RAINFALL INTENSITY-DURATION-FREQUENCY RELATIONSHIP FOR COLOMBO REGION IN SRI LANKA

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ABSTRACT

This paper presents a rainfall intensity-duration-frequency curve for 2, 5, 10, 20, 50, 100 and 200 years return periods for Colombo region. Annual peak rainfall values for different durations such as 1, 2, 4, 6, 12 and 24 hours were extracted for the purpose of this analysis. Then these values were fitted to Log Pearson type III (LP3) and Gumbel Extreme Value (EV1) distribution. Subsequently, the best fitted distribution for a particular duration was selected based on the goodness-of-tests approach. LP3 distribution was found to be the best fitted distribution for 1, 4, 6 and 24 hour's duration of annual peak precipitation while, EV1 was the most appropriate distribution for other durations such as 2 and 12 hour's. Further, the IDF curve was developed for Colombo region and it is recommended for the predication of maximum rainfall intensities.

***Keywords*:** Return Period, Intensity-Duration-Frequency (IDF) curve, Probability Distribution, Goodness-of-Tests

1. INTRODUCTION

A rainfall intensity-duration-frequency (IDF) relationship is the most commonly used method for designing and planning of various water resource projects stated by Chow and Maidment [3]. The IDF is a kind of mathematical relationships between the rainfall intensity, duration and the return period. This relationship can be determined through statistical analysis of rainfall data collected from the corresponding stations.

The major objective of this study is to find the most appropriate probability distribution for annual maximum rainfall at different level of duration. And also, estimate the maximum rainfall intensity for a particular duration and their corresponding return period. In addition to this, develop IDF curve for Colombo region.

F. Y. Logah [4] analyzed the rainfall IDF relationship for Accra in Ghana by assuming that the data followed a Gumbel distribution. Furthermore, Garcia-Bartual and Schneider [5] used several statistical distributions and found the Gumbel distribution fitted to data well.

Moreover, Jebreen M.Al-jebreen (1985) [6] calculated the floods magnitude for different return periods 5,10,25,50 and 100 years, using extreme value Type I distribution and Log-Pearson Type III distribution. Further, they stated extreme value type I distribution is the most suitable distribution for this region.

2. METHODOLOGY

The maximum annual rainfall values for periods of 1, 2, 4, 6, 12 and 24 hour's were extracted from a data set of 11 years of precipitation data at 15 minute intervals which was obtained from the pluviograph charts recorded at the Colombo Meteorological Station by the Department of Meteorology. Then, two popular probability distributions such as EV1 and LP3 were considered in order to find the most appropriate distribution at different duration. Subsequently, the best fitted distribution was chosen based on the goodness-of-fit test. And also, mean ($\bar{X}$) and standard deviation (S) of the peak annual values of all durations were estimated.

2.1 Goodness of Fit Test

2.1.1 Akaike Information Criteria (AIC)

AIC is a method of selecting a best model from a set of models. In general, the preferred model is the one with the minimum AIC value. AIC is defined as,

$$AIC = 2k - 2\ln(L)$$

Where k is the number of parameters in the statistical model and L is the maximized value of the likelihood function for the estimated model.

2.1.2 Bayesian Information Criteria (BIC)

The Bayesian Information Criterion (BIC) is

$$BIC = -2k\ln(L) + k\ln(n)$$

Where k is the number of parameters in the statistical model, L is the maximized value of the likelihood function for the estimated model and n is the sample size. In practical application, after the computation of the BIC, for all of the operating models, one selects the model with the minimum BIC value.

2.1.3 Anderson Darling Test (A-D)

The Anderson-Darling statistics (A^2) is defined as

$$A^2 = \sum_{i=1}^{n} (2\mathrm{i} - 1).\left[\ln \mathrm{F}(\mathrm{X_i}) + \ln\left(1 - \mathrm{F}(\mathrm{X_{n-i+1}})\right)\right]$$

It is a test to compare the fit of an observed cumulative distribution function to an expected cumulative distribution function.

2.3 Frequency Factor Estimation (FFE)

Chow [1] proposed the following equation in order to calculate the frequency factor from the normal distribution. This is similar to standard normal deviate z.

$$K_T = \frac{x_T - \mu}{\sigma}$$

Frequency factor K_T can be calculated using the appropriate distribution in the following way.

2.3.1 Frequency Factor Estimation for EV1

Koutsoyannis et al. [8] stated that the type I distribution of maxima is most appropriate distribution for IDF analysis due to its suitability for modeling maxima. While, Chow [2] also developed a relatively simple approach for determining K_T for the EVI distribution, the frequency factor can be calculated by using the following equations.

$$K_T = \frac{\sqrt{6}}{\pi}\left\{0.5772 + ln\left[ln\left[\frac{T}{T-1}\right]\right]\right\}$$

2.3.2 Frequency Factor Estimation for LP3

According to Koutsoyannis et al. [8] the LP3 distribution has been commonly used distributions for IDF analysis. Here, log-transformed data is used to perform the frequency factor approach in Pearson Type III distribution.

