RAINFALL INTENSITY–DURATION–FREQUENCY RELATIONSHIP FOR DIFFERENT REGIONS OF KASHMIR VALLEY (J&K) INDIA

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ABSTRACT

Intensity–duration–frequency (IDF) relationship of rainfall amounts is one of the most commonly used tools in planning, design and operation of various water resources projects. This paper describes the development of IDF relationship of rainfall over different regions of Kashmir valley, Jammu and Kashmir, India. A relation for each region has been obtained to estimate rainfall intensities for different durations upto 24 hr and return periods ranging from 2 to 100 years. The relations have then been generated from a 30-year hourly rainfall data available at meteorological stations (Srinagar, Pahalgam, and Qazigund). Gumbel, and Log Pearson Type III frequency analysis techniques have been used for analysis of rainfall data for corresponding return periods. The parameters of the IDF equations and coefficient of correlation for different return periods (2, 5, 10, 25, 50 and 100) are calculated by using non-linear multiple regression method. The results obtained showed that in all the cases, the correlation coefficient is very high indicating the goodness of fit of the formulae to estimate IDF curves in the region of interest. The chi-square goodness of fit test was used to determine the best fit probability distribution. It was observed that Log Pearson Type III distribution gave better results for the three regions namely Srinagar, Pahalgam and Qazigund in terms of regional coefficients than Gumbel distribution.

Keywords: IDF relationship, Rainfall Duration, Rainfall Frequency, Rainfall Intensity, Return Periods

I. INTRODUCTION

Rainfall intensity–duration–frequency (IDF) curves are graphical representations of the amount of water that falls within a given period of time in catchment areas (Dupont and Allen, 2000). The establishment of IDF relationships goes back to the 1930's (Chow, 1988). Since then, different forms of relationships have been constructed for several regions of the world. Al-Shaikh (1985) derived rainfall intensity-duration-frequency relationships for Saudi Arabia through the analysis of available rainfall intensity data. Al-Khalaf (1997) conducted a study for predicting short-duration, high intensity rainfall in Saudi Arabia. Further studies by Al-Sobayel (1983) and Al-Salem (1985) performed Rainfall Frequency Distribution analysis for Riyadh, Shaqra and Al-Zilfi areas in KSA. Koutsoyiannis (1998) proposed construction of the intensity-duration-frequency curves using data from both recording and non-recording stations. Mohymont *et al*., (2004) assessed IDF-curves for precipitation for three stations in Central Africa and proposed more physically based models for the IDF-curves. Precipitation frequency values for Kinshasa-Yangambi have been produced by Mohymont *et al.* (2004). With the recent technology of remote sensing and satellite data, Awadallah *et al.* (2011) conducted a study for developing IDF curves in scarce data regions using regional analysis and satellite data. Awadallah *et al*. (2011) presented a methodology to overcome the lack of ground stations rainfall by the joint use of available ground data with TRMM satellite data to develop IDF curves and he used a method to develop ratios between 24 hr rainfall depth and shorter duration depths. Al-Hassoun (2011) developed an empirical formula to estimate rainfall intensity in Riyadh region.

Although the regional properties of IDF relationships have been studied in several countries, and in general, maps have been constructed to provide the rainfall intensities or depths for various return periods and durations. However, such relationships have not been accurately constructed in many developing countries (Koutsoyiannis *et al.*, 1998). The present study has been carried out for development of IDF curve for different regions of Kashmir Valley that will contribute to the planning, design and management of water infrastructure and to design safe and economical flood control measures.

II. STUDY AREA

Kashmir Himalayan region is nestled within the north-western folds of the recently designated Global Biodiversity Hotspot of the Himalayas. It is an integral but geologically younger part of the main Himalayan range. The region, sometimes referred to as 'Switzerland of Asia', lies between 32°-20' and 34°-54' Northern latitudes and 73°-55' and 75°-35' East longitudes, comprising an area of 15,948 sq. km. The altitude ranges between 1,600 m above sea level at Srinagar to 5,420 m at the highest peak Kolahoi (Gwashibror). Based on stratigraphy and altitude, the Kashmir region comprises the main valley floor, the side valleys and the valley facing slopes of Pir Panjal and the Greater Himalayan ranges. Valley floor is rich in alluvium, deposited by the river Jhelum and its tributaries, and has earned the name 'Rice Bowl of Kashmir'. Side valleys are carved out by the major tributaries of the river Jhelum. These include Daksum, Lidder and Sind valleys. Pir-Panjal Range (200 km) separates the valley from Chenab valley and Jammu region. The slopes of this range are gentle towards the valley and include famous meadows like Kong-Wattan, Yusmarg, Gulmarg and Khilanmarg. Greater Himalayan range (330 km) separates it from the valleys of Indus and Kishenganga. The slopes of the range, besides alpine and sub-alpine meadows, harbour high altitude lakes like Tarsar, Marsar, Satsar, Sheshnag, Gadsar, Vishansar, Krishansar and Gangbal. Administratively, Kashmir valley is the summer capital of the state. Jammu and Kashmir is home to several valleys such as the Kashmir Valley, Tawi Valley, Chenab Valley, Punch Valley, Sind Valley and Lidder Valley. The main Kashmir valley is 100 km (62 mi) wide and 15,520.3 km^2 (5,992.4 sq. mi) in area. The Himalayas divide the Kashmir valley from Ladakh while the Pir-Panjal range, which encloses the valley from the west and the south, separates it from the Great Plains of northern India. Along the north-eastern flank of the Valley runs the main range of the Himalayas. This densely settled and beautiful valley has an average height of 1,850 meters (6,070 ft) above sea-level but the surrounding Pir-Panjal range has an average elevation of 5,000 meters (16,000 ft). The Jhelum River is the only major Himalayan river which flows through the Kashmir valley. For Kashmir Valley, there are six rain-gauge stations installed at different areas. These rain-gauge stations are located at Srinagar, Pahalgam, Kupwara, Gulmarg, Kokernag and Qazigund. The location map of Kashmir Valley along with rain-gauge network is shown in Fig. 1.

