STATISTICAL METHOD TO ESTIMATE DROUGHT OCCURRENCE

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ABSTRACT

Rayalaseema region of Andhra Pradesh is chronically drought prone. The climate is generally dry with very low annual rainfall. Rayalaseema region comprises four districts viz., Ananthapur, Chittoor, Cuddapah and Kurnool. Chittoor district is located : southern part of Andhra Pradesh. Rainfall data collected from nearly 16 raingauge stations covering the entire 15000 sq.km area of Chittoor district is statistically analysed to determine the frequency of occurrence of the drought pattern and the results are presented in this paper.

The annual rainfall values are tabulated and it is shown that the data conform to Log Pearson Type-III distribution. Based on this, the mean, standard deviation and the skew coefficients are computed and the amount of rainfall having different return periods are obtained. Using the definition proposed by the India Meteorological Department for moderate drought and severe drought, the probability of occurrence of a few typical combinations of droughts of different intensities are obtained.

It is believed that the method of approach proposed would be of value in predicting the occurrence of drought in general and the results obtained in this study would of use in planning the drought management in Chittoor district of Andhra Pradesh.

INTRODUCTION

Drought has been the root cause of many famine in many parts of the world and more so in India where agricultural success and prosperity are virtually dependent upon the amount and distribution of rainfall. Drought is a temporary phenomenon experienced only when precipitation falls appreciably below normal. It differs from other types of natural hazards in terms of its variable duration and indefinite beginning or end. Drought is a meteorological phenomenon and the vulnerability of any area to drought depends on the extent to which physical and climatic conditions cause a deviation from normal precipitation. The most striking effect of drought is that it retards the economic growth of a region. Frequent

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occurrence of drought has been the prime cause of backwardness of many regions in India depressing its economy to stagnation and poverty. There is thus a need to study, in depth, the occurrence, management, trends and prediction, and effects of droughts.

Rayalaseema region in the southern part of Andhra Pradesh (See Fig.1) comprising the districts of Ananthapur, Chittoor, Cuddapah, and Kurnool is chronically drought prone. The frequent occurrence of drought in this region has been mainly attributed to a gradual decline in rainfall over the years. Rainfall data of Chittoor district is statistically analysed in this paper to determine the distribution of drought, its return period and the probability of their occurrence.

CLIMATIC FEATURES OF RAYALASEEMA

Rayalaseema region is generally warm all the year round. The mean temperature is always above 23°C. During the hottest part of the year, in April and May, the mean temperature ranges from 32°C to 35°C. Maximum temperatures of 45°C to 47°C have been recorded on individual days.

High humidity ranging between 70-75% prevails in the mornings and 55-60% in the evenings of June to December where as it is only 50-60% in the mornings and 25 to 35% in the evenings of February to May. Analysis of rainfall regionwise has disclosed that the rainfall in this region has always been lower than in any other regions of the state right from 1961-62. The annual rainfall in the Western parts of Rayalaseema is less than 600 mm and is fed by South-West and North-East monsoons. The quantum of rainfall that occurs during the South-West monsoon is very high when compared with the contributions from the North-East monsoon. The region is considered as one of the most important arid-zones of India.

A study[1] indicates that during the years 1900-1973 there had been, in all, 16 droughts in Rayalaseema resulting in a drought for every $4\frac{1}{2}$ years, on an average. The region suffered from drought conditions almost every year regularly from 1961.

ANALYSIS OF DROUGHT FOR CHITTOOR DISTRICT

The detailed analysis and study of drought incidence is restricted to Chittoor District in Rayalaseema region which represents nearly 15000 sq.km and accounts for about $5\frac{1}{2}$ percent of the state's area. There are 11 taluqs in Chittoor district out of which 7 taluqs are identified as drought prone by the Irrigation Commission[2] (shown shaded in Fig.1)