It is obvious, from $eq(1)$ when $C_s = 0$, the frequency factor is equal to the standard normal variable z then it becomes normal distribution. In contrast, $C_s \neq 0$, K_T is approximated by Kaite [7] as given below.

$$K_T = z + (z^2 - 1)k + \frac{1}{3}(z^3 - 6z)k^2 - (z^2 - 1)k^3 + zk^4 + \frac{1}{3}k^5$$

Where, $k = \frac{C_S}{6} - eq(1)$ and C_s is coefficient of skew of the log-transformed data and z is standard normal variable.

2.4 Return Level Estimation

Finally, the rainfall depth X_T, for a given return period (T) was estimated using the following equation.

$$X_T = \bar{X} + K_T S$$

Where, mean $(\bar{X})$ and standard deviation (S) of the maximum rainfall depth of a given period and K_T is the rainfall frequency factor for a given return period.

2.5 Intensity Duration Frequency formula

IDF curve is having a relationship between the rainfall intensity (mm/hr), the duration of the rainfall (hr) and the return period of an event and is defined by the reciprocal of the annual exceedance probability which is expressed as follows.

$$i = f(T, d)$$

Where, i is the rainfall intensity (mm/hr), d is the duration of the rainfall (hr) and T is the return period in years. Then the rainfall intensity can be computed by dividing the designed rainfall depth for a given return period (mm) by the given rainfall duration (hr) as defined in the following equation.

$$i = \frac{X_T}{d} - eq(2)$$

3. RESULTS

The best fitted distribution can be determined using GOF tests. According to the GOF tests, the best fitted distribution for annual maximum rainfall was selected based on the minimum error produced.

Table 1: GOF tests results for annual maximum rainfall in different durations in Colombo

Duration (hr)	EV1			LP3			Selected Distribution
	AIC	BIC	A-D	AIC	BIC	A-D	
1	85.70	86.50	0.622	79.39	80.59	0.377	LP3
2	92.82	93.61	0.118	94.80	96.00	0.197	EV1
4	108.5	109.3	0.798	100.2	101.4	0.044	LP3
6	113.5	114.3	0.239	113.3	114.5	0.198	LP3
12	116.8	117.6	0.101	118.0	119.2	0.088	EV1
24	130.0	130.8	1.010	122.6	123.8	0.122	LP3

The Table 1 shows the results of the GOF tests for annual maximum rainfall in Colombo. It can be clearly seen, both LP3 and

EV1 distribution performed well at different durations of annual maximum precipitation. The following Figure 1 shows the comparable performances of both EV1 and LP3 distribution.

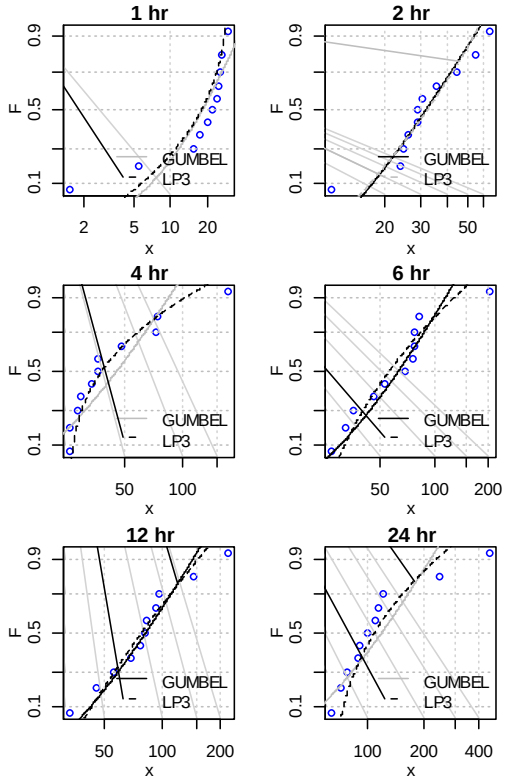

Figure 1: Fitted Distribution for Annual Maximum Rainfall for Different Duration

When considering the above Figure 1 we can say that both LP3 and EV1 fitted well to the maximum annual precipitation. However, based on the GOF tests result (Table1) LP3 distribution has produced minimum error value for the annual maximum rainfall depth in 1, 4, 6 and 24 hour's period of precipitation while, 2 and 12 hour's durations of peak annual precipitation data values represented by EV1 distribution. Therefore, we can conclude that both LP3 and EV1 distributions are the most appropriate distribution in order to determine the rainfall intensity at different duration level.

Further, the appropriate frequency factor was estimated for a given return period in order to calculate the return level at different durations of rainfall and return periods. Subsequently, these values are used to establish the IDF curve for Colombo region. The following Table 2 shows the return levels at different duration and different return periods. According to this table, it can be clearly seen that the extreme precipitations showed a wide range of variation.

