Estimation of precipitation intensity-duration frequency model relationship designed for some regions in southern Nigeria

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Abstract: Precipitation intensity-duration-frequency (IDF) Model was developed for designated regions in Southern Nigeria. Thirty-two years (1983-2014) daily rainfall data were collected for Lagos, Ibadan, Benin, Calabar, Port Harcourt and Warri from Nigeria Meteorological Agency (NIMET) Oshodi, Lagos State for the study. The procedure of annual maximum series was used to select data sets for precipitation investigation. The advanced storm, a pattern developed by United State Department of Agriculture (USDA) Soil Conservation service was used to in the development of the models, which was used to break down daily rainfall into shorter durations. Gumbel and Log Pearson Type III distributions were used to compute the observed rainfall intensity values at durations of 10, 15, 20, 30, 60, 120, 180, 240, 300, and 360 minutes for return periods of 2, 5, 10, 25, 50, and 100 years. To obtain parameters for the IDF models for each location, the computed rainfall intensities were subjected to non-linear regression analysis using Microsoft Excel Optimization Technique Solver wizard for the respective durations and return periods. The performance of the models were analyzed by determining the chi-square($\chi 2$), coefficient of determination (R^2), and root mean square error(RMSE) of the fitted distributions. Coefficient of determination values, R^2 obtained from the fitted IDF Models adopting Log Pearson Type 111 and Gumbel distributions gave perfect value of 1 for both regions. Gumbel distribution RMSE values ranged from 0.20 -11.73 for Port Harcourt, 0.50 – 10.94, 0.21 – 9.25 for Calabar and Warri, also Benin, Lagos and Ibadan regions has 1.31 – 9.5, 1.28 – 15.92, 0.49 – 13.08 while, Log Pearson Type 111 RMSE values ranges from 0.23 – 9.68 for Port Harcourt, 0.41 – 11.47, 0.01 – 10.23 for Calabar and Warri while Benin, Lagos and Ibadan regions has 0.29 – 10.0, 0.51 – 15.69, 0.79 – 10.37. However, there was no significant difference amongst the predicted intensities of the various IDF models.

Keywords: IDF curve, Precipitation intensity, Precipitation relationships, Nigeria

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1 Introduction

A life-threatening precipitation happening endangers the quality of water, annihilation of assets, loss of lives due to flooding and pollution (Hoblit et al., 2006). Furthermore, precipitation is an important component in the hydrologic cycle. Hoblit et al. (2006) posited that rainfall frequency analyses are desirable in the development plus designing of different water resources schemes, this includes storm

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sewers, culverts, and other hydraulic structures. Similarly, Elsebaie (2012) noted that rainfall intensity-duration-frequency curves are graphical demonstrations of the quantity of rainwater that falls within a specified period of time in catchment areas.

Prodanovic and Simonovic (2007) suggested, that to design flood protection structures involving hydrologic flows, rainfall events statistics (that is, in relations to intensity, duration, and period of return) are required. Additionally, Elsebaie (2012) noted that, graphically the measure of precipitation that falls within a catchment range in a specified period of time are denoted by Rainfall – Intensity - Duration-Frequency (IDF) curves. He added that, IDF curves are an important tool for the engineers when designing urban drainage works. Additionally, the IDF curves are utilized to aid the engineers while designing urban drainage works.

According to Koutsoyiannis (2003), and Koutsoyiannis et al. (1998) the IDF relationship is a mathematical connection between the precipitation intensity *I*, the duration *d*, and the return period *T* or it's equally, the annual frequency of exceedence *f* normally known as frequency. In addition, Al-Dokhayel (1986) accomplished a research on the estimation of rainfall depth duration frequency (DDF) relationships intended for Qasim region in Kingdom of Saudi Arabia (KSA) on different return periods, by the use of two continuous probability distributions, namely, Gumel (type I distribution) extreme value and Log Pearson type III (LPT III) distributions. He found that, between the two distributions under study, the LPT III distribution technique provided greater precipitation estimations with lesser standard errors. Similarly, David et al. (2019) noted that the institution of IDF relationships commenced in the nineteen thirties, subsequently many sets of connections have been lump together globally. Similarly, Awadallah et al. (2011) conducted a study for developing IDF curves in scarce data region using regional analysis and satellite data. According to Akpan and Okoro (2013), Nwaogazie and Duru (2002) and Nwoke and Okoro (2012) developed Rainfall Intensity Frequency Models based on statistical method of least squares. However, in Nigeria, current studies on rainfall IDF development have been done in Southern Nigeria, with little information made available about rainfall intensities in particular for short durations.

The insufficient accessible IDF curves for selected parts of the country are very costly and plotting of the curves was done manually. Hence, this method of developing IDF curves manually is prone to error. The broad objective of this research was to develop Intensity- Duration – Frequency (IDF) curves and empirical formulae to estimate the precipitation intensities for Port-Harcourt, Calabar, Warri, Ibadan, Lagos and Benin, using two statistical methods, that is Gumbel distribution and Log Pearson Type 111 distribution.

2 Materials and methods

2.1 Description of the study area

The research areas lies between Latitudes 4 – 14^{o} North and East 2^{o}2′ and 14^{o} 30′ Longitudes. It has an estimated land mass of 923.769 km^2 and a total land boundary of 4047 km, while, the coastline is 853 km. The research locations are in the Humid Rain Zones of Nigeria, which includes Port Harcourt, Calabar, Warri, Benin, Lagos and Ibadan (NFRA, 2008; Emeka-chris et al., 2022). These zones are shown in Figure 1 and Table 1.

Table 1 Characteristics of the meteorological stations of the study cities

Location State	Coordinate	Data Range
Port-Harcourt Rivers	4.75° N, 07°E	1983- 2014
Calabar Cross River	04° 57'N, 08° 19'E	1983 - 2014
Warri Delta	05° 31'N, 05° 45'E	1983- 2014
Benin Edo	06° 10'N, 05° 37' 20''E	1983 - 2014
Lagos Ikeja	06° 27'N, 03°23'E	1983- 2014
Ibadan Oyo	07° 23'N, 03° 55'E	1983- 2014

