Frequency analysis for one to five consecutive days annual maximum rainfall for Panchmahals of Central Gujarat

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ABSTRACT

Daily rainfall data for a period of 32 years (1974-2005) of Panchmahals of Central Gujarat have been analyzed by using five different theoretical distribution functions. The observed values are estimated by Weibull's formula and expected values were estimated by Normal, Lognormal, Gumbel's, Log Persons Type-III and Person Type-III distribution functions. The values obtained thus have been compared with observed values. The analysis indicates that Lognormal and Log Person type III gives the closest fit to the observed data. Chi-Square test showed the Lognormal distribution was the best fit distribution function for the Panchmahals region.

Key words: Rainfall; Frequency Analysis; Plotting Position Method;

The analysis of consecutive days maximum rainfall of different return periods is important for safe and economical planning and design of small and medium hydraulic structures such as small dams, bridges, culverts, drainage works etc.

Though the nature of rainfall is erratic and varies with time and space, it is necessary to estimate design rainfall fairly accurately for certain return periods using various probability distributions. Five commonly accepted functions are Normal, Lognormal, Gumbel's, Log Person Type-III and Person Type-III distribution (Upadhyaya and Singh 1998). Frequency analysis of a rainfall data has been attempted for different places in India (Jeevrathanam and Jay Kumar 1979;

Sharada and Bhushan 1985; Prakash and Rao 1986; Aggarwal *et al.* 1988; Bhat *et al.* 1996; Kumar 1999; Mohanthy *et al* 1999; Rizvi *et al* 2001; Sigh, 2001; Vijay Kumar, 2003; Shety *et.al*, 2004). In the present paper, frequency analysis of annual 1-day and 2 to 5 consecutive days maximum rainfall for watershed management planning of Panchmahal (Gujarat state) has been carried out by using frequency factor.

THE STUDY AREA

The Panchamahal district of Gujarat state falls between 22° 41´ 38˝ N latitude and 73° 33´ 22˝ E longitude. This district has total geographical area of about 885000 ha, out of which the cultivated area is about 473400 ha. The average annual rainfall is 871 mm and its distribution is quite uneven.

The mean monthly maximum temperature ranges between 26°C and 40°C, while the minimum monthly temperatures varies between 10.8° C and 26.4° C. The area has sandy loam soil, highly truncated and gently sloping terrain on both the sides of river results in quick build up of run off into shallow precipitous tributaries that drain into Mahi river. This region is characterized by semi –arid climate with little or no water surplus (Bhattacharjee *et al.*1982).

MATERIALS AND METHOD

Daily rainfall data of thirty-two years (1974 – 2005) was collected from Gujarat Agriculture University, Derol Station, Maize Research Station, Godhra and Collector Office's office of Panchamahal district for frequency analysis. The daily rainfall data for each year, is converted to 2 to 5 days consecutive days units. The maximum amount of 1 day and 2 to 5 days consecutive days rainfall for each year was taken for analysis. The observed frequency was calculated using the Weibull's plotting position method.

To apply plotting position method, rainfall for various consecutive days was arranged in descending order and ranking was done with rank one to the maximum rainfall value. Return period (T, years) is calculated by the following formula

$$T=N+1/m$$

Where,

N- Total number of years of record and m- Rank number.

Rainfall values are plotted against return period and best-fit equation curve was obtained. From this best fit equation, rainfall corresponding to return period of 1.05, 1.25,2.5,10,20 and 25 years were computed.

The following statistical distributions were used in the analysis.

Chow (1951) has given a general equation for hydrological frequency analysis:

$$X_T = X_{av} + K_T s$$

Where, X_T = is the rainfall amount for a return period of T years, X_{av} = is the mean rainfall series, s = is the standard deviation of rainfall series and K_T = is the frequency factor.

Frequency factor is dependent on the return period and probability distribution assumed for the series. But, in the case of skewed distributions, its value varies with the coefficient of skewness and can be affected greatly by the number of years of record.

A brief description of frequency analysis factors for various probability distributions is given below:

Normal distribution

In normal distribution, frequency factor is calculated as

$$K_r = u - \frac{2.515517+0.8022853u+0.010328u^2}{1+1.4327884u+0.1892u+0.001308u^3}$$

Where,

$$u = [\ln(1/p^2)]^{0.5}, p = 1/T, 0 < p \gamma 0.5,$$

For p>0.50, (1-p) can be substituted in this equation and value of K_T computed is assigned with negative sign.

