

Original Research Article

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## Frequency Analysis for One day to Six Consecutive Days of Annual Maximum Rainfall for Mulde, Dist: Sindhudurg

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### ABSTRACT

The primary need of water resource development in any area depends on estimation of rainfall at different probabilities for efficient planning and design of irrigation and drainage systems, command area development, soil and water conservation programmes and the optimum utilization of water resources in various agricultural production systems. The annual maximum daily rainfall data of 18 years (1991 to 2008) was obtained from ARS, Mulde. It was analyzed for maximum one day and extended days (up to 6 day) rainfall for Mulde. Normal, Log Normal, Gumbel, Pearson Type-III and Log Pearson Type-III were used for extreme rainfall events. The relationships between annual maximum values of 1 day and D-days rainfall were found polynomial for Mulde ( $R^2 = 0.9292$  to  $0.9615$ ). Based on statistical test for goodness of fit, the Pearson Type-III distribution was found as the best fit for observed 2-day, 5-day and 6-day annual maximum rainfall. Log Normal distribution gives the best for the annual maximum one day and 3-day annual maximum rainfall data whereas, normal distribution gives the best for the annual maximum 4-day annual maximum rainfall data for Mulde. Maximum value of 1-day rainfall for Mulde ranges from 102.8 to 295.0 mm. Maximum value of 2-day rainfall ranges from 185.0 to 371.3 mm. Maximum value of 3-day rainfall ranges from 260.2 to 463.8 mm. Maximum value of 4-day rainfall ranges from 270.7 to 523.5 mm. Maximum value of 5-day rainfall ranges from 295.2 to 643.3 mm. Maximum value of 6-day rainfall ranges from 358.4 to 676.3 mm. An annual maximum rainfall of 167.03 mm in one day, 261.79 mm in two days, 335.24 mm in three days, 390.42 mm in four days, 450.22 mm in five days and 505.17 in six days was expected to occur at every two years. For recurrence interval of 100 years, the annual maximum rainfall expected in one day, two days, three days, four days, five days and six days was 368.31 mm, 487.73 mm, 588.90 mm, 700.17mm, 835.89 mm and 1068.35 mm, respectively. Consecutive day's rainfall analysis provides valuable information for planning and management of runoff in watershed.

#### Keywords

Annual maximum rainfall, Probability Distribution functions, Frequency analysis

#### Article Info

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## **Introduction**

Most of the hydrological events occurring as natural phenomenon are observed only once. One of the important problems in hydrology deals with interpreting past records of hydrological events in terms of future probabilities of occurrence. The procedure for estimating frequency of occurrence of a hydrological event is known as frequency analysis.

Analysis of consecutive days annual maximum rainfall of different return period is a basic tool for safe and economical planning and design of structural and non-structural measures, small and medium hydraulic structures such as dams, bridges, culverts, spillways check dams, ponds, irrigation and drainage works in watershed management and command area development programme. Probability analysis can be used for prediction of occurrence of future events from available records of rainfall (Kumar and Kumar, 1989). Based on theoretical probability distributions, it would be possible to forecast the rainfall of various magnitudes with different return periods. Several distributions have been used for hydrological analysis as given by Chow (1951) and Youjvich (1972).

Several attempts have been made at different places for frequency analysis of annual maximum daily rainfall (Agarwal *et al.*, 1988; Ajay Kumar *et al.*, 2007; Dabral and Pandye 2008; Jeevarathnam and Jayakumar 1979; Patle, 2008; Sethy *et al.*, 2005). Mulde comes under heavy rainfall zone having average annual rainfall 3128 mm still there is a scarcity of water from the month of March onwards.