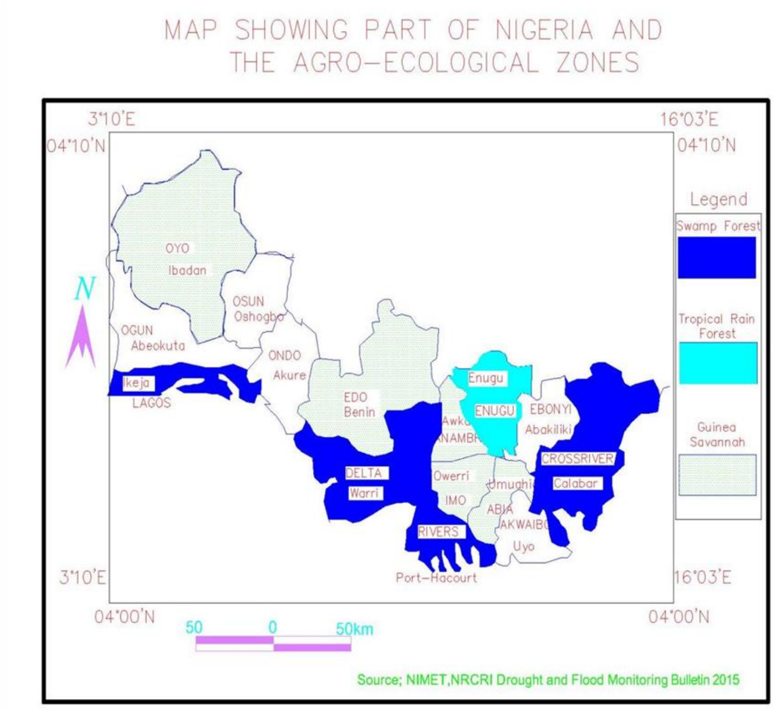

Figure 1 Map showing the ecological zones of selected locations

2.2 Data collection

The required data in this research are the precipitation depths for smaller durations namely, 5, 10, 15, 20, 30, 60, 120, 180, 240, 300 and 360 minutes. Precipitation data were collected from two different climatological stations, namely Nigeria Meteorological Agency Lagos and National Root Crop Research Institute Umudike Abia State, all in southern Nigeria. Thirty two years span of records was used for all the stations between 1983 -2014.

2.3 Gumbel theory of distribution

Gumbel assumption methodology was adopted to perform the flood probability studies. In addition, Elsebaie (2012) noted that this is because the method of the analysis is widely accepted for IDF analysis owing to its appropriateness for modeling maxima. The Gumbel methodology determines the 2, 5, 10, 25, 50 and 100 year return intervals for each duration period and hence requires several calculations. The frequency precipitation for duration with a definite return period is expressed by the following formula

$$P_T = P_{ave} + KS \quad (1)$$

Where, P_T =frequency precipitation (mm) P_{ave} = the average of the maximum precipitation corresponding to a specific duration (mm), S = standard deviation (hr), and K = Gumbel frequency factor given by Equation 2.

$$K = \frac{\sqrt{6}}{\pi}\ [0.5772 + In[In\left[\frac{T}{T-1}(8)\right]] \quad (2)$$

Where, T= return period (hr)

In utilizing Gumbel's distribution, the arithmetic average in Equation 3 was used.

$$P_{ave} = \frac{1}{n}\sum_{i=1}^{n} P_i \quad (3)$$

Where, Pi = the individual extreme value of rainfall and n is the number of events or years of record.

The standard deviation, S of P data was calculated using Equation 4.

$$S = \left[\frac{1}{n-1}\sum_{i=1}^{n}(P_i - P_{ave})^{2\frac{1}{2}}\right] \quad (4)$$

The frequency factor (K), which is a function of the return period and sample size, was multiplied by the standard deviation to give the departure of a desired return period rainfall from the average.

Then the rainfall intensities, I (mm h^{-1}) for return period T were obtained from:

$$I_T = \frac{P_T}{T_d} \quad (5)$$

Where, Td = duration (hr), P_T = frequency precipitation values (mm), and I_T = intensities for different durations (mm h^{-1}).

From the raw data, the maximum precipitation (*P*) and the statistical variables (average and standard deviation) for each of the duration (0.25 hr, 0.5 hr, 1 hr, 2 hr, 4 hr, and 6 hr) were computed.

2.4 Log Pearson type III

The Log Pearson Type III probability model was utilized in the calculation of the precipitation intensity at different precipitation durations and return periods to form the historic IDF curves for the designated localities. Logarithmically transformed data was used in determination of the mean and the standard deviation. The simplified expression for this latter distribution is given as:

$$P^* = \log(P_i) \tag{6}$$

$$P^*_T = P^*_{ave} + K_T S \tag{7}$$

$$P^*_{ave} = \frac{1}{n}\sum_{i=1}^{n} P^* \tag{8}$$

$$S^* = \left[\frac{1}{n-1}\sum_{i=1}^{n}(P^* - P^*_{ave})^2\right]^{1/2} \tag{9}$$

Where, P^*_T = frequency precipitation, P^*_{ave} = the average of the maximum precipitation corresponding to a specific duration, Based on the logarithmically transformed P_i values; i.e. P^* of Equation 6.

K_T is the Pearson frequency factor which depends on return period (*T*) and skewness coefficient (*Cs*).

The skewness coefficient (*Cs*) is required to compute the frequency factor for this distribution. The skewness coefficients were computed using Equation 1 as suggested by Chow (1988), and Burke and Burke (2008).

$$Cs = \frac{n\sum_{i}^{ni}(P^*i - P_{ave})^3}{(n-1)(n-2)(S^*)^3} \tag{10}$$

The computed frequency precipitation P^*T values and intensities (I_T) for six different durations and six return periods using LPT III methodology.

2.5 Intensity-Duration –Frequency (IDF) model development

The Intensity-Duration-Frequency (IDF) formulae are the empirical equations demonstrating a correlation between the variables. Several commonly used IDF equations relating the rainfall intensities, the frequencies, and durations are available in literature (Burke and Burke, 2008; Nhat et al., 2006; Mohammad, 2016). The commonly used IDF equations are

Bernard equation

$$i = \frac{aT^b}{t^c} \tag{11}$$

Talbot equation

$$i = \frac{aT^b}{t+d} \tag{12}$$

Kimijima equation

$$i = \frac{aT^b}{(t^c + d)} \tag{13}$$

Sherman equation

$$i = \frac{aT^b}{(t+d)^c} \tag{14}$$

Where, *i* = intensity of rainfall in mm hr^{-1}; *t* = duration of rainfall in minutes; *T* = return period of rainfall in years; *a*, *b*, *c*, and *d*, are the regional IDF parameters to be determined. Equation 14 which is the most general form of IDF equation has been used to develop the IDF equations by optimization method.

2.5.1 Application of excel solver optimization technique to estimate IDF Parameters

The excel solver methods are mainly the Generalized Reduced Gradient (GRG Solver) for optimization of nonlinear equations and the linear programming Solver (LP Solver) for linear equations. Due to the fact that IDF equations are nonlinear, the GRG Solver was used in this work to get the optimum of the parameters for the models.

2.5.2 Calibration of the Sherman Model

Sherman (1932) model as given in Equation 14 was calibrated using GRG Solver optimization method to obtain optimum values for the regional parameters namely *a*, *b*, *c*, and *d* for the models.

Thus the objective function becomes:

$$Min\ SSE = \sum_{i=1}^{n}(i_{obs} - i_{est})^2 \tag{15}$$

Where, i_{obs} = observed intensity corresponding to any duration, and i_{est} = estimated intensity corresponding to any duration.

Solving Equation 15 produces the optimum values for the parameters *a*, *b*, *c*, and *d* achieved through an iterative process that produces the least squared error.

