyzing annual maximum daily rainfall series in Calabar;

(c) GPA with the highest total score of 13 was selected as the best probability distribution model for analyzing annual maximum daily rainfall series in Port Harcourt; and

(d) Generalized Pareto probability distribution (GPA) with the highest total score of 12 was selected as the best probability distribution model for analyzing annual maximum daily rainfall series in Uyo.

The quantile estimates (Qt) based on 2, 5, 10, 25, 50, 100, 200 and 500 years return period was obtained based on LMO procedure using the best fit probability distribution model for each location. A graphical plot of the predicted annual maximum daily precipitation for the selected return period using the best fit probability distribution model is presented in Fig. 3. Result of Fig. 3 can be employed to predict the rainfall magnitude for selected return periods which is a key parameter needed for the design of hydraulic structures and other hydrological studies. Using the best-fit model, the following rainfall magnitude presented in Table 7 were estimated.

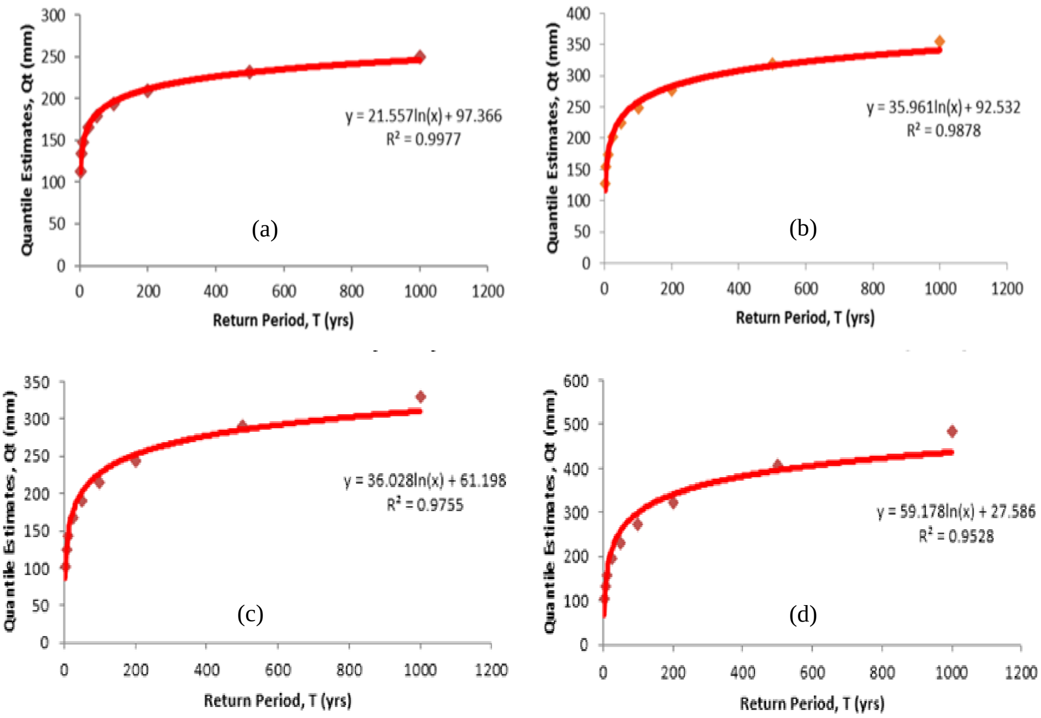

Fig. 3 Predicted precipitation values for selected return periods: (a) GLO for Warri, (b) GLO for Calabar, (c) GPA for Port Harcourt, and (d) GPA for Uyo.

Table 7 Estimated rainfall magnitude (mm) for selected return periods.

Return Period (y)	Warri	Calabar	Port Harcourt	Uyo
2	113.41	127.13	101.10	103.92
5	134.15	154.94	124.68	134.36
10	147.62	174.36	142.04	158.48
25	165.35	201.53	167.43	195.98
50	179.34	224.21	189.53	230.52
100	194.06	249.29	214.82	272.01
200	209.71	277.18	243.93	322.10
500	231.95	319.08	289.46	404.90
1000	250.07	355.14	330.21	483.15
Best-Fit Distribution	GLO	GLO	GPA	GPA

5. Conclusion

The focus of the study was to carry out a comprehensive rainfall frequency analysis for some selected stations within the south-south geopolitical zone of Nigeria. Results of the study have shown that only two of the selected probability distribution models (GLO and GPA) are the best-fit and can be utilized to predict the rainfall return levels at the stations. In addition, the study has also revealed that L – Moments and L – Moment ratios are key indicators for the analysis of hydrological data, which can subsequently be employed for estimating the parameters of any probability distribution model. It is recommended that the study be extended to other stations in order to clearly understand the probability distribution model that best describe the rainfall pattern.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] J. R. M. Hosking, "L-Moments: analysis and estimation of distributions using linear combinations of order statistics," *Journal of the Royal Statistical Society*, Series B, vol. 52, pp. 105-124, 1990.