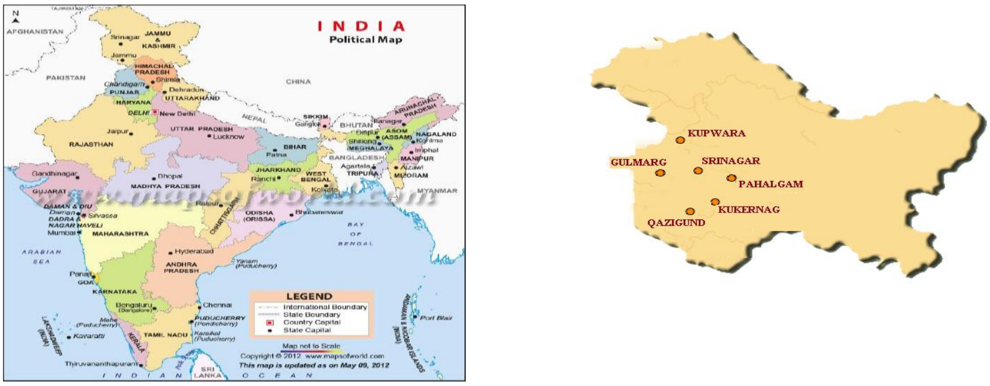

Fig. 1 Location map of Kashmir Valley

III. DATA BASE AND METHODOLOGY

3.1. Data collection: Data for different climatologically stations (Srinagar, Pahalgam and Qazigund) around Kashmir Valley, were obtained from Indian Meteorological Department, Srinagar, Kashmir (IMD) and National Data Centre (NDC) Pune. Rainfall data at Srinagar station was available for the years 1974-2013 while as for the other stations, it was available only for the years 1974-2004.

3.2. Data preparation: After obtaining the raw data, the maximum rainfall events were identified at selected durations, that is, 10 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours and 24 hours for all the three stations.

3.3. Fitting the probability distribution: A suitable probability distribution was fitted to the each selected duration data series. Gumbel's Extreme Value distribution and Log Pearson Type III distribution were used in the present study. The Gumbel theory of distribution is the most widely used distribution for IDF analysis owing to its suitability for modelling maxima. It is relatively simple and uses only extreme events (maximum values or peak rainfalls). The Gumbel method calculates the 2, 5, 10, 25, 50, 100 year return intervals for each duration period and requires several calculations. Frequency of a precipitation X (in mm) for each duration with a specified return period, Tr (in years) is given by the following equation.

$$X_T = M + K_T S \qquad (1)$$

Where M = mean, S = standard deviation and K_T = Gumbel's frequency factor for return period T and is given by

$$K_T = -\frac{\sqrt{6}}{\pi}\{0.5772 + \ln[\ln\frac{T}{T-1}] \qquad (2)$$

In utilising Gumbel's distribution, the arithmetic average is

$$X_{ave} = 1/n\sum x_i \qquad (3)$$

Where x_i is the individual extreme value of rainfall and n is the number of events or years of record. The standard deviation is calculated by using the following equation.

$$S = \left[\frac{I}{N-1}\sum(x_i - X_{ave})^2\right]^{1/2} \qquad (4)$$

Where S is the standard deviation of X data. The frequency factor (K_T) which is a function of return period and sample size, when multiplied by the standard deviation gives the departure of a desired return period rainfall from the average. Then the rainfall intensity, I (mm/hr) for return period Tr is obtained from I = X_T / Tr.

