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RESEARCH PAPER

Probability analysis for prediction of annual maximum rainfall of one to five consecutive months for Sultanpur region

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Abstract : The present study was conducted for probability analysis of 17th years (1994-2010) with the prime objective for prediction of annual maximum rainfall of one to five consecutive months Sultanpur region. The maximum rainfall values were estimated by proposed prediction models *viz.,* Gumbel, Log Pearson Type III and Log Normal. The predicted values were compared with observed values and correlation between the predicted and observed values was also established. Rainfall data had been in the above distributions and their corresponding rainfall events were estimated at 5.5, 11.5, 6.6, 33.3 and 50 per cent probabilities level. The goodness of fit models was tested by chi-square. The comparison between the measured and predicted maximum value of rainfall clearly shows that the developed model can be efficiently used for the prediction of rainfall. The statistical comparison by chi-square test for goodness of fit clearly indicates that the Gumbel distribution was found to be best model for predicting two, three, four and five consecutive months annual maximum rainfalls (mm) while Log Pearson types III are fairly close to observed for one and four consecutive months annual maximum rainfall (mm). Rainfall prediction by Log Normal distribution shows very close relation to the observed rainfall for one consecutive months annual maximum rainfall (mm).

Key Words : Probability analysis, Prediction, Annual maximum rainfall

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INTRODUCTION

Rainfall is one of the important hydrologic events, which plays an important role in many of agriculture and non-agriculture operation. The average rainfall of our country is 1190 mm per annum; it ranges from 350 to 2,000 mm. Most part of our country receives 80 per cent of the annual rainfall during four months (June to September) of a year. Rainfall is the amount of precipitation that has fallen within a specific length of time. This may be measured within a day, month or a year depending and is used to evaluate weather trends

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and to help predict future weather conditions. Rainfall does not just account for rain that falls from the sky; it also measures other forms of precipitation including hail, snow and sleet that fall to the ground. The level of rainfall can be measured using instruments such as rain gauges and tipping buckets that can then be used to determine how much precipitation has fallen within a set period of time. A rain gauge has a wide-opened top that allows the rain to fall down into a funnel shaped container that can then be used to measure the rainfall. This measuring process allows specific and very precise readings to be taken with some of them being able to provide precise readings of as little as one-hundred of an inch. Rain can also be measured using a tipping bucket. Like the rain gauge it has a funnel that leads down to two buckets that can each hold 0.1 inch of rain water. Once one of these buckets becomes full, it will tip over to be emptied and the other bucket will then start becoming filled. The device will then add on 0.1 inch every time the bucket becomes filled.

Detailed knowledge of rainfall pattern helps in planning crop calendar and designing of different storage structures (Ray *et al.*, 1987) to meet out irrigation requirement during drought period. Efficient utilization may increase the agriculture production many folds. Though the nature of rainfall is erratic and varies with time and space, yet it is possible to predict design rainfall fairly accurately for certain return periods using various probability distributions functions (Upadhyaya and Singh, 1998). Frequency analysis of rainfall data have been attempted places in India (Prakash and Rao, 1986; Agrawal *et al.*, 1988; Bhatt *et al.*, 1996; Upadhyaya and Singh, 1998; Mohanty *et al.*, 1999; Rizvi *et al.*, 2001 and Singh, 2001). Frequency analysis of rainfall is an important tool for solving various water management problems and is used to assess the extent of crop failure due to deficiency or excess of rainfall. Probability analysis of annual maximum daily rainfall for different returns periods has been suggested for the design of small and medium hydraulic structure (Bhatt *et al.,* 1996).

Rainfall distribution in India is uneven. The highest annual rainfall, that is around 1141.9 cm in the world, has been recorded at Cherrapunji in Meghalaya. On the other hand, the western part of Jaisalmer District of Rajasthan is one of the driest parts of the country recording around 9 cm of rainfall in a year. Thus, it is evident that there is a wide contrast in the amount of rainfall received by different parts of India. Total rainfall increases generally eastwards and with height. Increase in precipitation is high at an elevation of around 1,500 meters in the Himalaya Mountains. The monsoon depressions cause widespread rainfall in the north-eastern part of the Indian Peninsular Plateau and the Ganga Plain. It is due to these depressions that rainfall is evenly distributed in the north-eastern part of the country. Due to climatologically factors and regional conditions there is no general agreement among hydro-meteorologists and researchers about the selection of a probability distribution function to carry out frequency analysis. According to Kite (1977) the most important criteria in selection of distribution functions it should be theoretically based function and it should extract the maximum information from the data available. Since most of the distribution used in frequency analysis is theoretically based function, therefore commonly accepted probability functions namely Gumbel, Log Pearson Type III and Log Normal is used in the present study for Sultanpur region. Several distributions have been suggested for hydrological analysis as given by Chow (1951). Thus, study has been planned for prediction of annual maximum rainfall of one to five consecutive months by analyzing the seventeen years monthly rainfall (1994-2010) by using the proposed models.