The study and analysis presented herein based on the assumptions that rainfall is the only major factor influencing the occurrence of drought. Rainfall data available in the 16 raingauge stations in Chittoor district has been collected. The locations of these stations are shown in Fig.2. Rainfall data has been collected for nearly 47 years for almost all the stations except Pitchatur and Satyavedu in Puttur taluq for which only 34 and 29 years of records, respectively were available.
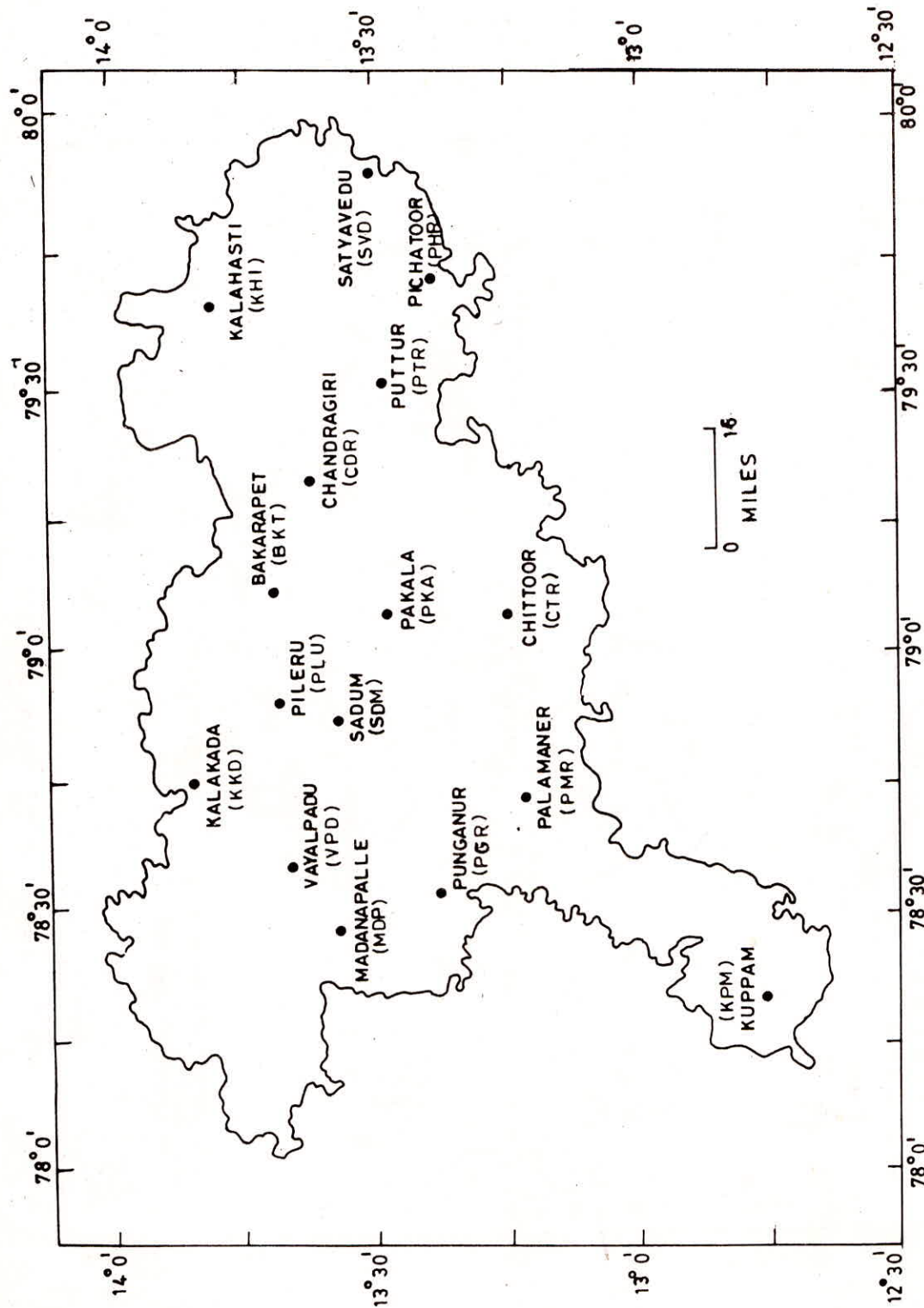
FIG. 1. LOCATION OF RAYALASEEMA

Fig. 2. Location of Rain gauge stations

CLASSIFICATION OF DROUGHT

The India Meteorological Department (IMD) defined the drought year as the one in which the actual rainfall received is below the normal by 25 percent or more; a moderate drought year as one in which the rainfall deficit is 26 to 50% and a severe drought year as one in which the rainfall deficit is more than 50%.

Based on this definition occurrence of drought for the Chittoor district has been evaluated. Table 1 shows the annual rainfall as a percentage of normal in column-3 and the classification of drought is shown in column-4 based on IMD definition. It is seen that there has been a total of 5 drought years. Also, the probability of occurrence of drought for Chittoor district is worked out as 0.106 (5 drought years out of 47 years).

