RAINFALL ANALYSIS IN MICROWATERSHEDS OF UPPER DAMODAR VALLEY

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Abstract: Daily rainfall data of 20 years (1972-91) was collected from the local observatories of Bishnugadh in Upper Damodar Valley. The data are analysed by fitting different distributions like Normal, Lognormal (LN), Log Pearson-III (LP-III) Gumbel and Gamma. One day maximum, weekly, monthly and seasonal rainfall data are fitted in the above distributions and their corresponding rainfall events are estimated at 20, 40, 60 and 80% probabilities of exceedence. From the present rainfall analysis, it is observed that, Gumbel followed by Gamma are identified the best for one day maximum rainfall; Log Normal for weekly rainfall; Gumbel for monthly rainfall and Normal, Gumbel and Log Normal for seasonal rainfall. The above inferences are drawn based on the minimum D-index values obtained in the analysis.

INTRODUCTION

Rainfall is a random hydrologic event which is highly variable in both space and time. Being the primary source of water resource development in the micro-watersheds, its estimation at different probabilities is important for efficient planning of soil and water conservation programmes and the optimum utilization of water resource in various production systems. Most of the watershed planning activities include the estimation of runoff volume, design of water storage structures and design of erosion control structures and efficient utilisation of run off for irrigation to different crops. Hence, analysis of rainfall at different time interval like one day, weekly, monthly and seasonal is important for better planning and management of costly input like water. The rainfall analysis was done by fitting different theoretical distributions like Normal, Log Normal (LN), Pearson Type-III, Gamma and Gumbel. A study conducted in Kullu Valley reveals that Gumbel distribution fitted well to the observed rainfall data of annual, seasonal, monthly and weekly totals (Rana and Thakur, 1995). There are several analyses of rainfall data by fitting different theoretical distributions for drainage planning (Bhattacharya and Sarkar, 1982; Abdul Islam and Ashwini Kumar, 1997). Similarly, the present rainfall analysis is done to identify the distributions suitable for estimation of rainfall and its occurrence at different probabilities in Upper Damodar Valley region of South Bihar.

MATERIAL AND METHODS

The study area is situated nearby the village Urgi in watershed no. 8/5 of Upper Damodar Valley catchment area of south Bihar and the catchment is divided into number of micro-watersheds and treated with soil and water conservation measures. It is 42 km away from Hazaribagh and 2 km from Bishnugadh. The latitude and longitude of the area are 24°2' N and 85°43'E respectively. The daily rainfall data for the months (June-October) was collected from the local meteorological observatories of Bishnugadh for the period of 20 years from 1972-1991. Five distributions *viz.* Normal, LN, LP-III, Gamma and Gumbel are considered for the present rainfall analysis. The rainfall total of one

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day maximum, weekly, monthly and seasonal (June-September) were made and fitted with above distributions. The Weibull's plotting position was used for calculating observed rainfall at different probabilities of 20%, 40%, 60% and 80%. For comparison of relative fitness of different distributions, D-index (Verma *et al.*, 1989) was calculated as given below and distribution with minimum index value was considered as best fit distribution.

$$D\text{-}Index = \sum_{i}^{4} \frac{\left| X_i.\ Observed - X_i.\ Estimated \right|}{\bar{X}} \quad \ldots(1)$$

Where $\bar{X}$= Mean of the observed rainfall, mm

i = Series of rainfall amounts at 20, 40, 60 and 80% probabilities of exceedence

For analysing weekly rainfall totals, the data comprised of 362 of non-zero events out of total 440 (22 standard weeks). To treat the zero's in weekly rainfall analysis, the joint probability method suggested by Haan (1994) is used to estimate the probability of exceedence of rainfall as given below:

$$Prob(X \geq x) = Prob(X \neq 0)Prob(X \geq x / X > 0) \quad \ldots(2)$$

For the analysis of weekly and monthly rainfall totals, the daily rainfall data from June to October are used. For seasonal rainfall analysis, a total of June to September months is considered. The rainfall amounts associated with 20%, 40%, 60% and 80% of exceedence, were estimated by using standard methods of selected distributions. Some of the best fitted distributions with rainfall data are given below:

Normal distribution

$$P_z(Z) = \frac{1}{\sqrt{2p}} e^{-\frac{z^2}{2}}, -\alpha < Z < \alpha \quad \ldots(3)$$