MATERIAL AND METHODS

Yearly rainfall data of year (1994-2010) were collected from Agriculture Department, Sultanpur and utilized for analysis. The recurrence interval is the average time interval that elapses between the two events that or exceed a particular level. It is also known as return period.

The available rainfall data of years (1994-2010) is arranged in descending order. The recurrence interval (T) and rank (m) is calculated by the Weibull's formula (1939).

$$T = \frac{(N+1)}{m} \qquad ...(1)$$

where,

T = Is the return period (in years), m = Rank number of rainfall even after arranging in descending order, N = Total number of years for which the data (1994-2010) are available.

The probability of an event is the chance that it will occur when an observation of the random variable is made. It is the inverse of recurrence interval. Probability is denoted by 'p'. It is express as a percentage.

$$P = \frac{1}{T}100 \quad ...(2)$$

Statistical parameters:

The statistical parameters were calculated to evaluate the probability analysis for prediction of annual maximum rainfall for one to five consecutive month of Sultanpur region; the following statistical parameters were used.

The mean annual rainfall for the year 1994-2010 was calculated. The following formula was used to evaluate.

$$\bar{X} = \frac{\sum x}{N} \quad ...(3)$$

where,

$\bar{X}$ = Mean of the rainfall, Σx = Sum of the rainfall, N = Total number of rainfall.

The standard deviation of one to five consecutive month annual maximum rainfalls for the year 1994-2011 was calculated. The following formula was used to evaluate.

$$\sigma_n = \sqrt{\frac{\Sigma(X-\bar{X})^2}{N-1}} \quad ....(4)$$

where,

σ_n = Standard deviation, which is a function of sample size, N = Total number of rainfall (1994-2010), $\bar{X}$ = Mean of rainfall (1994-2010).

The co-efficient of skewness of one to five consecutive month annual maximum rainfalls for the year 1994-2010 was calculated. The following formula was used to evaluate.

$$C_s = \frac{N\Sigma(Z-\bar{Z})^3}{(N-1)(N-2)(\sigma_n)^3} \quad ....(5)$$

where,

$\bar{Z}$ = Log value of the rainfall data, Z = Mean value of the rainfall data, N = Sample size, σ_n = Standard deviation.

Probability of occurrence of rainfall:

Probability of occurrence of rainfall after the estimated return period was calculated with the following formula. The product of standard deviation and frequency factor (k) can be positive or negative, large or small, irregular and variable. It expressed as:

$$\chi_t = X + \bar{K} \times \sigma_n \quad ...(6)$$

where,

χ_t = Rainfall amount for return period of T years, X= The mean of rainfall data, σ_n = Standard deviation, $\bar{K}$ = Frequency factor which depends upon the return periods.

Comparison of three rainfall probability distribution models:

The following formula were used to evaluate rainfall probability distribution models (*viz.*, Gumbel, Log Pearson Type III and Log Normal) at 5.5, 11.5,16.6, 33.3 and 50 percentage levels. The calculations were given below.

The following steps were used to analyze the one to five consecutive month rainfall probability distributions Gumbel (1954).

– Mean of one to five consecutive month rainfall were calculated.

– Standard deviation (σ_n) was calculated by the given formula.

– Using Appendix Table A and Table B determine Y_n and S_n appropriate to given N.