This is due to undulating topography of the area steep slope more than 15 %. The hilly track is characterized by lateritic and hard rock. The soil texture in most of the part of

the study area is loam to sandy loam with reddish brown colour. Rill erosion is very severe and has resulted in formation of gullies. Construction of rainwater harvesting structures, nala bund, embankment and masonry check dam is an important activity carried out in this area. This activity is presently done without ascertaining the amount of rainfall and corresponding expected runoff for the desired return period. Due to this fact, many of the soil conservation structures, constructed with huge investment and labour are failing occasionally due to flash floods. However analysis of rainfall data for computation expected rainfall for the desire frequency and consequent excess rainfall is required for safe design of any structure. The knowledge of consecutive days maximum rainfall can lead to successful crop planning. For prediction of design rainfall fairly accurately, various probability distribution functions are used. This study is an attempt to identify best theoretical frequency distribution out of the five based on Chi-square test of goodness of fit.

## **Materials and Methods**

The daily rainfall data were collected from the meteorological observatory of Agriculture Research Station, Mulde (MS) located at an altitude of 17 m above mean sea level with 73°2'E longitude and 16°42'N latitude. The annual maximum daily rainfall data of 18 years (1991 to 2008) were analyzed.

The daily data, in a particular year, is converted to 2 to 6 days consecutive rainfall by summing up the rainfall of corresponding days. The annual maximum amount of 1-day to 6-days consecutive rainfall for each year was then taken for analysis.

The probability values were obtained by using Weibull formula (Chow 1964). The expected values of maximum rainfall were calculated

by five well known probability distributions, viz., Normal, Log Normal, Gumbel, Pearson Type-III and Log Pearson Type-III distribution at different selected probabilities ie. 99, 95, 80, 50, 20, 5 and 1 per cent levels. Among these five distributions, the best fit distribution decided by Chi-square test for goodness of fit to observed values by the following equation

$$C = \sum \frac{(O - E)^2}{E} \dots (1)$$

Where, O is the observed value and E is the estimated values. The best probability function was determined by comparing Chi-square values obtained from each distribution and selecting the function that gives smallest chi-square value.

### **Results and Discussion**

Extended day duration rainfall for 2, 3, 4, 5 and 6 days for Mulde was computed from the daily rainfall given in Table 1. Maximum value of 1-day rainfall for Mulde ranges from 102.8 to 295.0 mm. Maximum value of 2-day rainfall ranges from 185.0 to 371.3 mm. Maximum value of 3-day rainfall ranges from 260.2 to 463.8 mm. Maximum value of 4-day rainfall ranges from 270.7 to 523.5 mm. Maximum value of 5-day rainfall ranges from 295.2 to 643.3 mm. Maximum value of 6-day rainfall ranges from 358.4 to 676.3 mm.

### **Relationship between annual maximum values of 1-day and D-days rainfall for Mulde**

The relationships were established by using the observed 1-day annual maximum rainfall and computed D-days annual maximum rainfall for same return period. All the relationships were found polynomial in nature with  $R^2$  values ranging from 0.93 to 0.96. The relationships are shown in Table 2.

### **Probability analysis of annual maximum 1-day and D-days rainfall**

#### **Normal distribution**

The parameters mean ( $\bar{x}$ ) and standard deviation ( $\sigma_x$ ) of transformed 1-day rainfall are 178.43 and 47.11, respectively. The theoretical values of 1 day to 6-day annual maximum rainfall for different return periods are obtained using Normal distribution and they are presented in Table 3.

#### **Log normal distribution**

The statistical parameters such as mean ( $\bar{x}$ ), standard deviation ( $\sigma_x$ ) coefficient of variation and coefficient of skewness were computed for transformed data for 1-day and D-days rainfall. They are as 5.15, 0.26, 0.26 and 0.82, respectively. The theoretical values of 1 day and D-days annual maximum rainfall for different return periods are obtained using Log Normal distribution presented in Table 4.

#### **Gumbel distribution**

The mean and standard deviation of original data for 1-day annual maximum rainfall are 178.43 and 47.11 respectively. The theoretical values of 1-day to D-days maximum rainfall for different return periods are obtained using Gumbel distribution presented in Table 5.

#### **Pearson type III distribution**

The parameters viz mean, standard deviation and coefficient of skewness of transformed 1-day and D-days rainfall data were determined as 178.43, 47.11 and 0.81, respectively. The frequency factor,  $K_T$ , values were determined for different return periods corresponding to the value of coefficient of skewness. The theoretical values of annual maximum 1-day to D-days rainfall for different return periods are obtained using Pearson Type- III distribution and presented in Table 6.

