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RAINFALL FREQUENCY STUDIES AT BARAPANI, MEGHALAYA

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ABSTRACT

Stochastic analysis of weekly rainfall at Barapani (Meghalaya) were carried out through various probability distributions to obtain information regarding the characteristics of monsoon –its period of occurence, amounts and distribution. Forecasting of rainfall was made at 20, 30, 40, 60, 70, 80 percent probabilities by using the statistical distributions. Maximum intensities were modelled for different durations and return periods. Intensity duration and frequency of rainfall were found highly interrelated. The topographical effect on the variation of rainfall was also studied by means of a network of seven raingauges spread over the hill slope.

INTRODUCTION

Precipitation phenomena being highly erratic, complex and of random nature, it can be interpreted only in a probabilistic sense. Determination of the rainfall probability is important for hydrologic planning and watershed management. Rainfall in hilly regions is generally much higher than in plains and so is the runoff produced. One of the important problem dealt in hydrology is to interpret the past record of rainfall events in terms of future probability of occurrence. It is obvious that all hydrological events do not have a practical significance in the design of hydraulic structures. The design of these structures depend upon a few extreme events. The maximum rainfall, that is expected, depends upon the period that is taken into consideration. The relationship between frequency, intensity and storm duration vary sufficiently from place to place and hence the local study is very important. Study of Intensity Duration Frequency (IDF) relationship has drawn the attention of many researchers during the recent years. In USA the generalized charts of rainfall intensity duration frequency, now revised by US weather bureau are being used for obtaining the value of 'I' the rainfall intensity (in the rational formulae) which is one of the most important factors in computing runoff. The present paper deals with the stochastic analysis of weekly rainfall and maximum intensities through various probability distributions to provide adequate information regarding the characteristics of monsoon relating to the time of occurence and amount.

MATERIALS AND METHODS

The site of the current study was at the ICAR Research Complex for North Eastern Hills Region situated at Barapani in the state of Meghalaya (Fig. 1). Barapani is located between 25°39' and 25°41' N latitude and between 91°54' and 91°63' E longitude and is 22 km away from Shillong (Meghalaya). The study area typically represents the soil and climate conditions of North Eastern Region. Rainfall was recorded by an automatic weighing type raingauge and a standard non recording raingauge during the period 1982-1993 at the site. In this study, along with the rainfall data recorded at the project site, daily rainfall data of Barapani for the years (1960-1992) recorded at the nearby meteorological observatory (located 2 km away from the site) was collected and analysed. The daily rainfall data were converted into weekly rainfall as per the India Meteorological Department (IMD) recommended standard weeks criteria. The depth of rainfall recorded at different time interval was converted into rainfall intensity values. The topographical effect on the variation of rainfall in the current project site was studied by means of a network of seven raingauges spread over an area of 15.03 ha.

Probability distribution functions

The weekly rainfall data were analysed to predict the expected rainfall at different probability levels. In this study six probability functions - Normal, Pearson type III, log extreme with various transformations (square root, cube root etc) of the date were used to predict the rainfall distribution, functions for different durations. The type 1 external distribution, some time known as Gumbel distribution, was often used for extreme type events and results from any initial unlimited distribution of exponential type which converge to an exponential function. Pearson type III distribution is a skew distribution with limited range in the left direction. In log normal, log pearson type III. and log extreme value distributions logarithm of variable was used instead of original data. The density functions of the said probability distribution along with the function parameters are presented in Table 1.

The rainfall charts during the period 1982-1993 for each storm event were analyzed for calculation of maximum intensities for 5, 10, 15, 30, 60, 120, 1440, minutes duration. The annual series of extreme data for different rainfall duration was prepared by selecting the maximum value of each calender year of record. The intensity duration records were subjected to stochastic analysis as described earlier. Intensity duration-frequency charts were developed by selecting the best fitted probability distribution function.