– Reduced variate calculated as:

Table A : Reduced mean Yn for the Gumbel distribution

N	0	1	2	3	4	5	6	7	8	9
10	0.4952	0.4996	0.5035	0.5070	0.5100	0.5128	0.5157	0.5181	0.5202	0.5220
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5309	0.5309	0.5332	0.5343	0.5353
30	0.5362	0.5371	0.5380	0.5388	0.5396	0.5402	0.5402	0.5418	0.5424	0.5430
40	0.5436	0.5442	0.5448	0.5453	0.5458	0.5463	0.5463	0.5473	0.5477	0.5481
50	0.5485	0.5489	0.5493	0.5497	0.5501	0.5504	0.5504	0.5511	0.5515	0.5518
60	0.5521	0.5524	0.5527	0.5530	0.5533	0.5535	0.5535	0.5540	0.5543	0.5545
70	0.5548	0.5550	0.5552	0.5555	0.5557	0.5559	0.5559	0.5563	0.5565	0.5567
80	0.5569	0.5570	0.5572	0.5574	0.5576	0.5578	0.5578	0.5581	0.5583	0.5585
90	0.5586	0.5587	0.5589	0.5591	0.5592	0.5593	0.5595	0.5596	0.5598	0.5599
100	0.5600									

N= sample size

Table B : Reduced standard deviation S_n for the Gumbel distribution

N	0	1	2	3	4	5	6	7	8	9
10	0.9496	0.9676	0.9833	1.0095	1.0206	1.0316	1.0411	1.0411	1.0493	1.0565
20	1.0628	1.0696	1.0754	1.0864	1.0915	1.0961	1.1004	1.01004	1.1047	1.1086
30	1.1124	1.1159	1.1193	1.255	1.1285	1.1313	1.1339	1.1339	1.1363	1.1388
40	1.1413	1.1436	1.1458	1.1499	1.1519	1.1538	1.1557	1.1557	1.1574	1.1590
50	1.1607	1.1623	1.1638	1.1667	1.1681	1.1696	1.1708	1.1708	1.1721	1.1734
60	1.1747	1.1759	1.1770	1.1793	1.1803	1.1814	1.1824	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1890	1.1898	1.1906	1.1915	1.1915	1.1923	1.1930
80	1.1938	1.1945	1.1953	1.1967	1.1973	1.1980	1.1987	1.1987	1.1994	1.2001
90	1.2007	1.2013	1.2020	1.2032	1.2038	1.2044	1.2049	1.2049	1.2055	1.2060
100	1.2065									

N= Sample size

$$y_t = -\left[\ln \frac{T}{T-1}\right] \quad ...(7)$$

where,

y_t = reduced variate, a function of T, T = Recurrence interval in years (Assume).

– Calculate frequency factor of Gumbel distribution.

$$K = \frac{y_t - y_n}{S_n} \quad ...(8)$$

where,

y_t = Reduced variate, a function of T

Both Yn (Reduced mean) and S_n (Redacted standard deviation) are function of sample size N and its values are available in tabular form for various values of N (Subramanya, 1984).

– Predicted rainfall was calculated by the formula given as below.

$$\chi_t = \overline{X} + K \times \sigma_n \quad ...(9)$$

where,

$\overline{X}$ = Mean of rainfall, χ_t = Predicted rainfall amount for return period of T years, K = Frequency factor of Gumbel distribution, σ_n = Standard deviation.

Log Pearson type III distribution:

In this method, the sample (*i. e.* Z in this case) is first transformed into logarithmic form before analyzing. For Log Pearson type III distribution, K_z is a function of both the return period and the co-efficient of skewness. The values of K_z are given by water resources council (1967) shown in appendix Table C. These steps were taken for log Pearson type III distribution.

– Log_x = Z of all rainfall data was taken

– $\overline{Z}$ (mean of the log values) was calculated.

– $(Z-\overline{Z})$ was calculated

– $(Z-\overline{Z})^2$ was calculated

– $(Z-\overline{Z})^3$ was calculated

– Standard deviation (σ_n) was calculated by the formula

– Co-efficient of skewness (Cs) was obtained from the formula.

– The value of frequency factor (K_Z) was taken from the statistical table (Appendix C) corresponding to Cs to T (recurrence interval). Thus,

$$Z_t = \overline{Z} + K \times \sigma_n \quad ...(10)$$

where,

T= Recurrence interval of years. (Assume), K_z = Frequency factor of Log Pearson type III distribution, σ_n = Standard deviation.

– Predicted rainfall was calculated

χ_t = Antilog (Z_t)

Log normal distribution:

Chow (1964) has derived the frequency factor for the Log Normal distribution. In this method, the sample (*i. e.* X in this case) is first transformed into logarithmic form before analyzing when the skew is zero, *i.e.* C_s = 0, the Log Pearson type III distribution reduces to Log Normal distribution. These steps were taken by the Log Normal distribution which is given below.