**Table.1** One day and extended days rainfall (mm) for different return periods

Return period (Years)	1-D	2-D	3-D	4-D	5-D	6-D
19.00	295.0	371.3	463.8	523.5	643.3	676.3
9.50	257.6	351.2	457.8	505.5	601.7	657.2
6.33	218.0	320.0	421.0	505.0	588.5	652.8
4.75	210.0	319.8	417.0	496.8	587.4	643.4
3.80	198.6	318.4	415.2	482.8	544.8	625.8
3.17	184.8	314.2	393.5	481.6	524.0	607.7
2.71	183.5	307.0	373.4	448.3	489.5	586.6
2.38	178.0	306.5	373.0	437.4	488.2	524.9
2.11	172.6	297.6	360.3	401.0	469.8	524.6
1.90	172.0	260.6	324.4	381.6	463.5	501.7
1.73	169.4	253.6	301.5	381.0	442.6	497.1
1.58	167.5	244.5	300.2	355.0	423.4	483.1
1.46	157.7	229.8	299.9	346.8	400.9	475.4
1.36	154.0	226.1	298.6	342.3	394.3	458.3
1.27	153.2	223.0	275.2	324.3	390.4	438.2
1.19	119.2	200.0	267.7	316.2	370.7	426.7
1.12	117.8	192.8	264.4	310.0	343.0	364.0
1.06	102.8	185.0	260.2	270.7	295.2	358.4

**Table.2** Relationship between 1-day and D-days annual maximum rainfall

D days	Relationship	R <sup>2</sup>
2	$Y = 1E-06x^4 - 0.0011x^3 + 0.3344x^2 - 40.297x + 1882.7$	0.94
3	$Y = 1E-06x^4 - 0.0012x^3 + 0.3645x^2 - 46.662x + 2332.9$	0.94
4	$Y = 2E-06x^4 - 0.0015x^3 + 0.4654x^2 - 57.745x + 2780$	0.93
5	$Y = 1E-06x^4 - 0.0011x^3 + 0.3302x^2 - 40.42x + 2016.6$	0.96
6	$Y = 2E-06x^4 - 0.0016x^3 + 0.4935x^2 - 60.676x + 2953.8$	0.95

x = One day maximum rainfall, mm (102.8 <x< 295.0); Y = Extended day maximum rainfall, mm

**Table.3** Theoretical values of 1-day to extended days rainfall (mm) using Normal distribution

Sr. No	Return period (Years)	1-D	2-D	3-D	4-D	5-D	6-D
1	1.0101	68.80	141.99	188.79	219.09	243.79	293.71
2	1.0526	100.91	180.49	235.48	273.87	310.07	362.31
3	1.25	138.78	225.89	290.53	338.47	388.24	443.21
4	2	178.43	273.41	348.17	406.10	470.07	527.90
5	5	218.07	320.94	405.81	473.73	551.90	612.59
6	20	255.94	366.33	460.87	538.33	630.06	693.49
7	100	288.05	404.83	507.56	593.11	696.34	762.09

**Table.4** Theoretical values of 1-day to extended days rainfall (mm) using Log Normal distribution

Sr. No	Return period (Years)	1-D	2-D	3-D	4-D	5-D	6-D
1	1.0101	108.59	179.46	234.99	270.47	308.89	314.99
2	1.0526	119.91	196.88	256.69	296.31	339.13	354.24
3	1.25	138.78	223.30	289.34	335.33	384.37	415.37
4	2	167.03	261.79	335.24	390.42	450.22	505.17
5	5	211.26	316.22	399.24	467.65	543.84	637.24
6	20	277.85	393.14	485.84	572.80	674.59	827.26
7	100	368.31	487.73	588.90	700.17	835.89	1068.35