FREQUENCY ANALYSIS OF DROUGHT OCCURRENCE IN CHITTOOR DISTRICT

While the definition of drought by IMD is generally acceptable, it implies incidence of a drought even in place of high rainfall since it is based only on rainfall deficit. To overcome this difficulty and to facilitate carrying out of the frequency analysis of drought occurrence in Chittoor district, a classification similar to the one defined by IMD but specifying ranges of rainfall is proposed for Chittoor district. The normal rainfall for Chittoor district is obtained by the mean of normal rainfalls of the 16 raingauge stations and is found to be 885.50 mm. The 50 percent and 75 percent of average of normal rainfalls for the entire district are also computed as 450 mm and 675 mm respectively. Based on this, the drought is classified into various categories as given in Table 2.

Table 2: Classification of Drought for Chittoor District Based on Rainfall Ranges.

Category	Ranges of Rainfall in mm	Classification
Class-I	less than 450	Severe drought
Class-II	450-675	Drought
Class-III	675-900	Rainy
Class-IV	More than 900	Good rainy

Scanning through literature one finds that many probability functions that fit virtually any distribution has been derived. Of particular interest to the present study has been the Log-Pearson Type-III distribution developed by Karl Pearson which has been widely used in practical works to define the shape of any distribution curve. For Log-Pearson Type-III distribution the skewness coefficient G is computed from the equation.

Table 1 : Drought years of Chittoor District based on IMD Definition.

Year	Annual rainfall in mm	$\dfrac{\text{Annual rainfall}}{\text{Normal rainfall}} \times 100$	Classification of drought
1939	1052.30	118.80	
1940	1024.70	115.70	
1941	775.40	87.50	
1942	639.20	72.20	Moderate*
1943	1247.40	140.80	
1944	1100.90	124.30	
1945	628.30	70.90	Moderate*
1946	1217.10	137.40	
1947	621.50	70.20	Moderate*
1948	814.20	91.95	
1949	876.40	98.90	
1950	621.70	70.20	Moderate*
1951	552.30	62.40	Moderate*
1952	760.20	85.60	
1953	901.90	101.80	
1954	874.80	100.10	
1955	805.30	90.90	
1956	1068.60	120.70	
1957	746.40	84.30	
1958	928.90	104.90	
1959	697.30	78.70	
1960	840.90	94.90	
1961	742.00	83.80	
1962	876.60	98.90	
1963	867.20	97.90	
1964	1047.40	118.30	
1965	683.60	77.20	
1966	1138.20	128.50	
1967	916.10	103.40	
1968	705.50	79.70	
1969	962.40	108.70	
1970	807.70	91.20	
1971	883.60	99.80	
1972	1035.40	116.90	
1973	726.50	82.00	
1974	746.70	84.30	
1975	1078.50	121.80	
1976	1042.30	117.70	
1977	1036.40	117.00	*Percentage
1978	1005.40	113.50	departure is
1979	962.60	108.70	between 26 & 50
1980	680.60	76.80	percent of
1981	933.80	105.40	normal
1982	686.30	77.50	
1983	1061.90	119.90	
1984	1087.80	122.80	
1985	907.20	102.40	

$$G = \frac{N(\log X - \overline{\log X})^3}{(N-1)(N-2)(S_{\log X})^3}$$ ...(1)

where N = Number of years of record.
       X = Annual rainfall
  $\overline{\log X}$ = Mean of logX
  $S_{\log X}$ = Standard deviation of log X

The value of X for various return periods is computed from

$$\log X = \overline{\log X} + K S_{\log X}$$ ...(2)

Where K is selected from standard tables[3] for the above computed value of G for the various return periods.

Rainfall data for the Chittoor District has been analysed to determine the type of distribution followed by the data. It is found that Log-Pearson Type-III distribution conforms to the data most as depicted in the semi-log plot in Fig.3.

The 47 year data of annual rainfall for Chittoor District gave a mean value of log X, $\overline{\log X}$ = 2.9386 and standard deviation, $S_{\log X}$ = 0.0868; the skewness coefficient G from equation (1) is computed as 0.3159. The return periods have been computed using equation (2) and selecting a value of K from standard tables. The calculated values of rainfall for different return periods is summarised in Table 3.

Table 3 - Computed rainfall for various return periods for Chittoor district.

Sl.No.	Return period of drought occurrence-T_p	Selected value of "K" from standard table	Computed rainfall X in mm
1	2	0.0634	879.20
2	5	-0.8171	737.20
3	9.5	-1.2591	675.00
4	10	-1.3157	667.40
5	25	-1.8707	597.30
6	50	-2.2369	555.10
7	100	-2.6037	515.80
8	200	-2.9342	482.90

It is seen that a drought (Rainfall less than 675 mm) occurs once in 9.5 years. Or, in the study period of 47 years, 5 droughts have occured. This agrees well with the estimated number of droughts based on IMD definition of drought.