– X = Log_x of all rainfall was taken

– $\overline{X}$ (Mean of log values) was calculated.

– $(X-\overline{X})$ was calculated

– $(X-\overline{X})^2$ was calculated

– $(X-\overline{X})^3$ was calculated

– Standard deviation (σ_n) was calculated by the formula.

– Co-efficient of skewness (C_s) was taken zero

Table C: Kz = F (Cs,T) for for use in Log-Pearson type III distribution

Co-efficient of skew, Cs	Recurrence interval T in years						
	2	10	25	50	100	200	1000
3.0	-0.396	1.180	2.278	3.152	4.051	4.970	7.25
2.5	-0.360	1.250	2.262	3.048	3.845	4.652	6.600
2.2	-0.330	1.284	2.240	2.970	3.705	4.444	6.200
2.0	-0.307	1.302	2.219	2.912	3.605	4.298	5.910
1.8	-0.282	1.318	2.193	2.848	3.499	4.147	5.660
1.6	-0.254	1.329	2.163	2.780	3.338	3.990	5.390
1.4	-0.225	1.337	2.128	2.706	3.271	3.828	5.110
1.2	-0.195	1.340	2.087	2.626	3.149	3.661	4.820
1.0	-0.164	1.340	2.043	2.542	3.022	3.489	4.540
0.9	-0.148	1.339	2.018	2.498	2.957	3.401	4.395
0.8	-0.132	1.336	1.998	2.453	2.891	3.312	4.250
0.7	-0.116	1.333	1.967	2.407	2.824	3.223	4.105
0.6	-0.099	1.328	1.939	2.59	2.755	3.132	3.960
0.5	-0.08.	1.323	1.910	2.311	2.686	3.041	3.815
0.4	-0.066	1.317	1.880	2.261	2.615	2.949	6.670
0.3	-0.050	1.309	1.849	2.211	2.544	2.856	3.525
0.2	-0.033	1.301	1.818	2.159	2.472	2.763	3.380
0.1	-0.017	1.292	1.75	2.107	2.400	2.670	3.235
0.0	0.000	1.282	1.751	2.054	2.326	2.76	3.090
-0.1	0.017	1.270	1.716	2.00	2.252	2.482	2.950
-0.2	0.033	1.258	1.680	1.945	2.178	2.388	2.810
-0.3	0.020	1.245	1.64.	1.890	2.104	2.294	2.675
-0.4	0.066	1.231	1.606	1.834	0.029	2.201	2.540
-0.5	0.083	1.216	1.567	1.777	1.955	2.108	2.400
-0.6	0.099	1.200	1.528	1.72	1.880	2.016	2.275
-0.7	0.116	1.183	1.488	1.663	1.806	1.926	2.15
-0.8	0.132	1.166	1.448	1.606	1.733	1.837	2.035
-0.9	0.148	1.147	1.407	1.549	1.660	1.749	1.910
-1.0	0.164	1.128	1.366	1.492	1.588	1.664	1.880
-1.4	0.225	1.041	1.198	1.270	1.318	1.351	13.465
-1.8	0.282	0.945	1.035	1.069	1.087	1.097	1.30
-2.2	0.330	0.844	0.888	0.900	0.905	0.907	0.910
-3.0	0.396	0.660	0.666	0.666	0.667	0.667	0.668

(Note: Cs = 0 corresponds to log-normal distribution)

for Log Normal distribution (Appendix C).

– The value of frequency factor (K_x) was taken from the statistical table (Appendix C) corresponding to C_s to T (recurrence interval). This:

$$X_t = \bar{X} + K \times X \sigma_n \quad ...(11)$$

Predicted rainfall was calculated as:

$$\chi_t = \text{Antilog}\,(x_t)$$

Test the goodness of fit:

The χ^2 test (Hogg and Tanis, 1977) is generally used to test the closeness of the expected values obtained by the fitted theoretical distribution and the observed values. For return period T, it is calculated as:

$$\chi^2 = \frac{\sum (O - E)^2}{E} \quad ...(12)$$

where,

O = Observed values for the return period, E = Expressed values for the return period

The least sum of the chi-square values gave the best fit.