2.6 Model performance analysis

The performance of the Intensity Duration Frequency (IDF) models given by Gumbel distribution and Log Pearson Type 111 Distribution (LPT 111) were evaluated by obtaining empirical data from the models and then goodness of fit test, correlation coefficient, and root mean square error (RMSE) analysis were carried out. To determine the best-fit distribution, the observed distributions were fitted to the theoretical distribution by comparing the frequencies observed in the data to the expected frequencies of the theoretical distribution. A Goodness-of-fit test between observed and expected frequencies is based on the chi-square quantity, which is expressed as:

$$\chi^2 = \Sigma^k{}_i = \frac{(Oi-Ei)^2}{Ei} \quad (16)$$

Where, χ^2 = random variable whose sampling distribution is approximated very closely by the chi-square distribution, O_i and E_i = observed and expected frequencies for the ith class interval in the histogram, and k = the number of class intervals.

Mohammad (2016) provided programmable formulae to obtain the coefficient of determination (R^2) and RMSE as follows:

$$R^2 = \frac{\sum_{i=1}^{n}(Iobs-Iavg)^2 - \sum_{i=1}^{n}(Iobs-Ipred)^2}{\sum_{i=1}^{n}(Iobs-Iavg)^2} \quad (17)$$

$$RMSE = \sqrt{\frac{1}{N}}\sum_{i=1}^{N}(Ii - \hat{I}*)^2 \quad (18)$$

The theoretical description of correlation coefficient (CC) is as given in Equation 19.

$$CC = \sum_{i=1}^{N}\left[\frac{(Ii-\hat{I})(I*i-\hat{I}*i)}{\sum_{i=1}^{N}(Ii-\hat{I})^2+\sum_{i=1}^{N}(Ii-\hat{I}*i)^2}\right] \quad (19)$$

Where, Ii = the recorded precipitation intensity of ith event, I_{*i} = estimated precipitation intensity of the ith event, $\hat{I}$=the average recorded precipitation intensity, $\hat{I}_{*i}$ =the average of estimated precipitation intensity.

3 Results and discussion

3.1 Intensity Duration Frequency IDF Curves by Gumbel and Log Pearson Type (LPT) 111 Methods.

The results of the computed precipitation intensities and frequency factors from observed frequency precipitation values for different durations and return periods using Gumbel and Log Pearson Type 111 methods for the study are shown in Tables 2 to 3.

Table 2 Model Performance/Validation for Port Harcourt IDF Model Obtained by Gumbel Distribution Methodology

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
Port-Harcourt	Gumbel	χ2	0.98	2.69	0.96	7.49	4.10	1.05	0.27	0.25	0.01	0.50
		RMSE	4.68	7.59	4.28	11.73	7.82	3.00	1.34	1.20	0.20	1.43
		R	1.00	1.00	1.00	0.99	0.87	0.98	0.99	1.00	1.00	1.00
		R^2	1.00	1.00	1.00	0.98	0.76	0.97	0.99	1.00	1.00	1.00
		P-value	0.96	0.75	0.97	0.19	0.54	0.96	1.00	1.00	1.00	0.99

Table 3 Model Performance/Validation for Port Harcourt IDF Model Obtained by Log Pearson Type 111 Method

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
Port-Harcourt	Log Pearson Type III	χ2	2.60	4.29	2.23	4.17	0.42	0.39	0.03	0.10	0.01	0.10
		RMSE	7.86	9.68	6.70	8.58	2.35	1.86	0.45	0.78	0.23	0.67
		R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R^2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.76	0.51	0.82	0.52	0.99	1.00	1.00	1.00	1.00	1.00

Computed Precipitation Intensities for varying Duration Frequency (IDF) Curves and Return Periods Using Gumbel Distribution and Log Pearson Type 111 (LPT 111) for Port Harcourt Nigeria. Goodness of fit tests was used to choose the best statistical distribution among those techniques. The correlation coefficient (R) and coefficient of determination (R^2) obtained from the fitted IDF Models adopting Gumbel distribution shows high ranged from 0.97 – 1.0 except at 60 minutes duration with R as 0.87 and

R^2 as 0.76. While, the correlation R and R^2 obtained from the fitted IDF Model adopting Log Pearson Type III distribution have perfect value of 1. Consequently, the values of RMSE obtained are lower for durations from 30 – 360 minutes using Log Pearson Type III, except for durations 300 minutes when compared to Gumbel distribution.

Table 4 Model Performance/Validation for Calabar IDF Model Obtained by Gumbel Distribution

Location	**Distribution**		**Duration (min)**									
			10	15	20	30	60	120	180	240	300	360
		χ2	9.61	4.92	1.97	5.62	0.25	0.77	0.93	0.16	0.08	0.80
		RMSE	10.94	9.45	5.34	8.60	1.77	2.23	2.19	0.82	0.50	1.51
Calabar	Gumbel	R	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R^2	0.98	0.98	0.99	0.99	1.00	0.99	0.99	1.00	1.00	1.00
		P-value	0.09	0.43	0.85	0.35	1.00	0.98	0.97	1.00	1.00	0.98

Table 5 Model Performance/Validation for Calabar IDF Model Obtained by Log Pearson Type III Method

Location	Distribution		Duration (min)									
			10	15	20	30	60	120	180	240	300	360
Calabar	Gumbel	χ2	2.93	5.63	1.88	5.57	0.22	0.82	0.32	0.03	0.05	0.63
		RMSE	8.56	11.47	6.40	10.45	1.73	2.86	1.58	0.41	0.55	1.73
		R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.71	0.34	0.87	0.35	1.00	0.98	1.00	1.00	1.00	0.99

Table 6 Model Performance/Validation for Warri IDF Model Obtained by Gumbel Distribution Methodology

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
		χ2	2.12	3.85	1.42	3.55	0.24	0.62	0.12	0.01	0.01	0.37
		RMSE	7.14	9.25	5.42	8.04	1.85	2.40	0.94	0.21	0.23	1.29
Warri	Gumbel	R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R^2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.83	0.57	0.92	0.62	1.00	0.99	1.00	1.00	1.00	1.00

3.2 Results of Intensity Duration Frequency (IDF) Curves by Gumbel and Log Pearson Type (LPT III) Methods for Port Harcourt

The results of the computed precipitation intensities and frequency factors from observed frequency precipitation values for different durations and return periods using Gumbel and Log Pearson Type III (LPT III) methods for the regions under study.

Figures 1 and 2 illustrate outcomes of the Intensity Duration Frequency curves obtained by Gumbel and LPT III methods for the district. Furthermore, the Intensity Duration Frequency curves precipitation estimates are increasing with increase in the return period and the precipitation intensities decrease with precipitation durations in all return periods. The developments of the results from the two procedures indicate good steadiness.

3.3 Outcomes of Intensity Duration Frequency curves by Gumbel and Log Pearson Type (LPT III) methods for Calabar Nigeria

Figures 3 and 4 show results of the IDF curves obtained by Gumbel and LPT 111 methods for Calabar Nigeria. Nevertheless, precipitation intensity values are higher for all the durations and return periods for Log Pearson Type 111 indicates higher responses when compared to Gumbel distribution. The trends of the results from the two approaches show good consistency.

