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Prediction of extreme rainfall events for mid central table zone of Orissa

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ABSTRACT

For designing and planning of soil conservation structures on watershed basis, knowledge of maximum one day rainfall is very useful. Thirty one years rainfall data of two stations of mid central table land zone of Orissa viz., Dhenkanal and Kamakhyanagar were collected and one day maximum rainfall was predicted using 4 different probability distribution functions viz., Normal, Log normal, Log Pearson and Extreme value type-1. Study reveals that for both the stations, Extreme value type-1 distribution was the best fit probability distribution function for predicting maximum one-day rainfall in a year. Using this distribution, frequency of 2, 3, 4, 5 and 10-days rainfall extremes were computed.

Key words: Probability, Normal, Log normal, Log Pearson, Extreme value type-1

The mid central table zone of Orissa covers the districts of Dhenkanal, Angul, Athgarh and Sukinda block of Jajpur. It covers 12,422 sq. kms, comprising 8% of the total geographical area of the state. The zone is generally flat with undulated and folded topography and has an average elevation of 300 meters form mean sea level. The climate of the zone is hot and dry sub humid. The mean maximum summer temperature is 38.7 °C and the mean minimum winter temperature is 14°C. The average annual rainfall in the zone ranges from 1300 mm at Angul to 700 mm in Palhara. Climatic water balance study shows PET as 1536.4 mm with AET of 800.5 mm at 200 mm available water holding capacity (Kar and James, 2000). A surplus of 529.8 mm rainfall was computed, for the south west monsoon period.

Soils are light textured lateritic Rhodustalfs, Paleustalfs, Haplaustalfs and Ultisols. Rice is the principal crop of the area comprising 53% of the gross cultivated area. But rice yield is low and uncertain because of highly erratic and uneven distribution of rainfall. In this region, major portion of its rainfall occurs due to southwest monsoon with heavy downpour, resulting in substantial runoff and flood. Whereas, during other seasons water stress conditions create adverse conditions for growing crops and agricultural droughts of varying intensities limit the crop production potential. Some times high intensity of rainfall caused severe soil erosion. Design of hydraulic structures and soil conservation measures are thus effective tools for development and restoration of wasteland and maximum daily rainfall data of different return periods are required for safe planing. Prediction of maximum daily rainfall with their return periods is usually done by a probability distribution function which fits with the observed rainfall data better. Several workers have attempted (Agarwal *et al.*, 1988; Bhatt *et al.*, 1996, Prakash and Rao, 1996) to predict one day maximum rainfall at different places. The Extreme value type-1 distribution was found to be one of the most widely used models for the probabilistic characterization of a variety of extreme hydro-meteorological sequences (Singh 1989 and Singh *et al.*, 1999). In the present paper, an attempt has been made to find the best fit probability distribution to predict one-day maximum rainfall. Using Extreme value type-1 distribution, frequency of rainfall events of 2, 3, 4, 5 and 10-days were also computed at two stations of mid central table land zone of Orissa *viz.*, Dhenkanal and Kamakhyanagar.

MATERIALS AND METHODS

The daily rainfall of thirty one years (1970-2000) of two stations (Dhenkanal and Kamakhyanagar) were collected from district agricultural office, Dhenkanal. One-day maximum rainfall was picked up for each year and were fitted to 4 probability distribution functions viz., Normal, Log normal, Extreme value type-1 and Log Pearson type-III. These values were compared with observed values, computed by Weibull's formula. The 2, 3, 4, 5 up to 10-days rainfall extremes were computed using Extreme value type-1 probability distribution.

The Weibul's formula is given by

$$P = \frac{m}{N+1} \times 100$$

where, m = rank number, N = total number of years of record, P = Plotting position

Different probability distribution functions (Chow *et al.*, 1988) are given as follows:

Probability distribution model

a. Normal distribution

$$f(x) = \frac{1}{\sigma(\sqrt{2\pi})} e^{[-\frac{(x-\mu)^2}{2\sigma^2}]}$$

The normal distribution arises from the central limit theorem, where sequence of random variables X_i are independently and identically distributed with mean μ and variance σ^2.

b. Log normal distribution

$$f(x) = \frac{1}{x\sigma(\sqrt{2\pi})} e^{[-\frac{(y-\mu_y)^2}{2\sigma^2_y}]}$$

where y = log x ; μ_y and σ_y are the mean and standard deviation, respectively for the variate y.

c. Log-Pearson type III distribution

$$f(x) = \frac{\lambda^\beta (y-\epsilon)^{\beta-1} e^{-\lambda(y-\epsilon)}}{x\, T(\beta)}$$

log x $\geq \epsilon$ where, x T(β)

$$\lambda = \frac{S_y}{\sqrt{\beta}};\ \beta = [\frac{2}{C_s(y)}]^2\ ;\ \epsilon = y - s_y\sqrt{\beta}$$

y, S_y and $C_s(y)$ are the mean, standard deviation and skewness coefficients of variate y, respectively.

d. Extreme value distribution type 1

For Extreme value type-1 distribution, the probability density function f(x) and distribution function F(x) are given as:

$f(x) = [\exp - (x-u)/\alpha - \exp\{-(x-u)/\alpha\}]/\alpha$

and $F(x) = \exp[-\exp\{-(x-u)/\alpha\}]$

$-\alpha < x < \alpha; -\alpha < u < \alpha; \alpha > 0$

where, α and u are the shape and location parameters of the distribution, respectively. In terms of the reduced variate $Y = [(x-u)/\alpha]$

$$F(x) = \exp[-\exp(-Y)]$$

The method of moment estimator of the parameters have been used for this study to fit extreme value distribution. The moment estimators of the parameters α and u of the extreme value distribution are as follows.

