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Probability analysis of rainfall for Udhagamandalam

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ABSTRACT

Daily rainfall data of 43 years (1960-2002) of Udhagamandalam were used for annual, seasonal and monthly analysis at different probability levels to obtain the rainfall distribution pattern. At 80 per cent probability level, the rainfall available in the first (May to August) and second (September to November) season are more than the water requirement of the crops which are grown in this region. In the third season (December to April) the rainfall availability is not enough to support any crop without irrigation. Annual maximum daily rainfall was estimated at different return period which will be useful for design of any water harvesting and soil conservation structures. The annual one day maximum rainfall at 50 and 100 years return period was found to be 238.8 and 293.6 mm, respectively. The depth-duration-frequency relationship was developed for duration of 1 to 6 days maximum rainfall for different frequency.

Key words: Probability analysis; frequency analysis, Weibull's formula, return period, probability density function, Depth-duration-frequency relationship

Udhagamandalam forms a part of the Nilgiris district of Tamil Nadu which is located in the confluence of the Western and Eastern Ghats at a latitude of 11°11' N to 11°42'N and longitude of 76°14' E to 77°01'E. It is predominantly a hilly area with elevation ranging up to 2636m above MSL. The geographical area of the Nilgiris district is 2529 sq. kilometer. The area receives an annual rainfall of 1214mm (average of 1960-2002) spread all over the three seasons of the year viz., May to August, September to November and December to April. This rainfall is mainly received through the South-West monsoon which spans from May to August and North-East Monsoon which spans from September to November. In the remaining part of the year i.e. December to April, the rainfall is scanty and unevenly distributed.

In Udhagamandalam commonly grown annual crops are Potato, Cabbage, Carrot, Beans, Peas, Radish, Cauliflower, Beetroot etc. The different crops are being raised under rainfed condition depending upon the availability of rainfall. As the rainfall is unevenly distributed through out the year, analysis of rainfall and its distribution is very much important for crop planning, safe disposal of excess runoff based on crop tolerance and hydrological design of soil conservation and water harvesting structures if any within the watershed.

Weekly, monthly and seasonal rainfall data are very much useful for planning of agricultural operation. Probability and frequency analysis of rainfall data enables us to determine the expected rainfall at various percent chances. Rainfall at 80 per cent probability can be safely taken as assured rainfall while 50 per cent can be taken as maximum limit for taking any risks (Gupta *et. al.,* 1975).

The knowledge of one day maximum rainfall is of great importance for hydrologic design of structure and planning of soil conservation measures for safe disposal of excess runoff. Probability analysis of one day maximum rainfall, weekly, monthly and seasonal rainfall has been attempted by many scientist at different places (Sharda and Bhushan,1985; Bhatt *et.al.*,1996; Mohanty *et.al.*,2001). Since the rainfall amount and its distribution are region specific, an attempt has been made in this paper for probability analysis of monthly, seasonal and annual total rainfall at different probability level, annual maximum daily rainfall at different return period and to develop depth-duration-frequency relationship.

MATERIALS AND METHODS

Daily rainfall data of forty three years (1960-2002) was collected from the meteorological observatory of CSWCRTI, Research center, Udhagamandalam and used for frequency analysis with the help of Weibull's formula as given by $P = m / (N+1)$.

Where P=Probability of rainfall magnitude being equal to or exceeded to a given value.

m=Rank of the rainfall magnitude when arranged in descending order.

N=Number of years of records.

Rainfall at various probability levels was worked out for monthly, seasonal and annul time period. For the seasonal analysis the entire year is divided into three seasons based on the onset and end of the monsoons. The period that receives South-West monsoon is considered as first season (May to August), North-East monsoon (September to November) as second season and the remaining period (December to April) as third season.

For prediction of annual maximum daily rainfall for higher return period the extreme values type-I distribution function and Log-Pearson type III distribution function has been used.