[2] G. L. S. K. Chaitanya, "Regional flood frequency analysis using parametric estimation method," National Conference on Water, Environment & Society, 30th - 31st July, Hyderabad, India, 2015, pp. 3-7.

[3] J. O. Ehiorobo, and O. C. Izinyon, "Flood frequency analysis of Oshun River in Asejire dam site, Nigeria," *Journal of Earth Science and Engineering*, vol. 3, pp. 292-300, 2013.

[4] N. Vivekanandan, "Flood frequency analysis using method of moments and L-moments of probability distribution," *Cogent Engineering*, vol. 2, no. 1, pp. 1-10, 2015.

[5] M. A. Sharma, and J. B. Singh, "Use of probability distribution in rainfall analysis," *New York Science Journal*, vol. 3, no. 9, pp. 40-49, 2010.

[6] I. R. Ilaboya, and E. A. Otuaro, "Analysis of maximum rainfall series in Benin city using generalized extreme value (gev), generalized logistics (glo) and generalized pareto (gpa) distribution by method of L-moment," *Journal of Civil and Environmental Systems Engineering*, vol. 17, no. 1, pp. 100-112, 2019.

[7] J. R. M. Hosking, and J. R. Wallis, "Regional frequency analysis: an approach based on L-moments," Cambridge: Cambridge University Press, 1997.

[8] O. C. Izinyon, and J. O. Ehiorobo, "L-moments method for flood frequency analysis of River Owan at Owan in Benin Owena river basin in Nigeria," *Current Advances in Civil Engineering*, vol. 3, no. 1, pp. 1-10, 2015.

[9] J. M. Landwehr; N. C. Matalas, and J. R. Wallis, "Probability weighted moments compared with some traditional techniques in estimating Gumbel parameters and quantiles," *Water Resources Research*, vol. 15, no. 5, pp. 1055-1064, 1979.

[10] U. N. Ahmad, A. Shabri, and Z. A. Zakaria, "Flood frequency analysis of annual maximum flows using L-moments and TL-moments approach," *Applied Mathematics Sciences*, vol. 5, no. 5, pp. 243 -253, 2011.

[11] F. E. Eregno, "Regional flood frequency analysis using L-moment in the tributaries of Upper Blue Nile River, South Western Ethiopia," *Merit Journal of Engineering, Pure and Applied Sciences*, vol. 2, no. 2, pp. 12-21, 2014.

[12] G. Sanjib, K. R. Manindra, and C. B, "Soma determination of the best fit probability distribution for monthly rainfall data in Bangladesh," *American Journal of Mathematics and Statistics*, vol. 6, no. 4, pp. 170-174, 2016.

[13] H. Herlina, "Modeling extreme rainfall with gamma-pareto distribution," *Applied Mathematical Sciences*, vol. 9, no 121, pp. 6029-6039, 2015.

[14] Center for Ecology and Hydrology (CEH), FLOODS version 1.1, Regional flood frequency analysis software manual, Water Resources section, CEH Wallingford, U.K., 2001.

[15] T. S. Gubareva, and B. I. Gartsman, "Estimating distribution parameters of extreme hydrometeorological characteristics by L-moment method," *Water Resources*, vol. 37, no. 4, pp. 437-445, 2010.

[16] J. U. Emeh, A. J. Isangedighi, P. Asuquo, I. Kalu, and A. M. Ogaboh, "Curriculum review: reactions from education stakeholders in south-south states of Nigeria," *Global Journal of Human Social Science*, vol. 11, no. 2, pp. 33-42, 2011.

[17] D. Raes, P. Willens, and F. Gbaguidi, "Rainbow - a software package for hydrometeorological frequency analysis and testing the homogeneity of historical data sets," Proceedings of the 4th Int. Workshop on Sustainable Management of Marginal Drylands, 27 – 30 January, Islamabad, Pakistan, 2006, pp. 41-55.

[18] H. Maleki-Nezhad, "Regional flood frequency analysis using L-moments approach," 7th Int. Congress on Civil Engineering, Tehran Iran, May 8-10, 2006, pp. 1-7.