Relationship between one day maximum rainfalls and two to five consecutive month maximum rainfall:

By using least square technique the relationship between two to five consecutive month maximum rainfall and one month maximum was established. The equation for slope and intercept are as follows:

$$Y = mx + c \quad ...(13)$$

$$m = \frac{N(\sum XY) + (\sum X)(\sum Y)}{N(\sum X^2) - (\sum X)^2}$$

and

$$C = \frac{(\sum y) - M + (\sum X)}{N} \quad ...(14)$$

where,

N = No. of observed data of x and y, M = Slope, x = One day annual maximum rainfall (mm), y = Two to five consecutive days annual maximum rainfall (mm), C = Intercept.

The co-efficient of correlation r is given by:

$$r = \frac{N(\sum xy) - (\sum x)(\sum y)}{\sqrt{N(\sum X^2) - (\sum X^2)} - \sqrt{N(\sum y^2) - (\sum y^2)}} \quad ...(15)$$

RESULTS AND DISCUSSION

One to five consecutive months annual maximum rainfall data were arranged in descending order. The expected values for one to five consecutive months annual maximum rainfalls were estimated by three most widely used probability distribution method *viz.*, Gumbel, Log Person Type III and Log Normal. The one to five consecutive months annual maximum rainfall values were

Table 1 : One to five consecutive months annual maximum rainfall different return periods in year (1994-2010)

Sr. No.	1 month, rainfall (mm)	2 month, rainfall (mm)	3 month, rainfall (mm)	4 month, rainfall (mm)	5 month, rainfall (mm)	Probability, P (%)	Recurrence interval (T), in years
1.	145.00	239.06	302.74	424.50	483.30	5.5	18
2.	81.16	167.90	282.40	387.03	406.60	11.1	9
3.	61.10	124.60	220.60	337.50	404.60	16.6	6
4.	49.36	123.00	217.90	335.00	322.10	22.2	4.5
5.	44.40	122.74	202.80	307.10	289.70	27.7	3.6
6.	38.60	115.50	202.40	269.66	271.70	33.3	3
7.	30.80	87.30	166.60	251.33	235.05	39.8	2.51
8.	18.70	86.35	161.20	220.47	229.30	44.4	2.25
9.	13.26	80.80	117.77	195.70	197.22	50.0	2.0
10.	12.90	68.50	108.28	188.00	159.95	55.5	1.8
11.	5.80	60.30	104.30	180.82	136.15	61.3	1.63
12.	4.33	51.14	94.34	178.22	131.15	66.6	1.5
13.	2.97	46.60	82.85	176.90	124.05	72.4	1.38
14.	0.25	15.16	81.24	166.68	117.42	78.1	1.28
15.	0.00	14.97	79.40	163.00	105.14	83.3	1.2
16.	0.00	14.03	70.21	121.03	91.83	89.2	1.12
17.	0.00	13.87	10.66	63.82	84.30	95.2	1.05

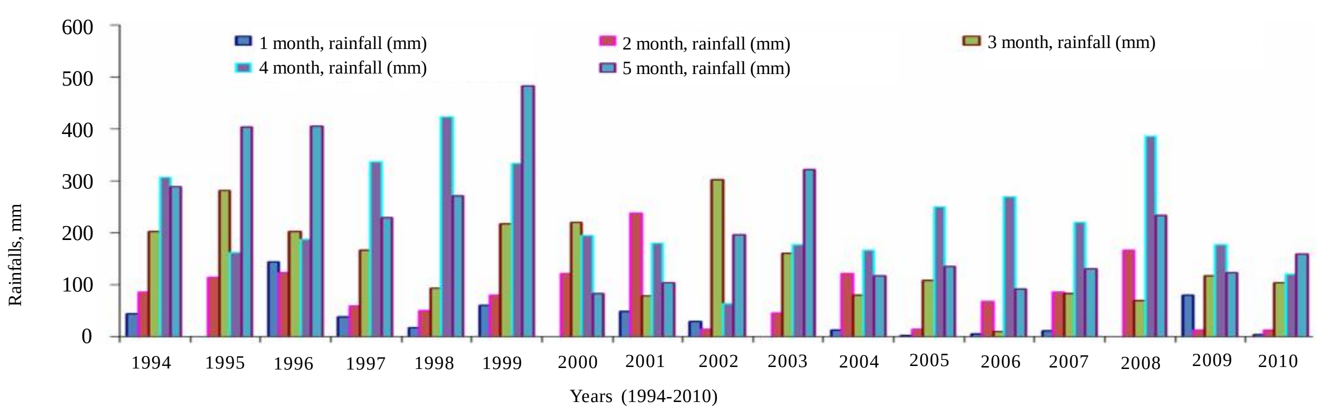

Fig. 1 : Comparison of annual maximum rainfall at different consecutive months

computed for recurrence intervals shown in Table 1. The Table 1 and Fig. 1 revealed that the maximum rainfall (mm) at Sultanpur was 145.00, 239.06, 302.74, 424.5, and 483.3 for one, two, three, four and five consecutive months, respectively.