Log Pearson Type III distribution (LPT III distribution) involves logarithms of the measured values. The mean and the standard deviation are determined using the logarithmically transformed data. K_T is the Pearson frequency factor which depends on return period (T) and skewness coefficient Cs for the log transferred series, given by equation 5.

$$Cs = N\sum_{n=1}^{n} \frac{(X-M)^3}{N-1(N-2)S^3} \quad (5)$$

The rainfall depths were determined by using frequency factors or using the CDF of the distribution. IDF curves were developed for all the three regions by two distribution techniques.

3.4. Developing IDF equations: The IDF formulae are the empirical equations representing a relationship between maximum rainfall intensity as a dependant variable and the other parameters of interest, that is, the rainfall duration and frequency as independent variables. There are several commonly used functions relating those variables previously mentioned found in the literature of hydrology applications (Chow (1988), Burke and Burke (2008) and Nhat *et al*. (2006)). The IDF equations were developed by determining the logarithmic values of rainfall intensities and then the regional coefficients were determined. The Chi-Square goodness of fit test was used to evaluate the accuracy of the fitting of a distribution.

IV. RESULTS AND DISCUSSIONS

4.1 Analysis of data for Srinagar region: Rainfall depths and their intensities for various return periods were analysed for Srinagar station using two different techniques and the IDF relations were developed. Table 1 to Table 2 show the computed values of frequency factor (K_T) and intensities for different durations (Td) and different return periods. Fig. 2 and 3 show the IDF curves for Srinagar region obtained using Gumbel and Log-Pearson distribution techniques, respectively.

Table 1 Rainfall intensities (mm/hr) at different return periods by Gumble Technique

Duration (hr)/ Mean/ Standard deviation	Return period Tr (years)/K_T values					
	2/-0164	5/0.719	10/1.305	25/2.044	50/2.592	100/3.137
Rainfall intensities (mm/hr)						
0.161/1.520/2.734	6.429	20.909	30.518	42.63661	53.785	63.096
0.50/4.193/4.916	6.774	15.455	21.217	28.482	33.870	39.228
1.0/8.133/9.356	6.599	14.860	20.343	27.256	32.383	37.482
2.0/6.843/9.281	2.661	6.758	9.478	12.907	15.450	17.979
3.0/6.867/7.288	1.890	4.036	5.459	7.255	8.586	9.910
6.0/7.857/11.390	0.998	2.674	3.787	5.190	6.230	7.265
12.0/7.867/112.9995	0.478	1.434	2.069	2.869	3.463	4.053
24.0/4.743/13.514	0.105	0.603	0.932	1.349	1.657	1.964

Table 2 Rainfall intensities (mm/hr) at different return periods by Log Pearson Technique

Duration (hrs)/ Mean/ Standard deviation	Return period Tr (years)					
	2	5	10	25	50	100
Rainfall intensities (mm/hr)/K_T values						
0.161/1.520/2.734	4.98/ -0.099	18.73 / 0.800	30.44/ 1.328	48.87/ 1.939	56.89/ 2.359	62.89/ 2.755
0.50/4.193/4.916	4.18/ 0.033	12.60/ 0.850	21.85/ 1.258	38.61/ 1.680	55.21/ 1.945	62.79/ 2.178
1.0/8.133/9.356	3.87/ 0.116	12.10/ 0.857	20.99/ 1.183	37.87/ 1.488	49.97/ 1.663	61.13/ 1.806
2.0/6.843/9.281	1.64/ - 0.033	5.95/ 0.830	8.82/ 1.301	16.93/ 1.818	27.44/ 2.159	57.32/ 2.472
3.0/6.867/7.288	1.73/ 0.000	4.02/ 0.842	6.24/ 1.282	14.57/ 1.751	20.78/ 2.045	35.67/ 2.362
6.0/7.857/11.390	0.76/ -0.21	2.74/ 0.719	5.75/ 1.339	13.78/ 2.108	19.47/ 2.666	28.97/ 3.211
12.0/7.867/112.9995	0.57/ -0.116	1.99/ 0.790	4.21/ 1.333	12.89/ 1.967	18.47/ 2.407	26.54/ 2.824
24.0/4.743/13.514	0.46/ -0.360	1.33/ 0.518	3.22/ 1.250	10.94/ 2.262	15.38 /3.048	19.32/ 3.845