RESULTS AND DISCUSSION

Rainfall probability estimates

The entire region except southem half of the MIzo hills lies within the subtropical belt having south Asiatic monsoon climate with good amount of rainfall. The weekly probability analysis of rainfall showed that no single probability model could fit to rainfall for all the 52 weeks. One or more distributions were fitted to the different weekly rainfall data or to their various transformations (Table 2). The distributions selected to fit the date could be fitted to the probability during the monsoon period (17 to 41st week) without any transformation except for 17, 20, 32, 35 and 40th weeks when square root and cube root transformations were used. For the weeks with very scanty rainfall, the data could be fitted with the use of 1 transfomation. Five percent level of significance was considered for the distributions except for the 51st week, where 10% level of significance was used.

The probability analysis of annual rainfall values was also conducted in the similar manner. Based on this analysis, the average annual rainfall was found to be 2232.35 mm with the standard deviation of 379.48 mm. It may be interesting to note that the area is located close (about 50 km distance) to Cherrapunji and Mausinram recording world's highest annual rainfall (more that 10,000 mm). The presence of hills and mountain ranges in the region is primarily responsible to cause such variation in the rainfall pattern. The predicted rainfalls during each week at the probability levels of 10, 20, 30, 40, 50, 60, 70, 80 percents (Fig. 2) The analysis of rainfall at 70 percent probability shows very scanty rainfall from November to March which constitute the dry period. The rainfall magnitude starts peaking up from the month of May with the onset of monsoon and more than 88% of annual rainfall occurs during the period from May ot October. It can be seen that more than 1 cm rainfall at 80% probability level is expected between 17-41 weeks. The monsoon withdraws from the area almost abruptly following this period and post monsoonal as well as winter rainfall are very scanty. This kind of analysis weekwise all the year round provides detailed information for developing integrated water management plans. The information can be utilized for quantitative evaluation of runoff disposal, amount of water to be supplied from different sources and also as base information for calculating the capacity of water harvesting pond.

Rainfall intensity-duration-frequency relationship

It is a general fact that discontinuous rain spells give higher rainfall magnitudes as compared to continuous rain spells. Knowledge of the size and frequency of rainfall events that produce the most runoff and erosion would be helpful in desiging conservation practices. The annual series of extreme rainfall data for different rainfall duration calculated as per the procedure given earlier when subjected to frequency analysis yielded intensity-duration values for different return periods as presented in Table 3. The predicted rainfall values for different duration were used to obtain the intensity duration frequency chart for the area (Fig. 3). It would be possible to find out the theoretical value of the rainfall intensity (I) for any duration from 5 minutes to 24 hrs. and for return periods of 2 years to 100 years. The table 3 shows that maximum expected rainfall intensities for 5 minutes duration varies from 11.87 cm/hr to 15.38 cm/hr for the retum period 2--100 years. The maximum observed rainfall intensity for 5 minutes duration was 14.40 cm/hr during 1992. The IDF curves can be used in the rational method for estimated peak runoff from small watersheds. The rainfall intensity for the desired frequency can be computed from these curves for the duration equal to the time of concentration of the watersheds. The frequency chosen should reflect the economics of flood damage reduction.

The intensity (I) duration (D) frequency (F) obtained by the above procedure (Table 3), when subjected to regression analysis to obtain a IDF relationship yielded the optimum equation as follows :

$$I = \frac{128.74 \times T^{0.066}}{(t + 18.44)^{0.77}}$$

(r = 0.99)

Where I = Maximum intensity (cm/hr)
T = return period (years)
t = duration of rainfall intensity (minutes)
r = correlation coefficient.

It can be seen that the intensity, duration and frequency of rainfall are highly interrelated with the correlation coefficient of more than 0.99 between the observed and estimated values. In spite of very high correlation coefficient, the estimates for higher return periods (100 years and above) should be used with caution since the length of data is only 12 years. The results are to be updated as more and more years data become available. The findings would, however, be helpful in the design of small water control structures such as involved in drainage, terracing, bund outlets and gully plugging works.