The statistical parameter *i.e.* chi-square test for goodness of fit was conducted for all proposed models. The least value of the chi-square (χ^2) value is taken as the best (Bhatt, 1996 and Agrawal *et al.*, 1988). The rainfall data had been fitted were estimated at 5.5, 11.5, 16.6, 33.3 and 50 per cent probabilities levels.

The result of one month annual maximum rainfall is tabulated in Table 2. It shows that the sum of chi-square value is minimum (3.3455) for Log Normal, which reveals the overall accuracy of the model for predicting rainfall. But when the chi-square values where compared individually that result obtained that the better prediction at 11.5 per cent probability levels. The Log Normal is predicting the rainfall very near to the observed rainfall. Log Person type III is giving the better result but over all prediction by Log Normal is very close to be observed rainfall.

The result of two consecutive months annual maximum rainfall is tabulated in Table 3. It shows that the sum of chi-square value is minimum (9.6341) for Gumbel distribution. At 50 per cent and 5.5 per cent probability levels Log Person Type III and Log normal is also showing much nearer to observed values. The rainfall prediction by the Gumbel method is very close to the observed rainfall.

The result of three consecutive months annual maximum rainfall data are tabulated in Table 4 the table

Table 2 : Chi-square test of goodness of fit various distribution for one consecutive month annual maximum rainfall (mm)

P %	Return periods (T)	Observed rainfall (O), mm	Predicted rainfall (E), mm for one month			Chi-square $x^2 = \sum(O-E)^2/E$		
			Gumbel	LPIII	LN	Gumbel	LPIII	LN
50	2	80.80	76.29	77.14	61.09	0.2727	0.1736	0.3226
33.3	3	115.5	108.8	87.25	70.54	0.4125	9.1468	0.6373
16.6	6	129.6	157.51	124.27	108.6	6.876	0.0008	2.3572
11.5	9	167.9	184.09	178.92	167.19	1.4238	0.6260	0.0030
5.5	18	239.06	273.83	300.30	241.54	0.0063	12.4886	0.0254
			Total			8.9913	22.4358	3.3455

Table 3 : Chi-square test of goodness of fit various distribution for two consecutive month annual maximum rainfall (mm)

P %	Return periods (T)	Observed rainfall (O), mm	Predicted rainfall (E), mm for two month			Chi-square $x^2 = \sum(O-E)^2/E$		
			Gumbel	LPIII	LN	Gumbel	LPIII	LN
50	2	195.70	220.57	245.5	212.76	2.8041	10.1019	1.3679
33.3	3	269.66	272.78	260.1	229.26	0.0356	0.3513	7.1192
16.6	6	337.50	350.62	309.39	309.10	0.4931	2.5539	2.6093
11.5	9	387.03	393.18	367.99	381.37	0.0961	0.9851	0.0840
5.5	18	424.50	479.02	490.38	434.55	6.2052	8.8506	0.2324
			Total			9.6341	22.7945	11.4128

Table 4 : Chi-square test of goodness of fit various distribution for three consecutive month annual maximum rainfall (mm)

P %	Return periods (T)	Observed rainfall (O), mm	Predicted rainfall (E), mm for three month			Chi-square $x^2 = \sum(O-E)^2/E$		
			Gumbel	LPIII	LN	Gumbel	LPIII	LN
50	2	197.22	206.75	218.73	193.10	0.4392	2.1153	0.0879
33.3	3	271.70	272.83	236.23	211.00	0.0046	5.3258	17.4620
16.6	6	404.60	371.35	297.59	300.91	2.9771	38.4795	35.816
11.5	9	406.60	425.22	374.9	386.18	0.7318	2.6804	1.0797
5.5	18	483.30	533.85	511.20	450.97	5.1497	1.5227	2.3177
			Total			9.3024	50.2473	56.7633

gives the minimum sum of chi-square values (9.3024) for Gumbel distribution. The Gumbel distribution is predicting the rainfall very near to the observed rainfall.