Where Z = standard normal variate

$Z = (x-\bar{X})/\sigma$

$\bar{X}$ = mean of the rainfall data, mm

σ = standard deviation of the rainfall data, mm

Gumbel Distribution

$$P_x = e^{-ey} \quad \ldots(4)$$

Where y = reduced random variate

$X_1 = \bar{X}(1+KC_V)$

CV = coefficient of variation ($\sigma/\bar{X}$)

$K = (y-\bar{y}_n)/\sigma_n$

$\bar{Y}_n$ = expected mean of reduced extremes

σ_n = Expected standard deviation of reduced extremes (the value of $\bar{Y}_n$ and σ_n are taken from standard tables for the given 'n' number of observations)

Lognormal Distribution

$$P_x(Z_y) = \frac{1}{\sqrt{2\pi}} e^{\frac{z_y^2}{2}} \quad \ldots(5)$$

Where $Zy-(y-\bar{y})/\sigma_y$

$y=\ln X$; $\bar{y} = \ln X$

$\sigma_y = \ln \sigma$

$X_1 = \text{Antilog}\ (y+\sigma_y.Zy)$

For normal and lognormal, the standard variates for the selected probabilities are obtained from the standard tables and the corresponding rainfall was estimated.

RESULTS AND DISCUSSION

The estimated one day maximum rainfall at different probabilities are presented in Table 1. It is seen from this table that the per cent deviations from the observed rainfall data (Weibull distribution), are more in numerical value at both 20% and 80% probabilities. The per cent deviation values ranged from 2.44 and 13.52 at 20% probability and 7.19 to 18.53 at 80% probability. Moreover, the numerical deviations are observed to be more in Normal,

LN and LP-III distributions when compared to Gumbel and Gamma. Also, D-index is observed to be minimum (0.19) for Gumbel, followed by Gamma with 0.20. Hence, Gumbel and Gamma distributions fitted well with the one day maximum rainfall and give the reliable estimates in the selected study region. The estimated weekly rainfall presented in Table 2 indicates that the per cent deviations are numerically minimum (3.71 to 25.28) in LN distribution when compared to other distributions. The D-index value for LN distribution is minimum (0.62) over the other distributions. It can be inferred from the above results that Lognormal distribution used for estimating weekly rainfall totals is the best fitted for the study region. For the weekly rainfall totals, Normal, Gumbel and Gamma distributions gave over estimate of rainfall with high per cent deviations (16.05 to 122.99) from the observed rainfall (Table 2).

Table 1: Estimated one day maximum rainfall (mm) at different probabilities from selected distributions

Probability of exceedence	Distributions					
	Normal	LN	LP-III	Gumbel	Gamma	Weibull
20%	128.5 (-7.62)	120.3 (-13.52)	125.9 (-9.49)	131.1 (-5.75)	135.7 (-2.44)	139.1
40%	108.3 (7.77)	102.3 (1.89)	103.0 (2.89)	104.3 (3.88)	107.1 (6.67)	100.4
60%	90.8 (4.37)	84.1 (-12.07)	76.5 (-12.07)	85.1 (-2.18)	89.3 (2.64)	87.0
80%	70.4 (12.46)	69.6 (11.18)	51.0 (-18.53)	67.1 (7.19)	70.0 (11.82)	62.6
Mean	99.5 (2.26)	94.1 (-3.29)	89.2 (-8.33)	96.9 (-0.39)	100.5 (3.34)	97.3
D-Index	0.31	0.32	0.39	0.19	0.20	

Values given in parentheses are per cent deviations from the observed data.

Table 2: Estimated weekly rainfall (mm) at different probabilities from selected distributions

Probability of exceedence	Distributions					
	Normal	LN	LP-III	Gumbel	Gamma	Weibull
20%	115.5 (19.57)	121.0 (25.28)	102.9 (6.52)	112.1 (16.05)	115.8 (19.88)	96.6
40%	85.9 (38.55)	58.7 (-5.37)	74.2 (19.68)	76.9 (24.03)	73.7 (18.87)	62.0
60%	52.9 (51.14)	33/7 (-3.71)	53.0 (51.43)	53.0 (51.43)	50.0 (42.86)	35.0
80%	38.8 (122.99)	18.5 (6.32)	13,0 (22.41)	33.0 (89.66)	31.6 (81.61)	17.4
Mean	73.3 (38.91)	58.0 (99.0)	60.9 (15.45)	68.8 (30.33)	67.8 (28.48)	52.8
D-Index	1.56	0.62	0.77	1.21	1.14	

Values given in parentheses are per cent deviations from the observed data.