Rainfall distribution on hilly microwatershed

Singh (1985) reported that runoff increases with the increase in slope steepness up to 45% and there after it decrease with further increase in slope. The probable explanation of this peculiar phenomena, is that, the amount of rain water falling per unit area of land surface decreases with the increase of slope. The topographical effect on the variation of rainfall in the current location was studied by means of a network of seven raingauges spread over the area during these years, 1987 and 1988. It was observed that the annual rainfall decreased with the increase of elevation due to the combined effect of wind and topography.

The analysis of weekly rainfall data indicated that no single probability model could fit the rainfall significantly for all the weeks. However, the data could be fitted to one or more distributions in their various transformations (square root, cube root etc.). The analysis showed that more than 1 cm rainfall at 80% probability level is expected between 17-41 weeks. The maximum expected rainfall intensities for 5 minutes duration varies from 11.87 cm/hr to 15.38 cm/hr for the return period 2-100 years. The IDF relationship differs due to environmental factors. The annual rainfall decrease with the increase of elevation due to combined effect of wind and topography.

REFERENCES

Singh, M. D. (1985). Rainfall, runoff and soil loss relationships on varying degrees of hill slope. Unpublished M. E. Desertation, Dept. of Civil Engg. Assam Engineering College Gauhati, India 1 - 135.

The probability functions selected for frequency analysis together with their function parameters

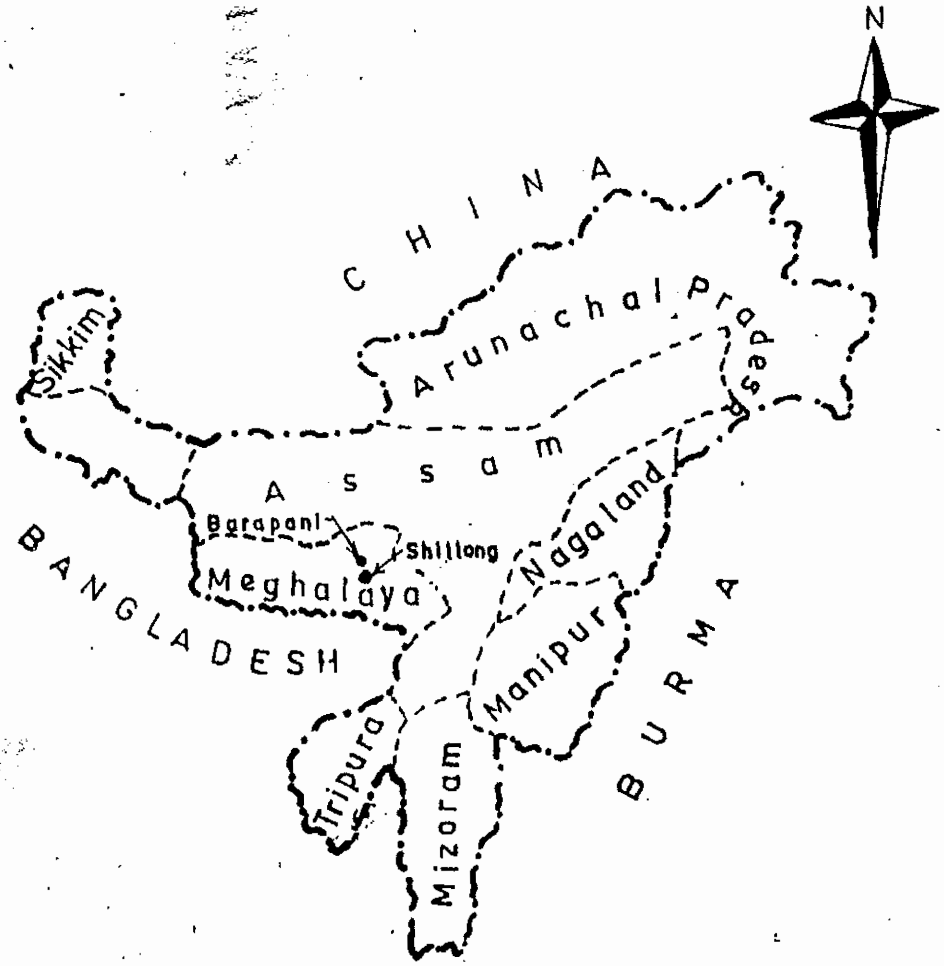
Name of statistical distribution function	Probability density function	Parameters	Mean	Va
Two parameter normal distribution	$f(x) = \frac{1}{6\sqrt{2x^x}}$ $\exp(1/2(x-\mu)^2/\delta^2)$	μ,δ	μ	μ^2
2. Parameter Log-Normal Distribution	$f(x) = \frac{\exp[-1/2(\mu x - \mu y)^2/\delta y^2]}{\sqrt{2\mu x^x \delta y^2}}$ where $y = \ln x$	$\mu y,\delta y$	$e^{\mu y^4 \delta_{y^2/2}}$	$\mu^2 \times (e^{\delta^2} - 1)$
3. Extreme value Type - I Distribution	$f(x) = \exp(-y - n^{-y})$ where $y_1 = (\ln x - \beta)/\alpha$	α,β	$\beta t 0.577\alpha$	$1.645\alpha^2$
4. Log Extreme Value Type I Distribution	$f(x) = \exp(-y - n^{-y})$ where $y = (\ln x - \beta)/\alpha$	α,β	$\beta t 0.577\alpha$	$1.645\alpha^2$
5. Pearson Type III Distribution	$f(x) = \frac{\lambda^n x^{n-1} e^{-\lambda x}}{f(x)}$	μ,λ	μ/λ	μ/λ^2
6. Log Pearson Type III Distribution (Gamma)	$f(x) = \frac{\lambda^n x^{n-1} e^{-\lambda x}}{f(x)}$ where $y = \ln x$	μ,λ	μ/λ	μ/λ^2