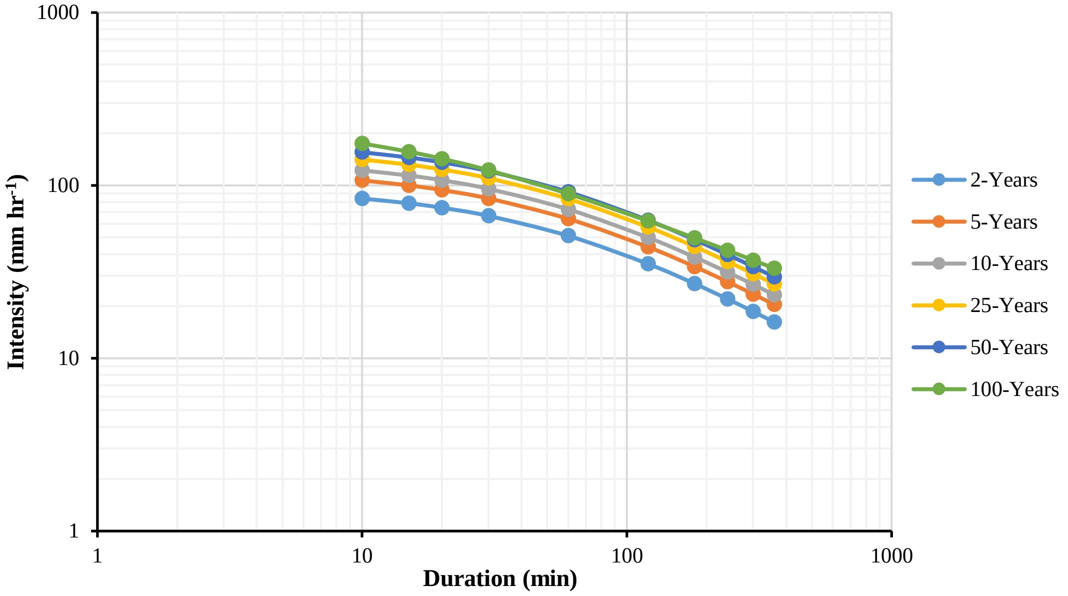

Figure1 Intensity Duration Frequency curves by Gumbel method at Port-Harcourt

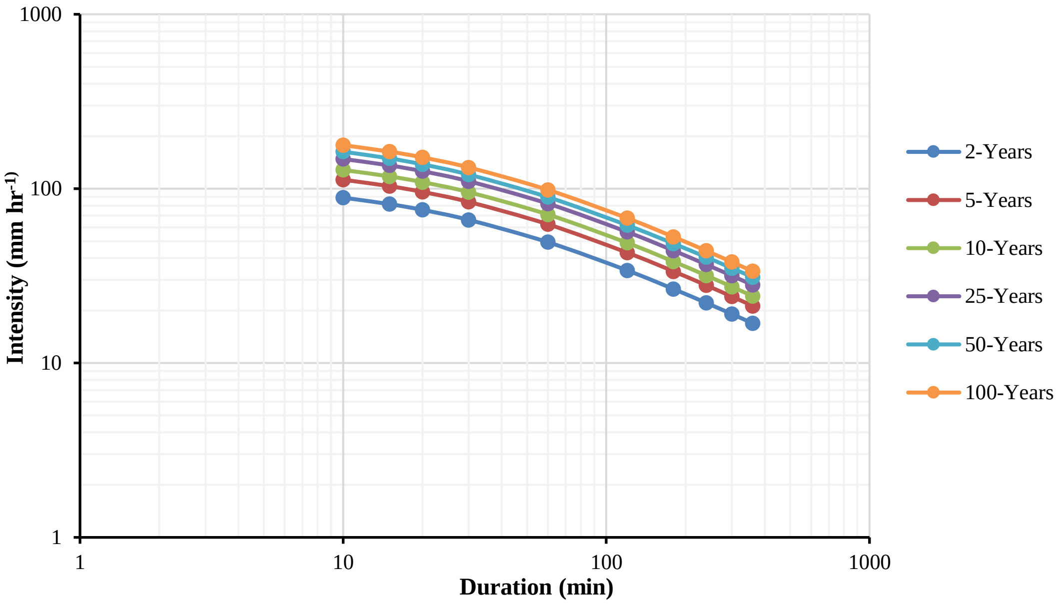

Figure 2 Intensity Duration Frequency curves by LPT III method at Port-Harcourt Nigeria

Table 7 Model Performance/Validation for Warri IDF Model Obtained by Log Pearson Type 111 Method

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
Warri	Log Pearson Type III	$\chi 2$	2.73	4.62	2.64	6.06	0.12	0.67	0.07	0.00	0.00	0.18
		RMSE	7.90	9.89	7.19	10.23	1.24	2.43	0.68	0.01	0.07	0.89
		R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R^2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.74	0.46	0.76	0.30	1.00	0.98	1.00	1.00	1.00	1.00