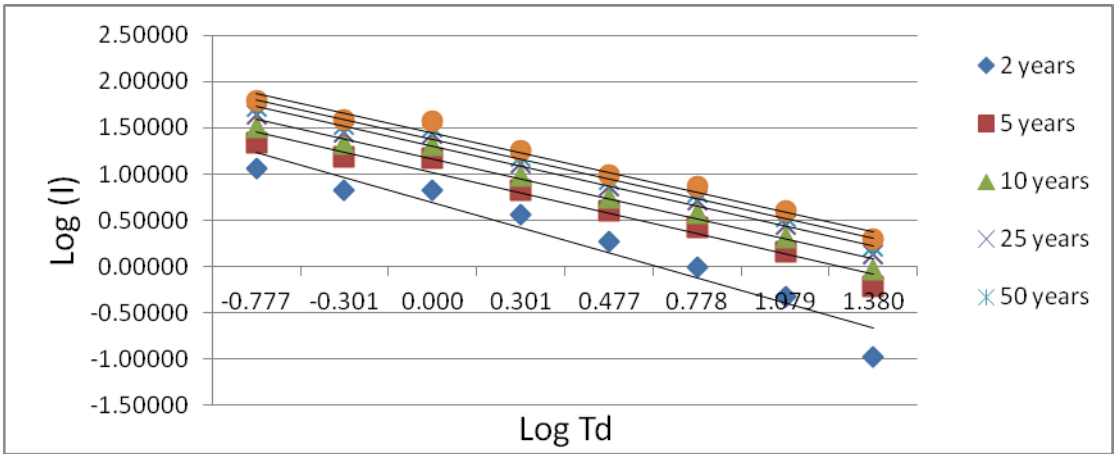

Fig. 2 IDF equation generated by Gumble method for Srinagar region

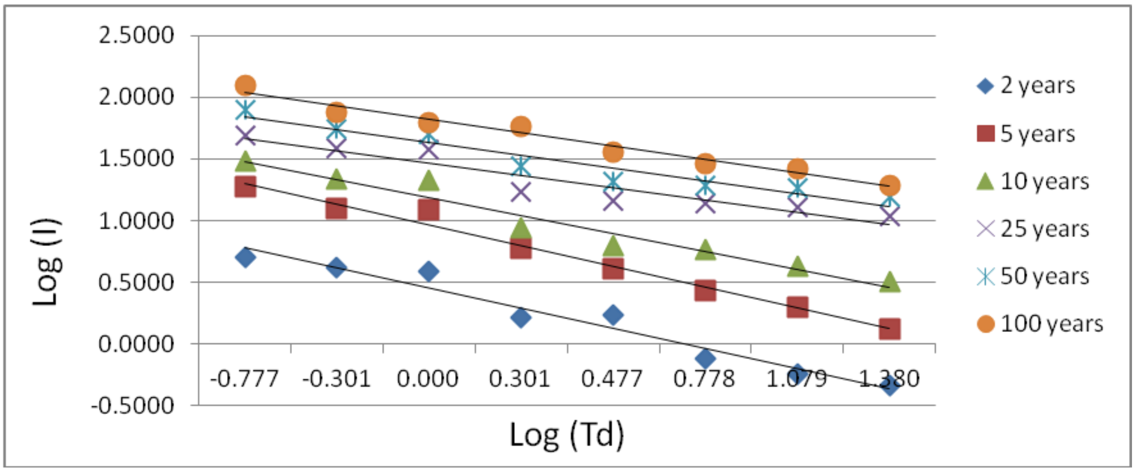

Fig. 3 IDF equation generated by Log Pearson Type-III method for Srinagar region.

4.2. Analysis of data for Pahalgam and Qazigund regions: Table 3 to Table 6 show the computed K_T values and intensities for different durations and different return periods along with frequency factors for Pahalgam and Qazigund regions . Figure 4 to 7 show IDF curves for Pahalgam and Qazigund region by Gumbel and Log-Pearson distribution techniques.

Table 3 Rainfall intensities (mm/hr) at different return periods for Pahalgam region by Gumbel Technique .

Duration (hrs)/ Mean/ Standard deviation	Return period Tr (years)/K_T values					
	2/-0164	5/0.719	10/1.305	25/2.044	50/2.592	100/3.137
Rainfall intensities (mm/hr)						
0.16/3.05/8.415	10.040	54.622	84.210	121.521	149.190	176.708
0.50/5.44/5.205	9.173	18.364	24.464	32.157	37.862	43.535
1.0/12.98/14.765	5.373	14.564	20.664	28.357	34.062	39.735
2.0/10.83/8.425	4.726	8.446	10.914	14.027	16.336	18.632
3.0/11.28/8.648	3.287	5.833	7.522	9.652	11.232	12.803
6.0/15.32/10.045	2.279	3.757	4.738	5.975	6.893	7.805
12.0/34.00/31.328	2.180	3.060	4.116	4.980	6.035	7.550
24.0/30.96/31.555	1.074	2.235	3.006	3.977	4.698	5.415

Table 4 Values of intensities at different durations corresponding to return periods for Pahalgam region, by Log Pearson Technique