Table 3 . Obseved maximum rain fall intensity (cm/hr) for selected durations and return periods.

Duration	Return Period					
	2	5	10	25	50	100
5 mts.	12.09	12.79	13.84	14.26	14.26	14.83
10 mts.	10.05	11.07	12.18	12.56	12.56	12.89
15 mts.	8.81	10.01	11.33	11.78	11.78	12.16
30 mts.	6.24	6.97	8.07	8.52	8.52	8.98
1 hr	4.13	4.48	4.91	5.05	5.05	2.20
2 hrs	2.34	3.02	4.02	4.42	4.42	4.81
24 hrs	0.40	0.64	1.01	1.16	1.16	1.31

Table 2 . Probability distributions fitted to rainfall data of various weeks

Name of the distribution	Weeks Transformation			
	1	0.5 (Square root)	0.33 (Cube root)	0.1
Normal	18,	16, 17, 19, 32, 42, 46	9, 14, 20	1, 2, 6, 7, 8, 10, 13, 47, 48, 49, 50, 51, 52
Extreme	15, 22, 24, 29 36	3, 4, 35, 40, 44, 45	5, 11, 12	
Log normal	21, 23, 25, 26, 27, 28, 30, 31, 33, 34, 37, 38, 39, 41, 43			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CHINA
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Barapani
Shillong
Meghalaya
Nagaland
Manipur
Tripura
Mizoram
BANGLADESH
BURMA