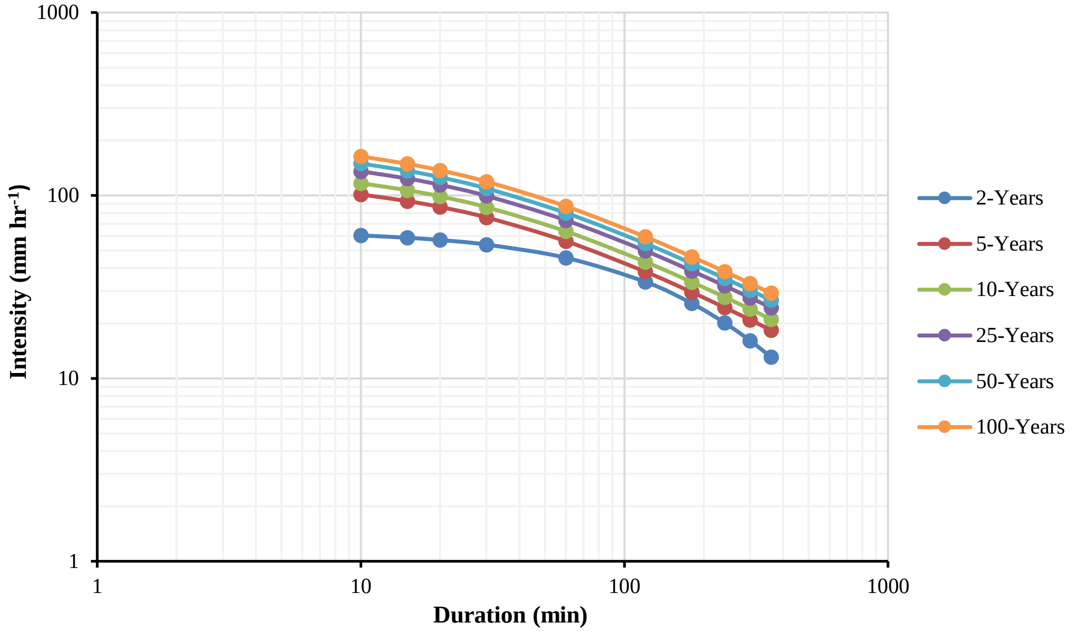

Figure 3 Intensity Duration Frequency curves by Gumbel method at Calabar Nigeria

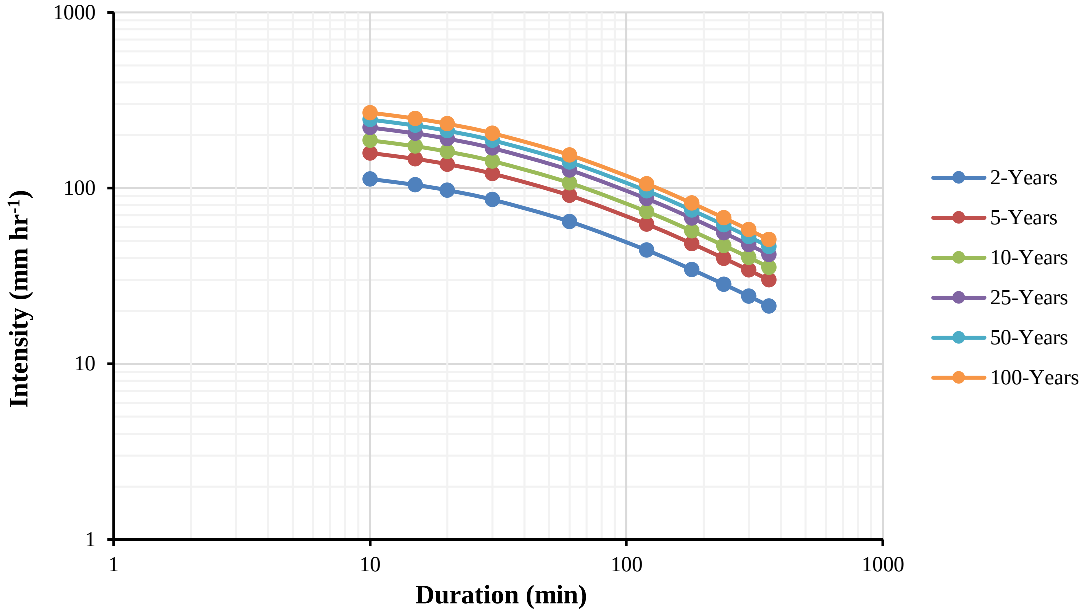

Figure 4 Intensity Duration Frequency curves by LPT III method at Calabar Nigeria

3.4 Results of IDF curves by Gumbel and Log Pearson Type (LPT) 111 methods for Warri region

Figures 5 and 6 show outcomes of the IDF curves obtained by Gumbel and LPT 111 methods for Warri region. The trends of the curves from the two methods show good consistency. However, in the IDF curves obtained using Log Pearson Type 111, rainfall intensity values are higher for all the durations and return periods compared to Gumbel distribution.

Table 8 Model Performance/Validation for Benin IDF Model Obtained by Gumbel Distribution Methodology

Location	Distribution	Model validation	Duration (min) 10	15	20	30	60	120	180	240	300	360
Benin	Gumbel	χ2	2.54	3.49	1.63	4.69	0.56	1.74	0.28	0.29	0.79	2.29
		RMSE	7.46	9.04	5.92	9.5	2.37	3.77	1.31	1.34	1.74	2.51
		R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
		R^2	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	0.99	0.98
		P-value	0.77	0.62	0.9	0.45	0.99	0.88	1.00	1.00	0.98	0.81

Table 9 Model Performance/Validation for Benin IDF Model Obtained by Log Pearson Type 111 Method

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
		χ2	2.41	4.52	1.87	4.83	0.31	1.36	0.19	0.02	0.06	0.50
		RMSE	7.60	10.0	6.46	9.62	2.15	3.87	1.14	0.29	0.60	1.56
Benin	Log Pearson Type III	R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R^2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.79	0.48	0.87	0.44	1.00	0.93	1.00	1.00	1.00	0.99