Duration (hr)/ Mean/ Standard deviation	Return period Tr (years)					
	2	5	10	25	50	100
Rainfall intensities (mm/hr)/K_T values						
0.16/3.05/8.415	15.45/ -0.282	29.52/ 0.643	48.76/ 1.318	58.55/ 0.193	78.97/ 2.848	115.21/ 3.499
0.50/5.44/5.205	7.57/ 0.00	19.94/ 0.842	45.23/ 1.282	51.89/ 1.751	59.43/ 2.045	73.45/ 2.326
1.0/12.98/14.765	7.00/ -0.099	14.56/ 0.800	27.33/ 1.328	46.87/ 1.939	54.45/ 2.359	62.57/ 2.755
2.0/10.83/8.425	4.03/ -0.033	8.66/ 0.830	11.19/ 1.301	16.61/ 1.818	21.56/ 2.159	27.39/ 2.472
3.0/11.28/8.648	3.58/ 0.255	5.71/ 0.817	6.62/ 0.994	9.78/ 1.116	15.87/ 1.166	19.68/ 1.197
6.0/15.32/10.045	2.52/ 0.330	4.27/ 0.752	5.14/ 0.844	8.56/ 0.888	10.98/ 0.900	16.56/ 0.905
12.0/34.00/31.328	1.48/ 0.164	3.76/ 0.852	4.87/ 1.121	7.77/ 1.366	9.87/ 1.492	10.43/ 1.588
24.0/30.96/31.555	0.36/- 0.164	2.02/ 0.758	3.90/ 1.340	4.68/ 2.043	6.09/ 2.542	8.34/ 3.022

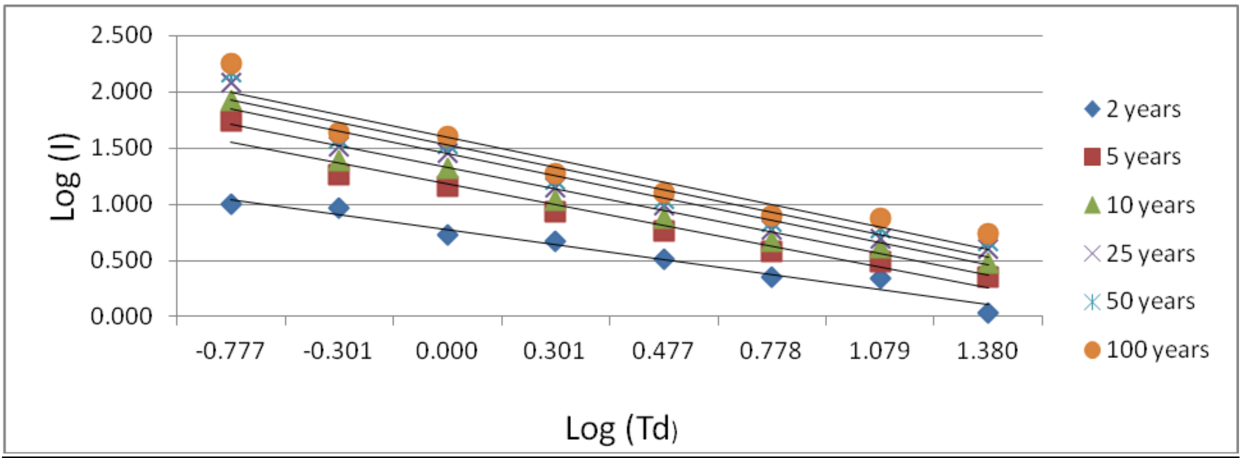

Fig.4 IDF equation generated by Gumbel method for Pahalgam region

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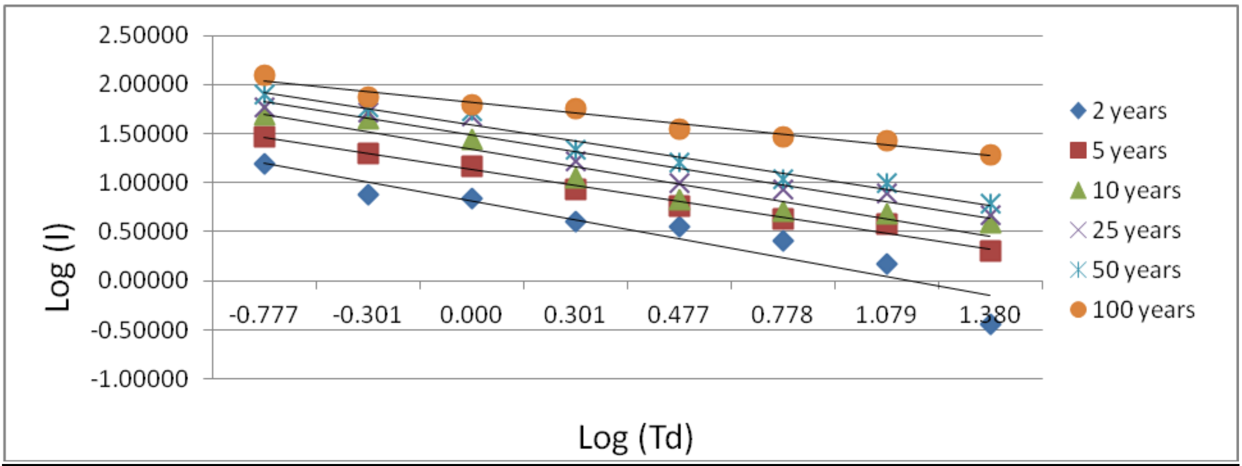

Fig. 5 IDF equation generated by Log-Pearson Type-III method for Pahalgam region.