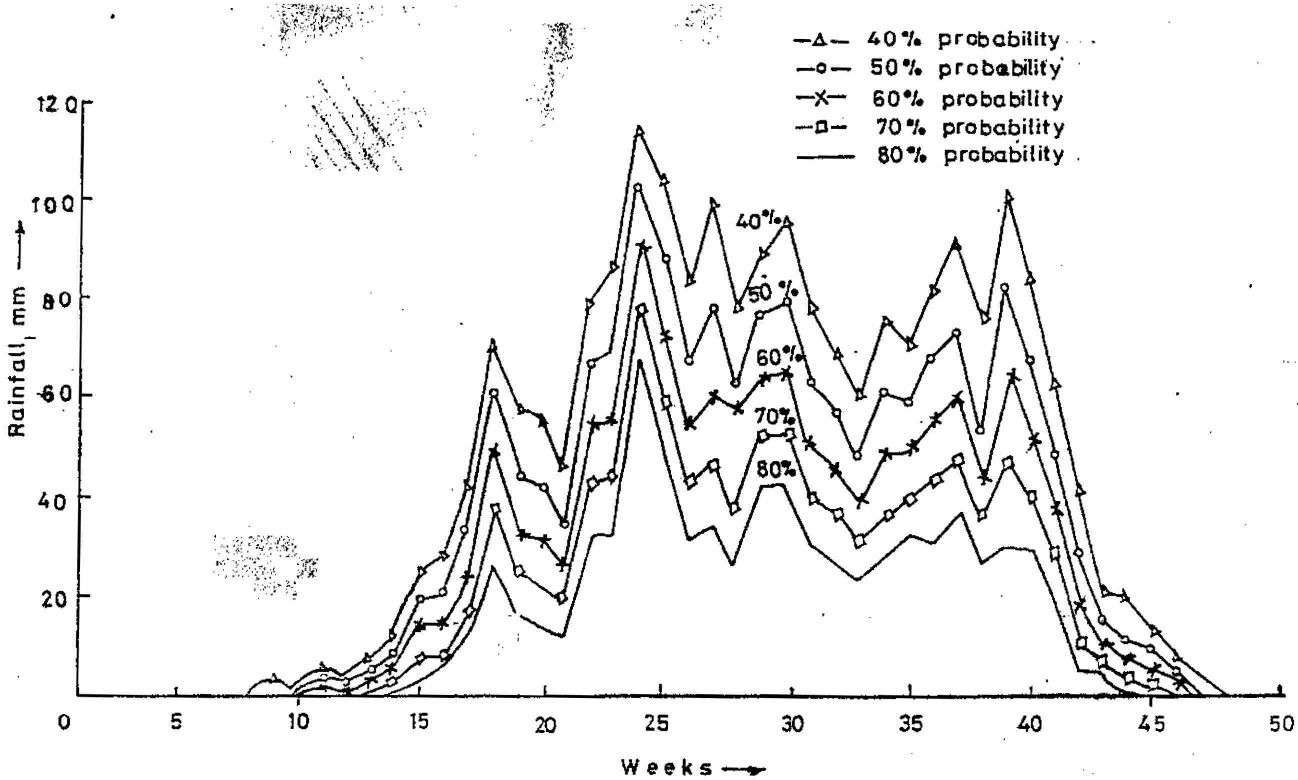

Fig. Weekly rainfall at different probability levels at Barapani.