**Table.5** Theoretical values of 1-day to extended days rainfall (mm) using Gumbel distribution

Sr. No	Return period (Years)	1-D	2-D	3-D	4-D	5-D	6-D
1	1.0101	101.12	180.74	235.78	274.23	310.50	362.75
2	2	170.68	264.14	336.93	392.90	454.10	511.37
3	5	212.32	314.05	397.46	463.93	540.04	600.32
4	10	239.88	347.09	437.53	510.94	596.93	659.20
5	25	274.75	388.90	488.23	570.43	668.91	733.70
6	50	301.01	420.37	526.41	615.22	723.11	789.80
7	100	326.20	450.57	563.03	658.19	775.10	843.60

**Table.6** Theoretical values of 1-day to extended days rainfall (mm) using Pearson type III distribution

Sr. No	Return period (Years)	1-D	2-D	3-D	4-D	5-D	6-D
1	1.0101	96.66	140.40	202.99	219.28	251.88	288.51
2	2	113.07	179.88	241.21	273.95	313.26	360.32
3	5	138.22	225.99	289.82	338.46	387.75	443.57
4	10	172.20	273.77	344.97	406.06	468.24	529.08
5	25	215.00	321.04	404.65	473.72	551.31	612.92
6	50	265.06	365.71	466.06	538.40	633.12	691.46
7	100	315.20	403.23	521.62	593.29	704.41	756.89

**Table.7** Theoretical values of 1-day to extended days rainfall (mm) using Log Pearson type III distribution

Sr. No	Return period (Years)	1-D	2-D	3-D	4-D	5-D	6-D
1	1.0101	93.54	154.53	219.28	237.68	266.69	310.46
2	2	173.38	271.02	341.19	402.72	465.59	524.81
3	5	215.27	321.37	402.72	473.15	552.08	613.76
4	10	240.43	348.33	440.55	512.86	598.41	660.69
5	25	271.64	378.44	485.29	555.9	650.13	712.85
6	50	293.76	398.11	516.42	583.45	683.91	751.62
7	100	314.05	415.91	547.02	609.54	714.50	783.42

**Table.8** Chi-square test of goodness of fit for probability distributions for annual maximum 1-D to 6-D rainfall of Mulde for different distributions.

Sr. No	Consecutive days`	Normal Distribution	Log Normal Distribution	Gumbel Distribution	Pearson Type III Distribution	Log Pearson Type III Distribution
1	1- D	10.3	6.8	9.0	8.0	8.6
2	2- D	6.4	7.0	11.9	6.3	8.3
3	3- D	3.6	3.2	7.0	3.7	7.5
4	4- D	4.07	8.7	8.2	4.09	17.5
5	5- D	4.7	6.8	7.9	4.5	21.1
6	6- D	7.05	15.5	13.1	6.96	20.4



### Log Pearson type III distribution

The parameters like mean, standard deviation and coefficient of skewness of transformed data for 1-day and D-days rainfall were determined as 2.238, 0.113 and -0.044 respectively.

The theoretical values of annual maximum 1-day to D-days rainfall for different return periods are obtained using Log Pearson Type-III distribution and presented given in Table 7.

### Test for goodness of fit

The observed and expected values of rainfall were statistically compared for their goodness of fit using Chi-square test. The Chi-square values for various return periods were calculated and are presented in Table 8.

The Pearson Type-III distribution was found as the best fit for observed 2-day, 5-day and 6-day annual maximum rainfall. Log Normal distribution gives the best for the annual maximum one day and 3-day annual maximum rainfall data whereas; Normal distribution gives the best for the annual maximum 4-day annual maximum rainfall data. An annual maximum rainfall of 167.03 mm in one day, 261.79 mm in two days, 335.24 mm in three days, 390.42 mm in four days, 450.22 mm in five days and 505.17 in six days was expected to occur at every two years.

For recurrence interval of 100 years, the annual maximum rainfall expected in one day, two days, three days, four days, five days and six days was 368.31 mm, 487.73 mm, 588.90 mm, 700.17 mm, 835.89 mm and 1068.35 mm, respectively. Consecutive day's rainfall analysis provides valuable information for planning and management of runoff in watershed.

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