The probability density function of extreme value type-I distribution (Chow *et.el.*, 1988) is given as

$$y= -\ln (\ln 1/F(x)) \qquad (1)$$

Where $y = (x-u)/ \alpha$

$u= \overline{x}-0.5772\, \alpha$

$\alpha= \sqrt{6}\, s/\pi$

$\overline{x}$ and s are mean and standard deviation respectively.

F(x) is the probability of an event to be less than a given magnitude for a given return period and x is the variate of a random hydrologic series.

In Log-Pearson type III probability distribution function, the variate is first transformed into logarithmic form (base 10) and transferred data is then analysed (Subramanya, 1997).

The transferred logarithmic series z, for any recurrence interval T is given by

$$Z_T=\overline{Z}+ K_z S_z \qquad (2)$$

Where K_z = a frequency factor which is a function of recurrence interval T

Sz=Standard deviation of the Z variate

Z= log x and x is the variate of a random hydrologic series.

A depth-duration-frequency relationship was developed for different durations and return periods. The duration was taken as all possible combinations of 1 to 6 days of cumulative rainfall. Thus the annual maximum rainfall of 1 to 6 consecutive days in all combinations corresponding to different return periods were estimated.

RESULTS AND DISCUSSION

The expected occurrence of monthly, seasonal and annual rainfall at different probability levels is given in Table 1.The annual rainfall from 1960-2002 varies between a maximum of 1710 mm to a minimum of 832 mm. The average monthly rainfall of 212.2 mm was maximum in July. It is minimum (8.2 mm) in the month of February. At 80 per cent probability the monthly rainfall in the first season ranges between 64.7 and 110.0 mm. Similarly at 80 per cent level the rainfall in the second season ranges between 45.6 and 88.6 mm. In the third season the chance of occurrence of rainfall is very less at 80 per cent probability.

The expected rainfall at 80 per cent probability in the first, second and third season are 485.32, 288.14 and 81.6 mm respectively. At 90 per cent probability the rainfall in first, second and third season are 396.26, 240.1, 76.4 2mm respectively. The rainfall at 80 per cent probability can be good enough in the first and second season to take any annual crop without facing water deficit.

The main crops in the first and second seasons are potato, cabbage and radish with their water requirements in the first season being 290, 301 and 206 mm and in the second season 220, 277 and 166 mm respectively (Sikka *et. el.*, 2001). So there is 90 per cent and 80 per cent success of getting the required

Table 1: Expected rainfall (mm) at Udhagamandalam at different probability levels

Period	Probability (per cent)								
	10	20	30	40	50	60	70	80	90
January	28.74	17.42	9.40	6.42	3.10	0.98	0.00	0.00	0.00
February	31.32	17.36	5.28	2.06	1.50	0.00	0.00	0.00	0.00
March	61.38	26.76	19.16	15.64	11.40	4.42	3.80	0.60	0.00
April	146.08	102.02	74.52	65.02	56.00	49.44	43.44	26.74	15.72
May	217.56	199.06	125.30	118.70	109.60	98.48	84.92	64.72	43.22
June	231.20	202.94	177.52	170.20	147.90	123.92	97.74	66.52	53.50
July	309.00	290.72	253.76	240.86	197.50	155.10	133.76	110.04	87.90
August	203.26	176.92	151.58	128.68	123.30	103.62	89.54	76.82	69.34
September	277.94	210.56	172.86	148.64	126.50	116.14	100.22	75.60	61.60
October	269.72	240.68	198.98	175.88	149.10	133.30	118.30	88.58	71.54
November	238.98	193.68	145.04	106.20	89.40	80.00	71.82	45.58	28.32
December	121.56	99.86	64.48	58.62	39.5	18.20	13.52	5.04	3.38
Ist season	928.16	755.84	671.84	624.84	596.4	562.26	531.32	485.32	396.26
IInd season	614.85	548.16	505.82	464.12	435.2	377.58	355.56	288.26	240.10
IIIrd season	277.22	217.17	174.94	162.86	146.6	121.6	106.64	81.6	76.42
Annual	1586.82	1451.74	1338.36	1258.70	1173.90	1098.75	1032.80	985.16	954.70

Table 2: Expected one day maximum rainfall for lower return period

Return period (years)	One day maximu	
	Weibull's formula	Type -I p.d
2	[illegible]	97
5	115.9	15
10	145.5	184
20	175.3	218
30	228.3	237
40	287.7	25

amount of water without failure in the first and second season respectively.