Log-Normal distribution

Frequency factor for this distribution is given by Chow (1964) as

$$K_T = \frac{e^{\sigma_y k - \sigma_y^2/2}}{[e^{\sigma_y^2} - 1]^{0.5}}$$

Where, $y = \ln x$, $k_y = (y - y_{av})/\sigma_y$,

σ_y =Standard Deviation of log transformed data.

Gumbel's distribution

Annual rainfall data series of extreme events less than 100 years length of records, the frequency factor for practical use is (Subramanya, 1984)

$$K_T = y_T - y_n/S_n$$

$$y_T = -[\ln\{\ln(T/T-1)\}]$$

Where, T = return period, y_n = reduced mean, S_n = reduced standard deviation

Both Y_n and S_n are function of sample size N and its value is available in tabular form for various value of N (Subramanya, 1984)

Person Type –III distribution

The frequency factor for this distribution is related to the return period and skew ness coefficient, and is available in standard tabular forms (Hann, 1994).

Log Person Type –III Distribution

Frequency factors for this distribution are also available in tabular forms for various recurrences interval and skew coefficients (Hann, 1994).

All five probability distribution functions were compared by Chi-square test of goodness of fit.

RESULTS AND DISCUSION

The statistical parameters of annual 1-day as well as annual consecutive days maximum rainfall are shown in Table 1. The one-day maximum rainfall was 303 mm for the year 1978 with a return period of 28 years, while the minimum rainfall was 60.5 mm for 1974 with a return period of 1.05 years.

The data presented in Table, 2 gives the 1-day and consecutive days maximum rainfall for different return periods as determined by the selected distributions. A maximum of 103.5 mm rainfall in 1-day, 144.0 mm in 2 –days, 189.7 mm in 3 days, 226.2 mm in 4 days and 268.1 mm in 5 days is excepted to occur at Panchmahals every 2 years. For the recurrence interval of 100 years, the maximum rainfall expected in 1-day, 2-days, 3-days, 4-days and 5 days is 290.1 mm, 480.0 mm, 682.4 mm, 688.8 mm and 698.2 mm, respectively.

The data presented in Table. 3 reveal

Table 1 : Statistical parameters of annual 1-day as well as consecutive days maximum rainfall.

Sr.No.	Parameters.	1-day	2-day	3-day	4-day	5-day
1.	Minimum (mm)	60.5	77.5	113.2	112.2	125.4
2.	Maximum (mm)	303.0	403.0	609.50	618.5	627.5
3.	Mean (mm)	128.0	167.0	226.0	225.5	290.6
4.	Standard deviation (mm)	59.0	74.7	110.0	111.61	116.7
5.	Coefficient of variation	0.50	0.44	0.48	0.43	0.40
6.	Coefficient of skew ness	1.1	1.38	1.74	1.32	0.91

Table 2 : 1-Day as well as consecutive days maximum rainfall for various return periods

Sr.No.	Return period (years)	Maximum rainfall (mm)				
		1-day	2-day	3-day	4-day	5-day
1.	1.053	60.5	82.6	118.0	128.3	132.3
2.	1.25	80.5	111.5	132.7	161.2	185.7
3.	2	103.5	144.0	189.7	226.2	268.1
4.	5	120.5	210.5	293.9	312.0	365.6
5.	10	160.8	284.5	386.9	372.0	414.2
6.	20	190.5	328.0	459.0	476.0	445.2
7.	25	210.0	360.0	608.2	589.0	509.0
8.	50	240.2	402.5	680.0	618.7	627.2
9.	100	290.1	480.0	682.4	688.8	698.2

Table 3 : Computed Chi-squared value of different probability distribution functions for one and consecutive days annual maximum rainfall.

Consecutive days	Probability distribution functions				
	Normal	Log-Normal	Gumbel's	Person type-III	Log Person Type-III
1-day	52.25	0.58	146	26.72	14.25
2-day	71.56	16.00	69.75	24.04	19.25
3-day	338.56	15.65	245	28.85	13.53
4-day	34.35	12.56	105.5	12.25	10.42
5-day	36.04	8.95	55.65	12.65	8.14

that, the computed chi-square values for five probability distributions were found to be less than the critical value of chi-square at 95% confidence level for 1-day as well as consecutive days maximum rainfall series. Lognormal distribution gave minimum value of X^2 for annual 1 day, 4-days and 5-days consecutive maximum rainfall as also the Log Person type –III distribution for 4 and 5-days rainfall series. The statistical comparison by Chi-Square test for goodness of fit clearly shows that Log normal and Log person type-III distribution were the best fitting representative function for rainfall frequency analysis in this region.

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