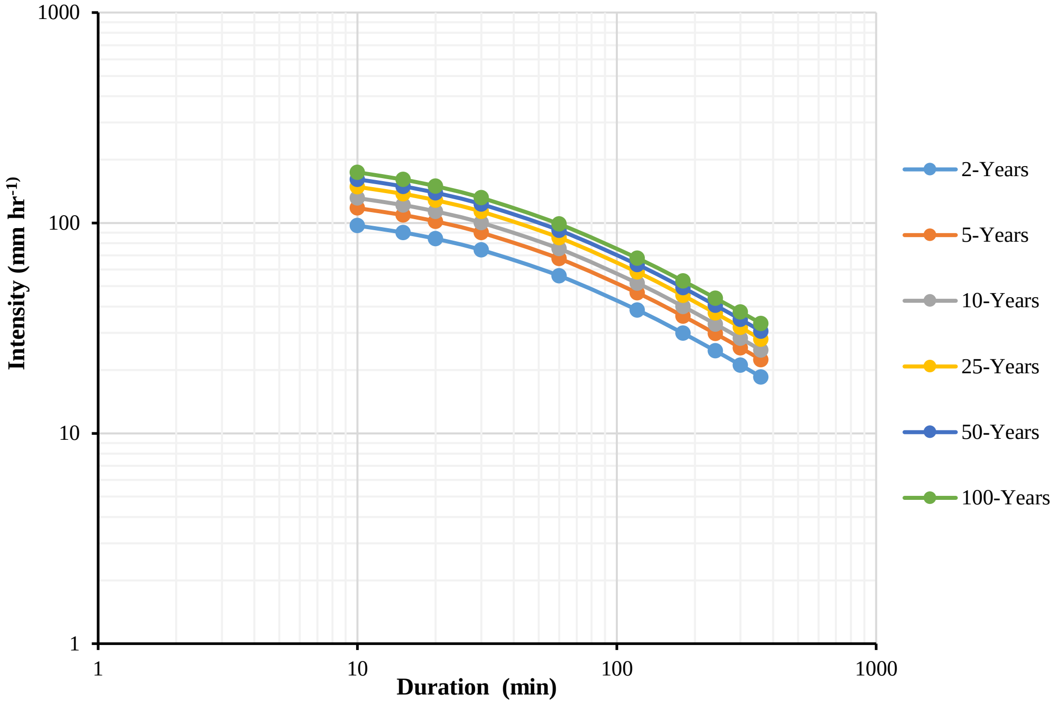

Figure 5 IDF curves by Gumbel method at Warri

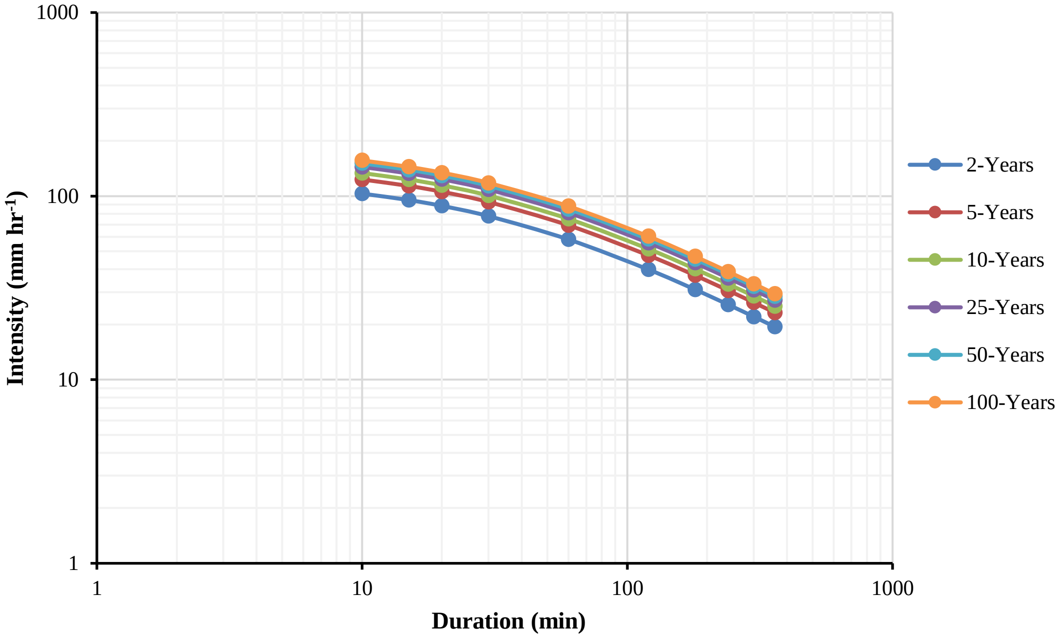

Figure 6 IDF curves by LPT III method at Warri

3.5 Results of IDF curves by Gumbel and Log Pearson Type (LPT) 111 methods for Benin region

Figures 7 and 8 show outcomes of the IDF curves obtained by Gumbel and LPT 111 methods for the region. The trends of the curves from the two methods show good consistency. However, in the IDF curves obtained using Log Pearson Type 111, rainfall intensity values are higher for all the durations and return periods compared to curves obtained using Gumbel distribution.

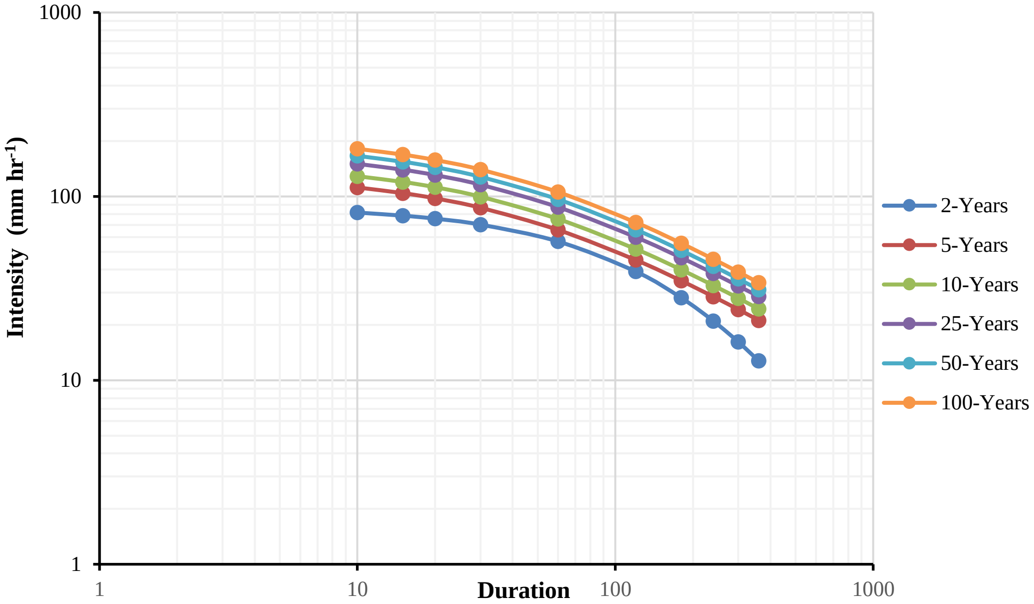

Figure 7 IDF curves by Gumbel method at Benin

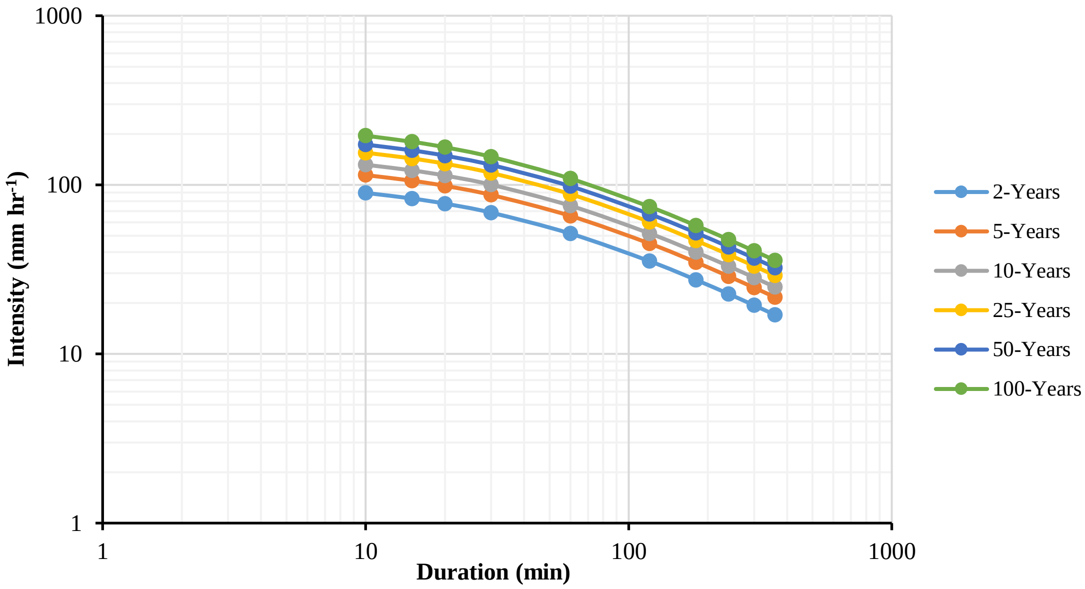

Figure 8 IDF curves by LPT III method at Benin

Table 10 Model Performance/Validation for Lagos IDF Model Obtained by Gumbel Distribution Methodology

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
Lagos	Gumbel	$\chi 2$	3.66	7.48	2.81	8.55	0.49	1.05	1.48	0.29	0.24	5.8
		RMSE	11.67	15.92	9.43	15.3	3.15	3.85	3.86	1.55	1.28	6.08
		R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R^2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.6	0.19	0.73	0.13	0.99	0.96	0.92	1.00	1.00	0.33

