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Rainfall Depth Duration Frequency Analysis for the Province of Punjab

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ABSTRACT

This study was designed to investigate the form of the frequency distribution of annual maximum rainfall data of twenty four hours durations by fitting generalized extreme value (GEV) distribution. The parameters of GEV distribution were estimated by the method of probability weighted moments (PWM). Kolmogrov Smirnove test statistic was used for goodness of fit. The fit is good for all stations and hence recommended for design purposes.

Key Words: Flood; Punjab; Generalized extreme-value distribution; Kolmogrov smirnove test statistic

INTRODUCTION

The frequency of annual maximum rainfall of various durations is required for several engineering purposes, including agricultural drainage, estimation of floods for inadequately gaged streams, estimation of erosion and sedimentation and designing the dimensions of storm sewers, flood channels and spill ways.

In Pakistan, rainfall measurements are not available frequently. Deficiencies have been reported even in record keeping, reading of graphs and charts. This thing lesser the reliability of the data. Good relationship may be found between the recorded data and frequency. Consequently probability distribution of rainfall frequency amounts may be found which is useful for the evaluation of records and for many purposes related to water management planning, design and research etc. The objectives of the present study were to develop rainfall depth duration frequency (DDF) relationships for each station as well as for total Punjab in Pakistan.

MATERIALS AND METHODS

The rainfall data on DDF were extracted from records of autographic rain gauges maintained by the Regional Meteorological office, Lahore (Anonymous, 1991). The depth duration frequency (DDF) of nine stations were examined and summarized as i.e. mean, median, standard deviation, co-efficient of variation, skewness and kurtosis etc. The skewed distributions were selected for non-normal data sets. GEV distribution was selected because of skewed data. Kendall and Buckland (1971) and Levin (1984) discuss the "Peakedness" and "Flatness" of the distribution and distinguished between mesokurtic, leptokurtic and platykurtic distributions. Siddiqui (1992) fitted the Gamma distribuiton for modelling the rainfall amount of Faisalabad.

Fitting of distribution. The GEV distribution Function is

$$F(x) = e^{-\left(1-\frac{k(x-a)}{b}\right)^{1/k}} \quad K \neq O$$

$$F(X) = e^{-e^{-\left(\frac{x-a}{b}\right)}} \quad K = O$$

with x bounded by $a+b/k$
From above if $k > 0$
From below if $k < 0$
Where a, b and k are the location, scale and shape parameters respectively.

The Inverse Distribution Function is

$$X(F) = a + \frac{b(1-(-1nF)^k)}{k}, \quad K \neq o$$

$$X(F) = a - b\ln(-lnF), \quad K = 0$$

Estimation of parameters. The probability weighted moments (PWM) method by Greenwood *et al.* (1979) was used to estimate the parameters of GEV distribution. Hence the estimated parameters of GEV distribution are derived as Hosking (1985).

Goodness of fit. Kolmogrove Smirnove (KS) test Agostino *et al.* (1986) was applied to test the goodness of fit of GEV distribution. Agostino and Steohenes (1986) described different techniques of goodness of fit.

RESULTS AND DISCUSSION

Table I presents the detail of each station utilized for the present study. Table II indicates that the mean annual 24 hours maximum rainfall ranges from

Table I. Station's detail utilized for the study

Station	Annual average maximum rainfall (mm)	Period of record	Total period (years)
Faisalabad	64.67	1944–1991	48
Mianwali	64.74	1959–1986	28
Khanpur	32.22	1959–1962 & 1968–1986	4 & 17 = 21
Khushab	63.25	1945–1976	32
Murree	81.18	1945–1984	40
Bahawalpur	38.36	1945–1985	41
Jhelum	76.47	1964–1983	20
Bahawalnagar	31.08	1972–1983	12
Sialkot	90.10	1963–1983	21