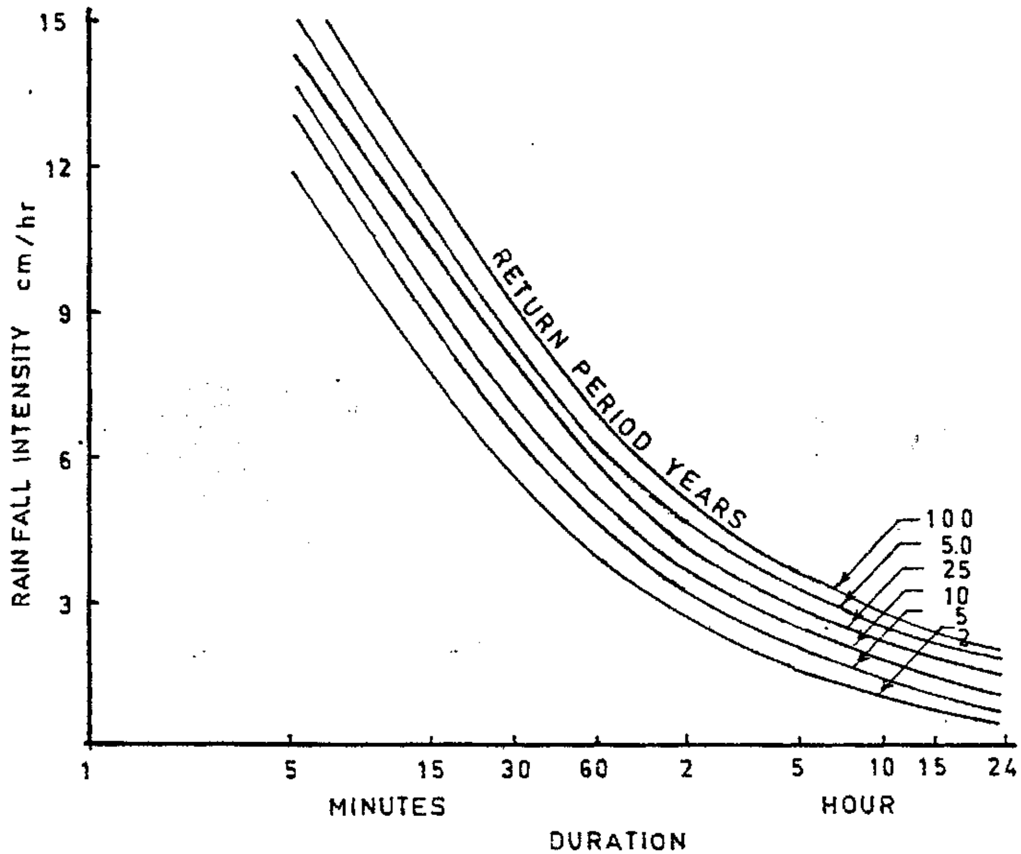

Fig. Rainfall intensity - duration - frequency chart of Barapan

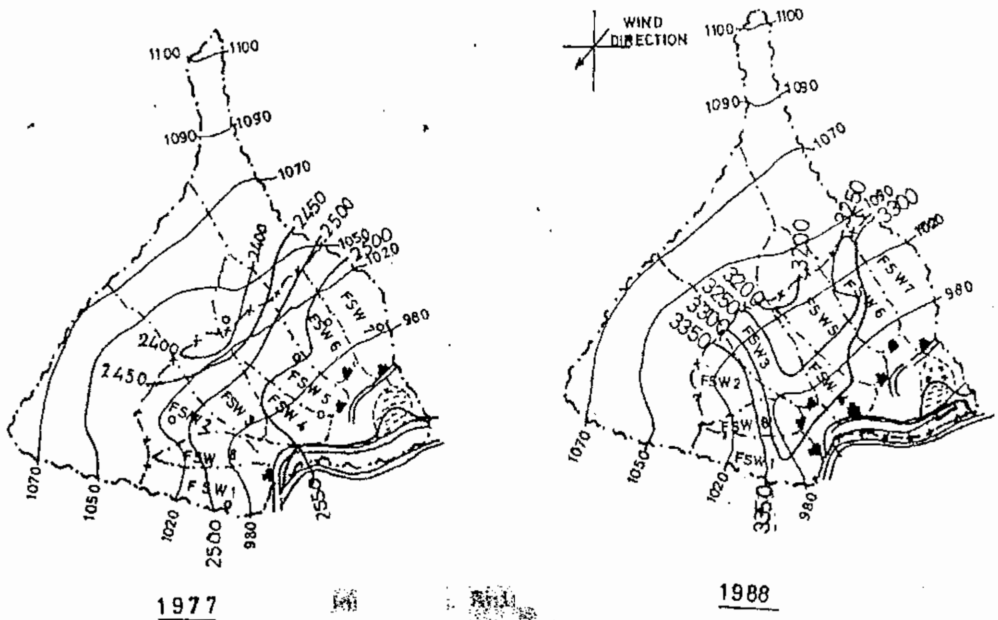

FIG. 4. ISOHYATAL MAP OF A 15.12 HILLY MICRO WATERSHED (BARAPANI)