Table 11 Model Performance/Validation for Benin IDF Model Obtained by Log Pearson Type 111 Method

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
Lagos	Log Pearson Type III	$\chi 2$	3.96	7.5	2.42	6.75	0.31	0.82	0.37	0.05	0.03	0.61
		RMSE	11.84	15.69	8.6	13.52	2.5	3.39	2.01	0.65	0.51	2.03
		R	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		R^2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		P-value	0.56	0.19	0.79	0.24	1.00	0.98	1.00	1.00	1.00	0.99

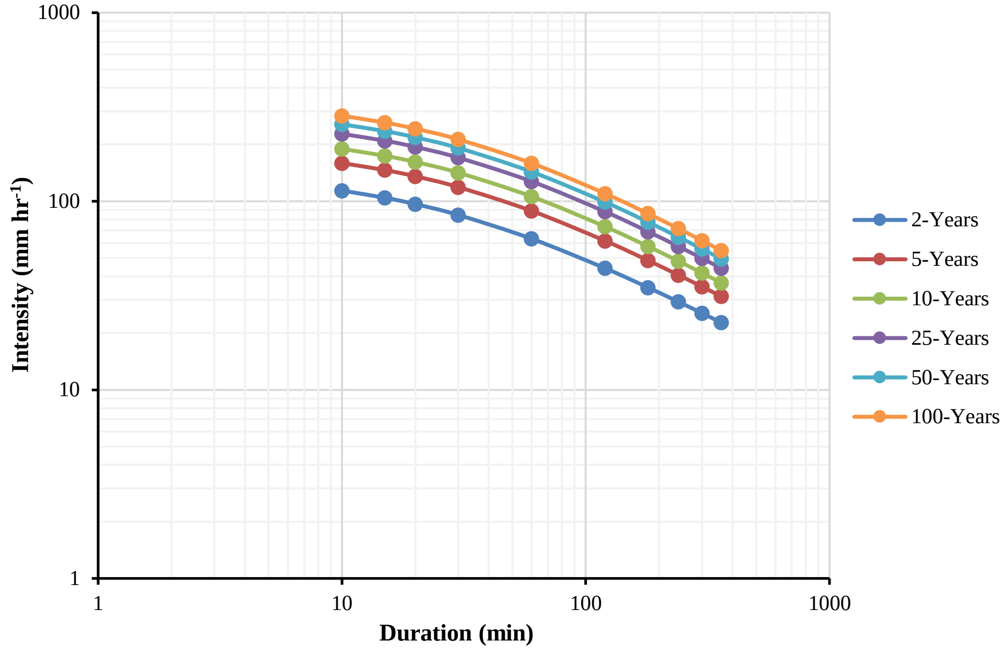

Figure 9 IDF curves by Gumbel method at Lagos

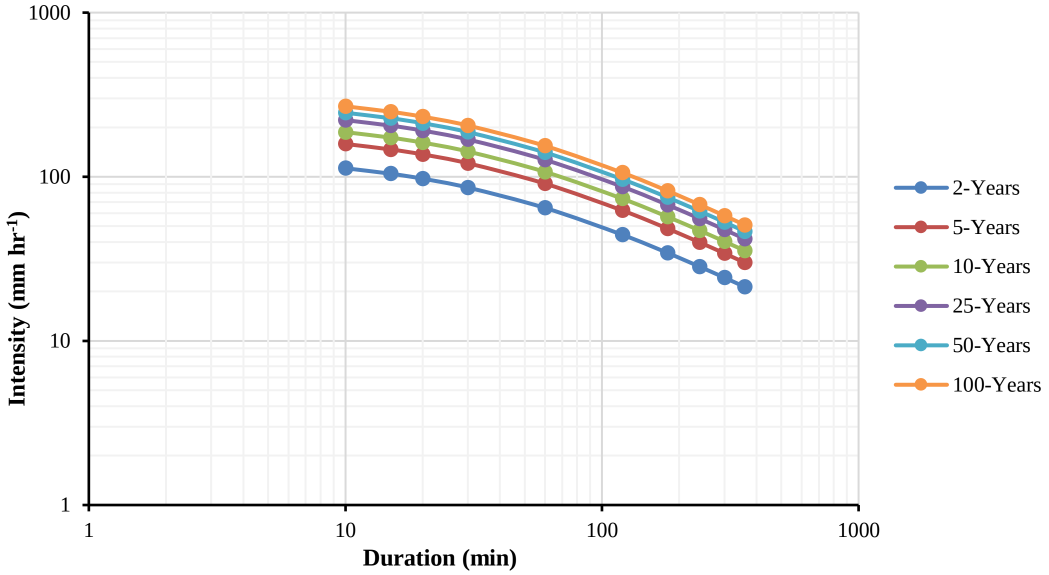

Figure 10 IDF curves by LPT III method at Lagos Nigeria

Table 12 Model Performance/Validation for Ibadan IDF Model Obtained by Gumbel Distribution Methodology

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
		$\chi2$	1.35	7.35	8.63	2.27	0.54	0.98	0.1	0.04	0.26	0.79
		RMSE	4.69	12.04	13.08	5.26	2.63	2.85	0.75	0.49	1.08	1.74
Ibadan	Gumbel	R	1	1	0.98	0.99	0.99	1.00	1.00	1.00	1.00	0.99
		R^2	0.99	0.99	0.96	0.99	0.99	1.00	1.00	1.00	0.99	0.98
		p-value	0.93	0.2	0.12	0.81	0.99	0.96	1.00	1.00	1.00	0.98

Table 13 Model Performance/Validation for Ibadan IDF Model Obtained by Log Pearson Type 111 Method

Location	Distribution	Model validation	Duration (min)									
			10	15	20	30	60	120	180	240	300	360
		$\chi2$	2.36	3.98	1.34	3.24	0.07	1.76	14.61	1.4	1.08	0.71
		RMSE	6.74	8.37	4.71	6.82	0.79	3.96	10.37	2.94	2.42	1.78
Ibadan	Log Pearson Type III	R	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.99
		R^2	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.99	0.99	0.99
		P-value	0.8	0.55	0.93	0.66	1.00	0.88	0.01	0.92	0.96	0.98