31.08 to 90.10 millimeters (mm). The distribution of these series indicates the diversity of the rainfall areas under consideration having semi arid to arid zone. The distribution of these series form moderately skewed i.e. from 0.089 to 2.659. These estimates support our preamble to select GEV distribution, for modeling annual Maximum rainfall data for the province of Punjab. The rainfall depth duration frequency (DDF) relationships for each of the nine stations of Punjab for twenty four (24) hours duration were developed by fitting GEV distribution to the corresponding annual maximum series of the available rainfall data. The parameter estimates are presented in the Table III along with Kolmogrove Smirnove (KS) test statistics values. It is found that fit is good for all the stations of Punjab. The increase in average rainfall also increases the variance but this increase does not seem to be linear. These results do not agree with Brokes and Carruthers (1946) from

Table II. Annual maxima summary statistics for 24 hours rainfall data set

Station	n	Mean	Median	cv	SK	KUR
Faisalabad	48	64.67	61.00	0.4266	1.421	6.3623
Mianwali	28	64.74	51.50	0.7071	2.659	11.8030
Khanpur	21	32.22	22.90	0.8361	1.124	3.2562
Kushab	32	63.25	53.95	0.5380	1.166	3.5401
Murree	40	80.18	75.45	0.2453	0.089	2.3785
Bhawalpur	41	38.36	33.00	0.5436	0.625	2.8112
Jhelum	20	76.47	69.50	0.4305	1.452	5.4514
Bha.nagar	12	31.08	30.50	0.4378	0.342	2.2137
Sialkot	21	90.10	71.10	0.6262	1.218	3.9006

Table III. Estimated parameters of the GEV distribution to fit rainfall depth duration frequency relationships for the individual station for 24 hours rainfall and KS-test values

Shape parameter	Scale parameter	Location parameter	KS Test
-0.048985	20.3037	51.9932	0.054081
-0.236011	23.0899	44.5601	0.101473
-0.230621	15.9023	18.4584	0.083253
-0.189790	21.3137	46.1422	0.090028
0.188957	19.3212	72.1322	0.082750
0.024000	17.2455	28.7667	0.105508
-0.124547	22.3951	60.4861	0.101707
0.086311	12.2398	24.9885	0.208489
-0.214877	34.0032	61.5354	0.122073

Sri-Lanka which has a fairly extensive network of daily recording rainfall stations (approximate 500).

The satisfactory goodness of fit results justifies the use of GEV distribution for estimating the rainfall magnitudes of 24 hours duration maximum rainfall. The derived return periods for 2, 5, 10, 15, 20, 25, 50, 100 and 200 years are given in Table IV.

CONCLUSIONS

The GEV distribution was recommended to model rainfall data of 24 hours duration annual maximum records of nine stations of Punjab. The derived return periods may be used by the design engineers. These return periods indicate an increasing trend of average rainfall. However the estimates having return period greater than 50 should be used with caution because the maximum data record length utilized in this study is 48 years. So, it is therefore, suggested that the Government of Punjab should try to make possible improvements in the agricultural drainage, designing the dimensions of storm sewers, flood channels and spill ways in the light of these results.

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Table IV. Rainfall depth duration estimator in millimeter (mm) for the individual station for selected return periods

Return period (Years)	Station								
	Faisalabad	**Mian-wali**	**Khanpur**	**Kushab**	**Murree**	**Bhawalpur**	**Jhelum**	**Bha.nagar**	**Sialkot**
2	59.502	53.400	24.540	54.232	78.974	35.060	68.884	29.4043	74.502
5	83.594	86.116	46.956	83.126	97.368	54.174	97.420	42.2087	121.716
10	100.297	113.124	65.369	105.977	107.550	66.546	118.655	50.0227	159.936
15	108.827	128.429	75.772	118.598	112.096	72.610	129.966	53.7206	181.342
20	116.907	143.936	86.292	131.175	116.049	78.206	140.976	57.0571	202.867
25	122.299	154.856	93.688	139.915	118.513	81.863	148.485	59.1987	217.932
50	139.295	192.441	119.082	169.347	125.466	93.003	173.005	65.5370	269 271
100	156.754	236.459	148.709	202.717	131.512	103.876	199.565	71.4591	328.512
200	174.753	288.156	183.375	240.666	136.793	114.530	228.426	77.0152	397.072

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