The result of four consecutive months annual maximum rainfall is tabulated in Table 5. The table gives the least sum of chi-square values (14.4394) for Gumbel distribution which reveals the overall accuracy of the model for predicting rainfall while comparing the individual values Log Person and Log Normal gives the better result at 16.6 per cent probability levels. The rainfall prediction by Gumbel distribution is very close to the observed rainfall.

The result of five consecutive months is tabulated in Table 6 Gumbel distribution value (13.53) is least sum of the chi-square test which shows that Gumbel distribution is better than other distribution. The Log Person type III and Log Normal method also gives better result at 50 per cent probability level. The Gumbel distribution is predicting the rainfall very near to the observed rainfall.

Relationship between one month annual maximum rainfall with two to five consecutive months annual maximum rainfalls:

To study the behaviour of theoretical probability distribution with respect to the proposed models, values of co-efficient determination (R^2), slope (m) and intercept (c) for various consecutive months annual maximum rainfall were computed. In order to develop a relation between one months annual maximum rainfall and two to five consecutive months annual maximum rainfall and corresponding duration a simple method recommended by Singh *et al.* (1992). In this method simple regression were obtained. The relationship between different consecutive months annual maximum rainfall with one month annual maximum rainfall is presented in Table 7

Table 5 : Chi-square test of goodness of fit various distribution for four consecutive month annual maximum rainfall (mm)

P %	Return periods (T)	Observed rainfall (O), mm	Predicted rainfall (E), mm for four month			Chi-square $x^2 = \sum(O-E)^2/E$		
			Gumbel	LPIII	LN	Gumbel	LPIII	LN
50	2	117.17	136.77	159.08	120.11	2.6589	11.0412	0.07196
33.3	3	202.4	180.04	173.48	136.11	2.7769	4.8211	32.2853
16.6	6	220.6	244.56	224.98	224.46	2.3474	0.0852	0.0663
11.5	9	282.4	279.84	291.77	318.67	0.0234	0.3009	4.1281
5.5	18	302.74	350.99	485.36	397.02	6.6328	68.7120	22.3885
		Total				14.4394	84.9604	58.9401

Table 6 : Chi-square test of goodness of fit various distribution for five consecutive month annual maximum rainfall (mm)

P %	Return periods (T)	Observed rainfall (O), mm	Predicted rainfall (E), mm for five month			Chi-square $x^2 = \sum(O-E)^2/E$		
			Gumbel	LPIII	LN	Gumbel	LPIII	LN
50	2	13.26	24.85	15.28	10.06	5.3984	0.2670	1.0178
33.3	3	38.6	45.49	19.78	13.54	1.0435	17.9065	46.3800
16.6	6	61.1	76.26	42.91	44.53	3.0137	7.7109	6.1658
11.5	9	81.16	93.08	93.08	103.67	1.5264	1.5264	4.8876
5.5	18	145	127.01	196.38	172.95	2.5264	13.648	4.5169
		Total				13.53	41.0588	62.9681

Table 7 : Relationship between one month annual maximum rainfall with two to five months annual maximum rainfall

Equation	Correlation co-efficient
1 month Vs 2 day month Y2 =1.517x+38.80	0.9208
1 month Vs 3day month Y3 =1.870x+94.60	0.7999
1 month Vs 4 day month Y4 =2.307x+164.3	0.8324
1 month Vs 5 day month Y5 =3.018x+132.5	0.8893

and shown in Fig. 2, 3, 4 and 5. It revealed that slope of the equation are decreasing while intercept is changing but not in a same manner. The decreasing trend of negative intercept shows that consecutive month of annual maximum rainfall is decreasing as the number of months increases. The value of co-efficient of determination should tend towards zero. The co-efficient of determination for all the different consecutive months

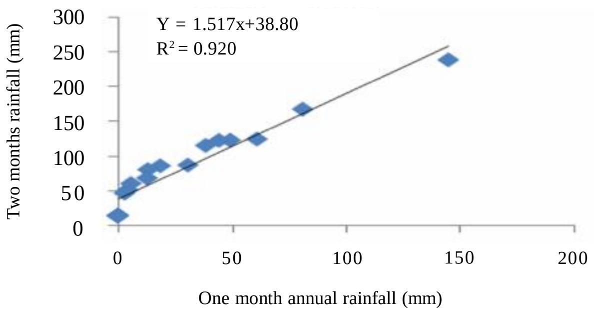

Fig. 2 : Comparison between one month maximum Vs two consecutive month annual maximum rainfall (mm)