3.7 Results of IDF curves by Gumbel and Log Pearson Type (LPT) 111 methods for Ibadan region

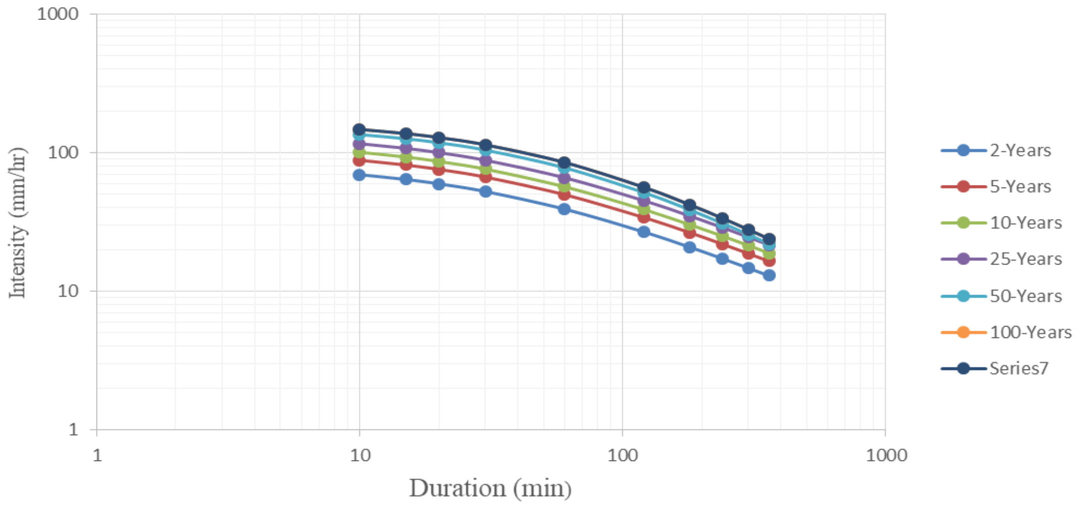

Figure 11 IDF curves by Gumbel method at Ibadan

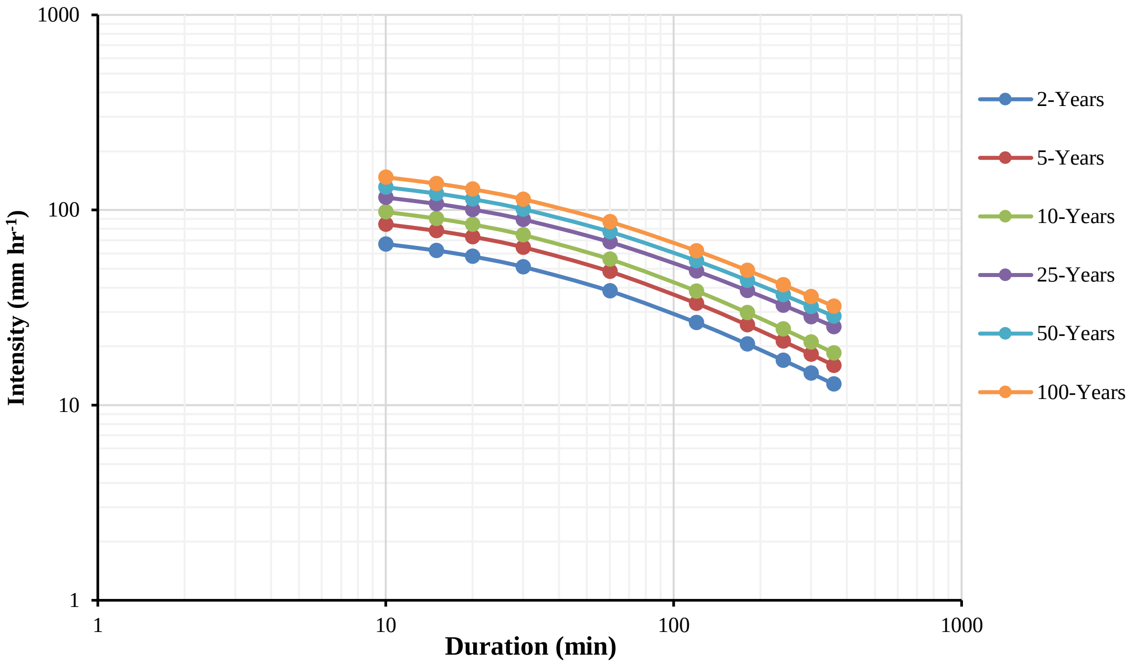

Figure 12 IDF curves by LPT III method at Ibadan

3.6 Results of IDF curves by Gumbel and Log Pearson Type (LPT) 111 methods for Lagos region

Figures 9 and 10 represents the IDF curves obtained by Gumbel and LPT 111 methods for Lagos region. The trends of the curves from the two methods show good consistency. However, the

Figures 11 and 12 represents the IDF curves obtained by Gumbel and LPT 111 methods for Ibadan region. The trends of the curves from the two methods show good consistency. However, the rainfall intensities are increasing more with return periods and durations in the IDF curves obtained using Gumbel distributions than in IDF curves

rainfall intensities are increasing more with return periods and durations in the IDF curves obtained using Gumbel distributions than in IDF curves obtained using Log Pearson Type 111 distributions. This shows that Gumbel method gave higher results in rainfall intensities than LPT 111 method. obtained using Log Pearson Type 111 distributions. This shows that Gumbel method gave higher results in rainfall intensities than LPT 111 method.

Also, the correlation coefficient (R) and coefficient of determination (R^2) obtained from the fitted IDF Models adopting both Gumbel and Log Pearson Type 111 distributions have perfect value of

1. This indicates that Gumbel and Log Pearson Type 111 methods fit the models properly. The outcomes of the RMSE obtained are lower for 20 to 360 minutes durations, with exemption for 10, 15 and 30 minutes durations for both Gumbel and Log Pearson Type 111 distributions. This study was conducted for the formulation and construction of IDF curves using data from recording stations by the use of two distribution methods. In over-all, the results attained using the two methodologies is relatively close at most of the return periods, in addition to same trend; this is in agreement with the obtained results from AlHassoun (2011) and Elsebaie (2012).

4 Conclusion

This study shows the technique for the estimation of precipitation intensity duration frequency models for some regions in tropical forest zones of Nigeria. The studied location includes Port Harcourt, Calabar, Warri, Benin, Lagos, and Ibadan in Nigeria. The study as well examined trends pattern of the studied locations. Similarly, the trend analysis result, it was evident that there is fluctuating rainfall pattern across the observed years. This has made it impossible to forecast the rainfall for a feature season. From the results of data analysis, the following conclusions were drawn from the study:

1) Gumbel and Log Pearson Type 111 IDF models of each examined region were developed by subjecting the observed precipitation intensities to frequency analysis using the Microsoft excel optimization technique solver wizard to generate the regional parameters of each model.

2) The coefficient of determination values R^2, obtained from the fitted IDF Models adopted through Gumbel and Log Pearson Type 111 distributions gave perfect value of 1

3) The results obtained for Gumbel and Log Pearson Type 111 distributions shows that it can be utilized to estimate any frequency precipitation data for southern region of Nigeria.

Finally, to achieve acceptable climate estimating capacity, the study, recommends that qualitative climatic data should be made available and accessible for easy analysis. The IDF Models are recommended for the prediction of precipitation intensities for the studied regions in southern Nigeria, to aid in designing of drainage systems and planning for water resources development, therefore it can be adopted by any nation with such topography. It is difficult to say that one distribution is superior to the other hence; further studies are recommended whenever there will be more data to verify the results obtained or update the IDF curves.

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