Table 5 Rainfall intensities (mm/hr) at different return periods by Gumbel Technique

Duration (hr)/ Mean/ Standard deviation	Return period Tr (years)/K_T values					
	2/-0164	5/0.719	10/1.305	25/2.044	50/2.592	100/3.137
Rainfall intensities (mm/hr)						
0.16/1.03/2.088	9.870	44.570	66.390	94.58	115.760	136.870
0.50/7.64/19.242	8.969	42.949	65.500	93.939	115.028	136.002
1.0/10.08/6.980	8.931	15.094	19.185	24.343	28.168	33.870
2.0/15.60/15.531	6.526	13.383	17.934	23.672	27.928	32.160
3.0/12.84/6.939	5.970	8.910	10.560	12.750	14.310	16.870
6.0/34.23/18.121	5.209	7.876	9.646	11.878	13.533	15.179
12.0/61.75/27.626	4.768	6.801	8.150	9.851	11.113	12.368
24.0/83.45/33.885	3.246	4.492	5.320	6.363	7.137	7.906

Table 6 Values of intensities at different durations corresponding to return periods for Qazigund region by Log Pearson Technique

Duration (hr)/ Mean/ Standard deviation	Return period Tr (years)/					
	2	5	10	25	50	100
Rainfall intensities (mm/hr)/K_T values						
0.16/1.03/2.088	28.450/ -0.307	46.559/ 0.609	69.358/ 1.302	97.922/ 2.219	119.410/ 2.912	135.110/ 3.605
0.50/7.64/19.242	16.670/ -0.210	27.980/ 0.719	43.676/ 1.339	58.450/ 2.108	95.450/ 2.666	115.656/ 3.211
1.0/10.08/6.980	12.911/ 0.195	17.083/ 0.844	22.152/ 1.086	27.685/ 1.283	36.220/ 1.379	41.780/ 1.449
2.0/15.60/15.531	10.506/ 0.180	15.372/ 0.848	19.220/ 1.107	26.540/ 1.324	32.980/ 1.435	39.540/ 1.518

3.0/12.84/6.939	9.950/ 0.330	10.899/ 0.752	13.528/ 0.844	16.092/ 0.888	18.980/ 0.900	27.550/ 0.905
6.0/34.23/18.121	9.189/ 0.396	9.865/ 0.636	12.614/ 0.660	15.220/ 0.666	17.183/ 0.666	22.556/ 0.666
12.0/61.75/27.626	8.748/ -0.099	8.790/ 0.800	11.118/ 1.328	13.194/ 1.939	14.763/ 2.359	17.440/ 2.755
24.0/83.45/33.885	7.226 / 0.282	6.481/ 0.799	8.287/ 0.945	9.705/ 1.035	10.787/ 1.069	13.670/ 1.187