Table 2: Comparisons of extreme precipitation in terms of Depth (mm)

Return Period (Years)	Duration (hrs)					
	1	2	4	6	12	24
2	18.01	31.52	45.67	62.88	82.04	118.86
5	28.53	44.88	68.72	94.2	119.29	178.61
10	35.49	53.72	83.98	114.94	143.95	218.17
20	42.17	62.2	98.62	134.83	167.61	256.12
50	50.82	73.18	117.57	160.58	198.23	305.24
100	57.3	81.41	131.77	179.87	221.17	342.04
200	63.76	89.6	145.92	199.09	244.04	378.72

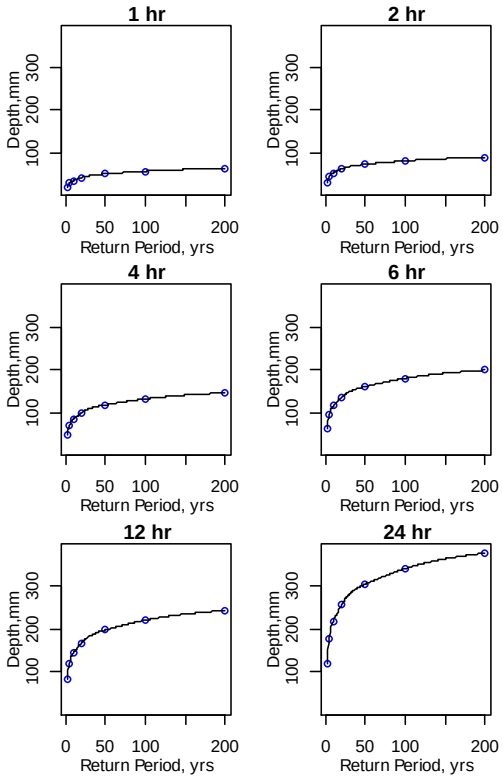

Figure 2: Variation of Rainfall Depth at Different Durations and Return Periods

According to the Figure 2 changes in extreme precipitation amounts in 24-hour showed the largest variation while it is comparatively less in other five durations. In addition to this, the relationship between the maximum rainfall intensities and the durations for every return period was determined using *eq*(2). The results of the IDF data were shown in the Table 3.

Table 3: Maximum rainfall intensity at different duration and each return period.

Return Period (Years)	Duration (hr)					
	1	2	4	6	12	24
2	18.01	15.76	11.42	10.48	6.84	4.95
5	28.53	22.44	17.18	15.70	9.94	7.44
10	35.49	26.86	21.00	19.16	12.00	9.09
20	42.17	31.10	24.66	22.47	13.97	10.67
50	50.82	36.59	29.39	26.76	16.52	12.72
100	57.30	40.70	32.94	29.98	18.43	14.25
200	63.76	44.80	36.48	33.18	20.34	15.78

Finally, the IDF curve was obtained by plotting the rainfall intensity against the corresponding durations for different return periods. The IDF curve of the Colombo region is shown in Figure 3.

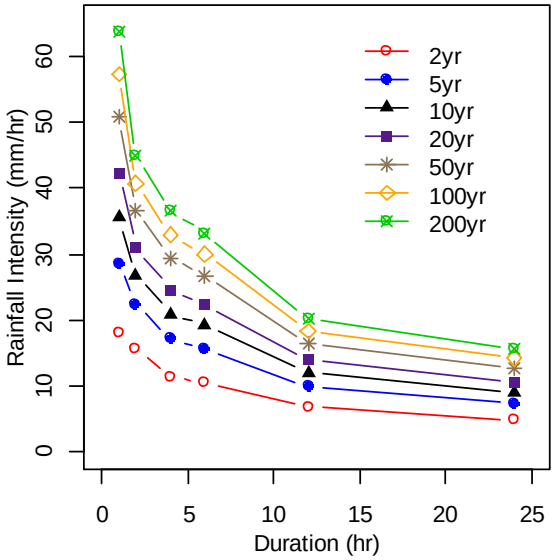

Figure 3: Rainfall Intensity-Duration-Frequency (IDF) relationship for Colombo

4. CONCLUSIONS

The study has been conducted to the formulation and construction of IDF curve using data from recording station of the Colombo region. The major findings of the present study is that the LP3 and EV1 distributions were the best fitted distributions at different duration of maximum annual precipitation based on three GOF tests. Moreover, these distributions were used to find the rainfall depth of the particular durations and different return periods at 2, 5, 10, 20, 50, 100 and 200 years.

Further, this study also reveals the rainfall IDF relationship and the development of the hourly IDF curve in the Colombo region. The rainfall IDF curve developed in this study is immensely helpful for designing water resources development in Colombo. Finally, we also recommend the IDF curve for the prediction of rainfall intensities in this region.

5. ACKNOWLEDGEMENTS

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