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D-Index	1.56	0.62	0.77	1.21	1.14	

Values given in parentheses are per cent deviations from the observed data.

The estimated monthly and seasonal rainfall totals at 20, 40, 60 and 80% probabilities are presented in Table 3 and Table 4. A close perusal of Table 3 indicates that Gumbel distribution gives reliable estimate of monthly rainfall with minimum D-index value of 0.16, when compared to other distributions. Moreover, the per cent deviations ranged from 1.43 to 5.24 and are the lowest at all probabilities for the Gumbel distribution. The normal followed by Gumbel and LN distributions are well fitted for seasonal rainfall data with D-index values of 0.12, 0.13 and 0.14 respectively (Table 4). The per cent deviations are also observed to be lower than the values under Gamma and LP-III distributions at all probabilities for seasonal rainfall.

Table 3: Estimated monthly rainfall (mm) at different probabilities from selected distributions

Probability of exceedence	Distributions					
	Normal	LN	LP-III	Gumbel	Gamma	Weibull
20%	350.8 (6.87)	376.7 (14.78)	359.6 (9.57)	340.8 (3.84)	327.1 (-0.34)	328.2
40%	261.5 (16.02)	193.4 (-15.20)	266.6 (18.28)	237.2 (5.24)	210.7 (-6.52)	225.4
60%	185.4 (15.23)	103.9 (-35.43)	89.2 (-44.56)	163.2 1.43)	132.1 (-17.90	160.9
80%	96.0 (7.38)	59.7 (-33.22)	13.5 (-84.90)	93.9 (5.03)	32.1 (-64.09)	89.4
Mean	223.4 (11.17)	183.4 (-8.73)	182.2 (-9.33)	208.8 (3.88)	175.5 (-12.68)	201.0
D-Index	0.45	0.83	1.10	0.16	0.51	

Values given in parentheses are per cent deviations from the observed data

Table 4: Estimated seasonal rainfall (mm) at different probabilities from selected distributions

Probability of exceedence	Distributions					
	Normal	LN	LP-III	Gumbel	Gamma	Weibull
20%	1228.6 (-3.36)	1230.0 (-3.25)	1232.2 (-3.08)	12.51.4 (-1.57)	1152.8 (-9.32)	1271.3
40%	1100.0 (0.23)	1090.6 (-0.71)	1093.5 (-0.45)	1077.3 (-1.92)	1041.71 (-5.16)	1089.4
60%	992.2 (-2.77)	958.0 (-6.12)	920.8 (-9.77)	953.1 (-6.60)	930.6 (-8.81)	1020.5
80%	864.4 (6.62)	848.0 (4.60)	741.1 (-8.59)	836.6 (3.19)	819.1 (1.04)	810.7
Mean	1046.5 (-0.35)	1031.6 (-1.77)	996.9 (-5.08)	1029.6 (-1.96)	986.1 (-6.11)	1050.2
D-Index	0.12	0.14	0.20	0.13	0.21	

Values given in parentheses are per cent deviations from the observed data

CONCLUSIONS

A twenty years (1972-91) daily rainfall data were obtained from the local observatories of Bishnugadh area in the Upper Damodar Valley. The data are analysed for fitting one day maximum, weekly, monthly and seasonal rainfall data, through distributions like Normal, LN, LP-III, Gumbel and Gamma. From the present rainfall analysis over the study area, the following distributions are identified for the reliable estimates of rainfall of different time interval considered:

1. Gumbel and Gamma distribution can be used for the estimation of one day maximum rainfall.
2. Lognormal can be used for fitting the weekly rainfall data and provides reliable estimates at different probabilities.
3. Gumbel distribution is identified as the best fitting distribution for the estimation of monthly rainfall at different probabilities.
4. Normal Gumbel and Log Normal distributions can be used as given in their order of preference for estimation of seasonal rainfall at different probabilities.

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