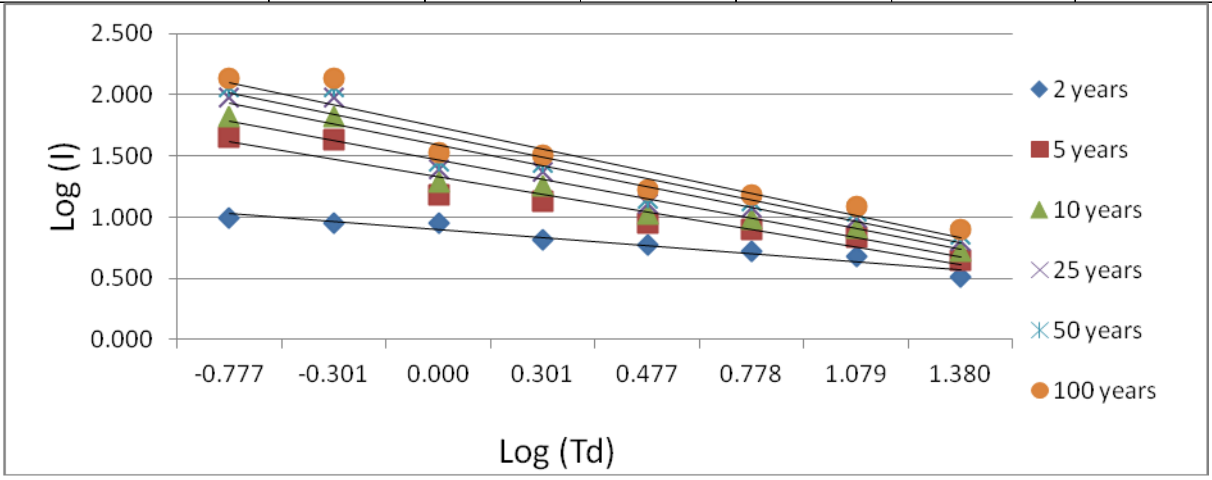

Fig. 6 IDF equation generated by Gumbel's method for Qazigund region

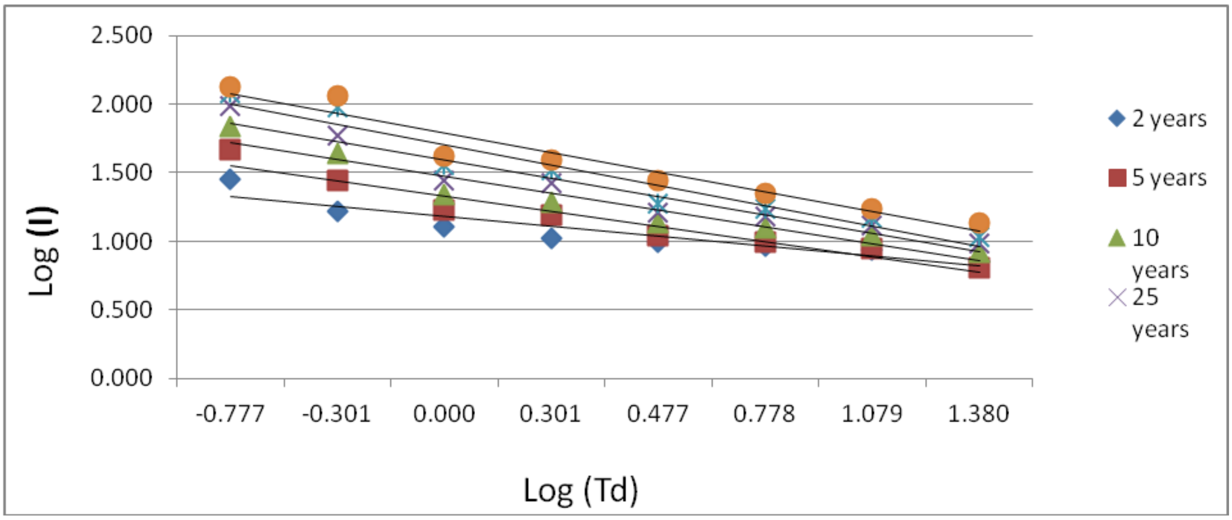

Fig. 7 IDF equation generated by Log-Pearson Type-III method for Pahalgam region

4.3. Parameter Estimation and Chi-square analysis: Parameter estimation along with the IDF relations are shown in Table 7 and Chi-square results for goodness of fit are shown in Table 8.

Table 7 The parameters values used in deriving formulas.

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.	Parameters	Gumbel	Log-Pearson Type-III	Equation
Srinagar	C	1.01	7.74	$I = \frac{1.01Tr^{0.33}}{Td^{0.22}}$
	m	0.33	0.12	$I = \frac{7.74Tr^{0.12}}{Td^{0.13}}$
	e	0.22	0.13	
Pahalgam	C	16.0	21.34	$I = \frac{16.0Tr^{0.182}}{Td^{0.184}}$
	m	0.182	0.150	$I = \frac{21.34Tr^{0.150}}{Td^{0.162}}$
	e	0.184	0.162	
Qazigund	C	14.31	20.18	$I = \frac{14.31Tr^{0.189}}{Td^{0.188}}$
	m	0.189	0.163	$I = \frac{20.18Tr^{0.163}}{Td^{0.122}}$
	e	0.149	0.122	

Table 8 Results of Chi-square goodness of fit for Srinagar station.

Region	Distribution	Duration (hr)							
Srinagar	Gumbel	0.16	0.5	1	2	3	6	12	24
	Log-Pearson Type-III	35.02	20.80	15.38	10.21	14.56	17.68	10.99	15.15
		16.14	12.09	9.48	10.21	15.29	7.64	11.19	11.17
Pahalgam	Gumbel	25.29	19.39	19.93	29.89	31.57	26.34	27.18	26.53
	Log-Pearson Type-III	14.64	16.77	16.90	13.09	22.11	14.74	12.45	15.96
Qazigund	Gumbel	19.45	20.17	34.73	21.41	20.92	28.88	19.63	18.81
	Log-Pearson Type-III	12.67	15.02	17.65	15.78	25.47	37.98	12.33	14.03

The results showed that the Log-Pearson Type-III gives best fit for Srinagar region at 0.01 level of significance. The results obtained also showed that, the correlation coefficient is not so high in some cases and it ranges from 0.005 to 0.1 when using Log-Pearson Type-III. As is seen, most of the data fits the distribution at the level of significance of $\alpha = 0.01$ which yields $\varkappa^2_{cal} < 11.345$ and at $\alpha = 0.05$, $\varkappa^2_{cal} < 7.81$. Only the data of Srinagar at 10 minutes and 30 minutes have slightly higher chi-square values and do not give good fit.