$\alpha = (\sqrt{6}/\pi)[\Sigma(x-\bar{x})^2/N-1)]^{1/2}$

$; u = \bar{x} - 0.577216\,\alpha$

Estimated T-yr rainfall

If x_t is the T-year event value of the variable x, and Y_t, the corresponding value of the reduced variate Y, $F(x) = \exp[-\exp(-Y)]$ can be written as,

$f(x_t) = 1-1/T = \exp[-\exp(-Y_t)]$,

$Y_t = -\ln[\ln[T/(T-1)]$

where, $$T = \frac{1}{1-P(x)}$$

All four probability distribution functions were compared by Chi-Square test of goodness of fit given by the following equation to find best fit probability distribution for predicting one-day maximum annual rainfall,

$$\frac{\Sigma(O-E)^2}{E}$$

where, O is the observed value obtained by Weibull's method and E is the estimated value by probability distribution functions .

RESULTS AND DISCUSSION

The observed (O) and probable rainfall values (E) with the return period by different probability distributions are given in Table 1 and 2 for Dhenkanal and Kamakhyanagar, respectively. The best fit probability distribution function was determined by comparing the Chi-sequence values obtained by each distribution and the function was considered best which gave least Chi-square value (Bhatt *et al.*, 1996). The computed Chi-square values were 11.04, 11.8, 11.45 and 12.16 for Extreme value type-1, Log Pearson, Normal, Log normal, respectively for the station, Dhenkanal. The lowest value having 11.04 for Extreme value type-1 distribution. It can be used for predicting one maximum day rainfall for the station Dhenkanal. For the station Kamakhyanagar the, Chi-square values were 12.23, 12.63, 13.16 and 13.27 for Extreme value type-1, Log Pearson, Normal, Log normal, respectively and lowest value was achieved by Extreme value type-1 probability distribution. Hence for Kamakhyanagar also, Extreme value type-1 distribution is useful for prediction of one-day maximum rainfall.

For Dhenkanal, according to Extreme value type-1 distribution 86 mm maximum one-day maximum rainfall would occur once every 2 years interval and for getting 137 mm rainfall, the return period is 20 years. The one-day maximum rainfall of 158 mm will occur once in 100 years. For the station, Kamakhyanagar according to this distribution, 82 mm rainfall occur once in 2 years. For 132 mm one-day maximum rainfall, the return period would be 20 years and for 153 mm daily maximum rainfall, it is 100 years.

Table 1: Comparison of maximum daily rainfall of Dhenkanal for different probability models

Return period(yrs)	Observed rainfall (mm) (O)	Probable rainfall (E)			
		Extreme value Type-I	Log pearson type-III	Normal	Log normal
2	92	86	81	81	81
5	104	112	108	108	109
10	106	125	126	126	126
15	111	133	138	137	138
20	134	137	143	143	142
25	162	140	149	149	147
50	----	149	165	166	163
100	----	158	181	183	178
$\frac{\Sigma(O-E)^2}{E}$		11.04	11.8	13.75	12.16

Table 2: Comparison of maximum daily rainfall of Kamakhyanagar for different probability models

Return period(yrs)	Observed rainfall (mm) (O)	Probable rainfall (E)			
		Extreme value type-I	Log pearson type-III	Normal	Log normal
2	88	82	78	77	77
5	102	108	104	104	104
10	103	121	121	122	121
15	103	129	132	132	133
20	126	132	137	139	139
25	156	135	142	144	144
50	-----	144	158	161	161
100	-----	153	174	177	179
$\frac{\Sigma(O-E)^2}{E}$		12.23	12.63	13.16	13.27

Table 3: Frequency of rainfall extreme at Dhenkanal

Frequency	2-day	3-day	4-day	5-day	10-day
2	120	131	136	141	154
5	146	165	174	175	189
10	161	206	245	251	215
15	181	218	261	262	264
20	186	224	263	266	279
25	190	237	276	275	300
50	203	246	295	312	323

Table 4: Frequency of rainfall extremes at Kamakhyanagar

Frequency	2-day	3-day	4-day	5-day	10-day
2	177	130	137	142	154
5	143	153	163	166	189
10	161	195	201	201	215
15	172	205	245	251	264
20	177	214	254	262	279
25	188	224	266	279	300
50	201	236	289	302	323

Since the Extreme value type-1 was found to be best fit probability distribution for both the stations, frequency distribution of 2, 3, 4. 5 up to 10-days rainfall extremes for these two station were computed (Table 3 and 4) for Dhenkanal and Kamakhyanagar, respectively.

Extreme value type-1 distribution was found to be the best probability distribution for predicting rainfall extremes at mid central table zone of Orissa. The prediction of these 1, 2, 3,4, 5 and 10-days rainfall extremes are useful for designing soil conservation and hydraulic structures etc. and thus will be helpful for sustainable watershed development which is the need of the hour to obtain food, nutrition and environmental security.

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