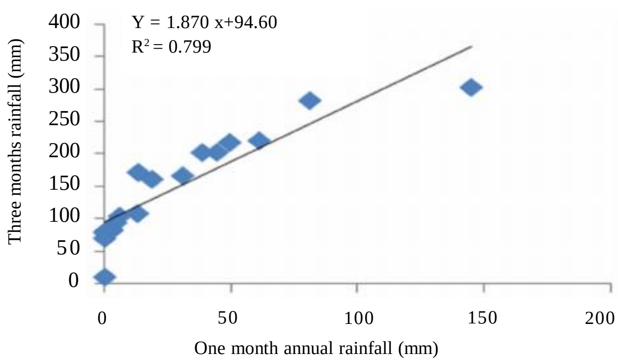

Fig. 3 : Comparison between one month maximum Vs three consecutive month annual maximum rainfall (mm)

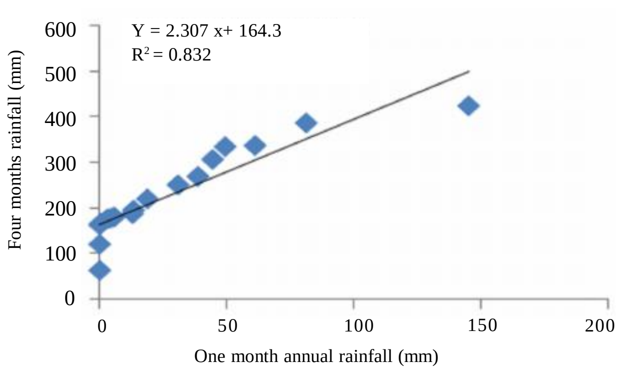

Fig. 4 : Comparison between one month maximum Vs four consecutive month annual maximum rainfall (mm)

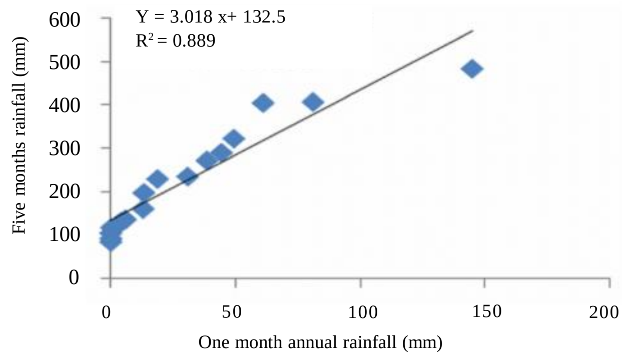

Fig. 5 : Comparison between one month maximum Vs five consecutive month annual maximum rainfall (mm)

is (*i.e.* 0.9208, 0.7999, 0.8324 and 0.8893) close to 1.0 which shows better dependences of different consecutive months annual maximum rainfall on one month annual maximum rainfall.

Summary and Conclusion:

The present study concluded those seventeen years (1994-2010) is sufficient to obtain one to five consecutive months maximum rainfall (mm) distribution pattern of Sultanpur region. Fig. 1 and Table 1 revealed that the maximum rainfall at Sultanpur was 145.00, 239.06, 302.74, 424.5, and 483.3 for one, two, three, three, four and five consecutive months maximum, respectively. The most suitable probability distribution function to represent the observed data may depend on rainfall pattern of the place. As rainfall pattern varies from place to place the most suitable distribution may also very from place to place.

– The statistical comparison at 5.5, 11.5, 6.6, 33.3 and 50 percentage probabilities by chi-square test for goodness of fit.

– Gumbel distribution was found to be best models for predicting two, three, four and five consecutive months maximum rainfalls (mm).

– Log Pearson type III results are fairly close to observed for one and four consecutive months maximum rainfall (mm).

– Rainfall prediction by Log Normal distribution is showing very near to the observed rainfall for one consecutive months maximum rainfall (mm).

– The co-efficient of determined for all the consecutive months is (*i.e.* 0.9208, 0.7999, 0.8324 and 0.8893) close to 1.0 which shows better dependence of consecutive months maximum rainfall on one month maximum rainfall. The co-efficient value of determination showed tends towards the zero.

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