For α = 0.01, degree of freedom = 3, the critical region is $\chi^2_{cal} > 11.345$

For α = 0.05, degree of freedom = 3, the critical region is $\chi^2_{cal} > 7.81$

Hence, χ^2 is significant at 0.01.

The results revealed that the Log-Pearson Type-III distribution gives best fit for Pahalgam region at 0.01 level of significance. The results obtained also showed that by Gumbel distribution technique, the chi-square values are in higher range than Log-Pearson Type-III distribution. As can be seen, by Log-Pearson Type-III distribution technique, most of the data fit the distribution at the level of significance of α = 0.01 which yields $\chi^2_{cal} < 15.09$. Only the data of Pahalgam at 30 minutes, 1 hour and 3 hours have slightly higher chi-square values and do not give good fit.

For α = 0.01, degree of freedom = 5, the critical region is $\chi^2_{cal} > 15.09$

For α = 0.05, degree of freedom = 5, the critical region is $\chi^2_{cal} > 11.09$

Hence, χ^2 is significant at 0.01.

For Kupwara region, the results showed that both the Log-Pearson Type-III and Gumbel distribution techniques give higher chi-square values and do not fit at any point at both levels of significance (0.05 and 0.01) . Pearson's method gives best fit only at 1 hour, 3 hours and 6 hours, at 0.01 level of significance, which yields $\chi^2_{cal} <$ 15.09, while as other durations (10 minutes, 30 minutes, 2 hours, 12 hours and 24 hours) do not give better fit even at 0.01 level of significance.

For α = 0.01, degree of freedom = 5, the critical region is $\chi^2_{cal} > 15.086$

For α = 0.05, degree of freedom = 5, the critical region is $\chi^2_{cal} > 11.070$

None of the values fits at significance level of 0.05.

Hence, the results obtained showed that in all the cases, Pearson's technique gives the best fit.

The results showed that the Log-Pearson Type-III gives best fit for Qazigund region at 0.01 level of significance. The results obtained showed that by Gumbel distribution technique, the chi square values are in higher range than those in Log-pearson Type-III distribution. As can be seen, by Log-Pearson Type-III, most of the data fit the distribution at the level of significance of α = 0.01 which yields $\chi^2_{cal} < 15.09$. Only the data of Qazigund at 3 hours and 6 hours have slightly higher chi square values and do not give good fit.

For α = 0.01, degree of freedom = 5, the critical region is $\chi^2_{cal} > 15.09$

For α = 0.05, degree of freedom = 5, the critical region is $\chi^2_{cal} > 11.09$.

Hence, χ^2 is significant at 0.01.

V. CONCLUSIONS

This research presents some insight into the way in which the rainfall can be estimated in different regions of Kashmir valley. The study showed that the maximum intensities occur at short duration with large variations with return period, while as with long duration, there is not much difference in intensities with return period for all the regions of Kashmir Valley. Gumbel method gave some larger rainfall intensity estimates compared to LPT III distribution. In general, the results obtained using the two approaches are very close at most of the return periods and have the same trend. For Srinagar region, maximum intensity of 63.096 mm/hr occurs at return period 100 years with duration of 0.16 hours and minimum intensity of 0.105 mm/hr occurs at return period of 2 years with duration of 24 hours. For Pahalgam region, maximum intensity for of 222.811 mm/hr occurs at return period 100 years with duration of 0.16 hours and minimum intensity of 0.36 mm/hr occurs at return period of 2 years with duration of 24 hours. For Qazigund region, maximum intensity of 136.870 mm/hr occurs at return period 100 years with duration of 0.16 hours and minimum intensity of 3.160 mm/hr occurs at return period of 2 years with duration of 24 hours. For Srinagar region, Log-Pearson gives smaller values of regional parameters as compared to the other distribution technique (c =7.74, m = 0.12, e = 0.13). For Pahalgam region, Log-Pearson gives smaller values of regional parameters as compared to the other distribution technique (c = 21.34, m = 0.15, e = 0.16). For Qazigund region, Log-Pearson gives smaller values of regional parameters as compared to Gumbel distribution technique (c = 20.18, m = 0.163, e = 0.122). As per the Chi-square goodness of fit test, Log-Pearson Type-III distribution gives the best fit and is suggested for all regions of the Kashmir Valley.

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