The probable annual maximum daily rainfall for the entire period of forty three years were analyzed using Weibull's formula. The maximum one day rainfall expected to be equaled or exceeded to the given values at different return period is given in Table 2. The maximum one day rainfall for 10, 20, 40 years return period were estimated as 145.5, 175.3 and 287.7mm. In the Nilgiris, the main crops are potato, cabbage and radish which are very much susceptible to water logging. To prevent from the crop damage, this can be used for designing the excess water disposal system. For the design of any soil conservation structure with respect to erosion control and/or water harvesting

Table 3: Predicted one day maximum rainfall for higher return period

Return period (Years)	One day maximum rainfall (mm)
50	238.8
60	248.9
70	259.4
80	270.3
90	281.7
100	293.6

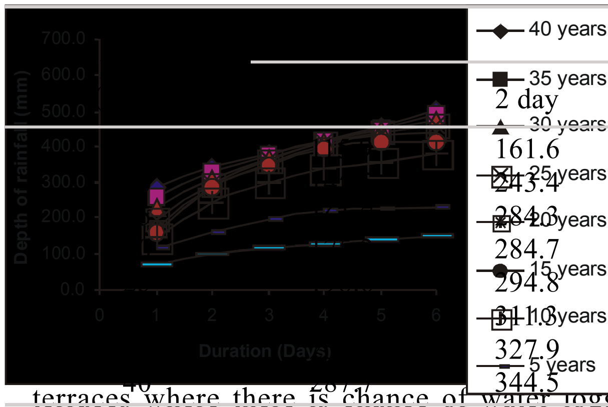

Fig. 1: Depth-duration-frequency curve

Table 4: Maximum rainfall for 1 to 6 consecutive days at different return periods.

Rainfall	
2 day	3 day
161.6	199.5
243.4	300.3
284.3	345.7
284.7	353.1
294.8	360.1
311.3	367.1
327.9	374.0
344.5	380.9

structure these extreme values at different return periods can also be used for any assumed expected life of the structure. For predicting annul maximum one day rainfall for higher return period the extreme value type-I probability distribution function and Log Pearson type III probability distribution functions were used for lower return periods and compared with the Weibull's formula values. Chi-squire test showed lower discrepancy with type III function than the extreme value type-I function (Table 2). The predicted values of one day maximum rainfall for higher return period was estimated using Log Pearson type III probability distribution function (Table 3). The one day maximum rainfall for 50 and 100 years return period was found to be 238.8 and 293.6 mm, respectively.

The probable maximum rainfall for 1 to 6 consecutive days in all combinations at different return periods is given in table 4 and presented in graphical form as depth-duration-frequency relationship (Fig.1).

terraces where there is chance of water logging/ stagnation in case of level and inward type terraces. Therefore, the estimated one day maximum rainfall for different return periods can be used for designing the excess water disposal system. For the hydrologic design of any soil conservation structure and/or water harvesting structure, these extreme values at different return periods can be used for any assumed expected life of the structure.

CONCLUSION

Monthly, seasonal and annual rainfall at different probability levels were estimated to ensure about the assured rainfall in different seasons for crop growth.

There is 90 per cent and 80 per cent success of getting the required amount of water without failure in the first and second season respectively for the commonly grown vegetable crops. Annual maximum one day rainfall for different return periods were estimated from observed data and for higher return period using Log-Pearson type III probability distribution which were obtained as 238.8 and 293.6 mm for 50 and 100 years return period respectively.

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