The analysis also indicated that the frequency of occurrence of various classes of drought and their probability of occurrence will be as given in Table 4.
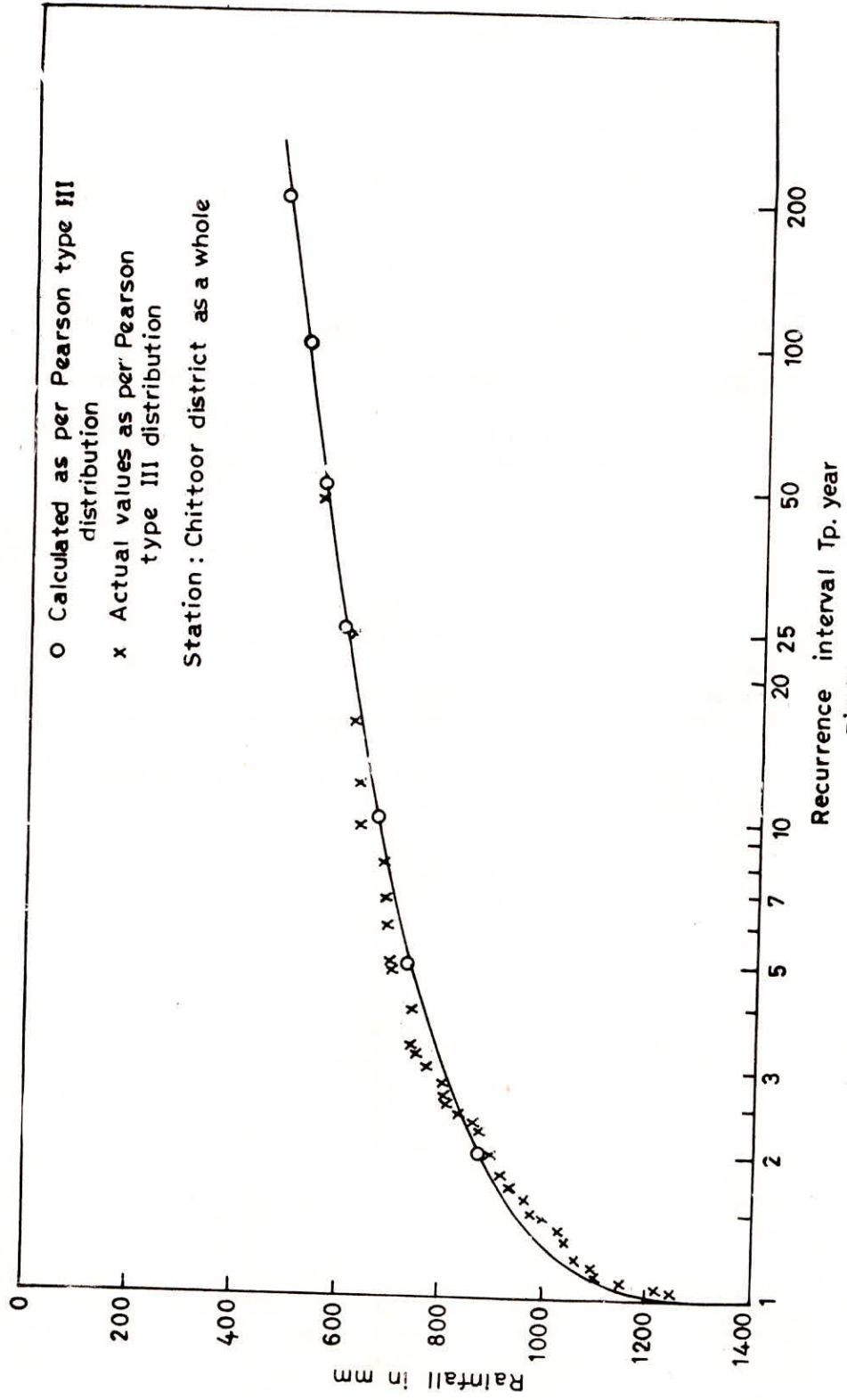
Calculated as per Pearson type III distribution

Actual values as per Pearson type III distribution

Station : Chittoor district as a whole

Fig. 5.

Recurrence interval Tp. year

Rainfall in mm

Table 4:

Class	Type	Frequency(f)	Probability(p)
1	Severe drought	–	–
2	Drought	5	0.106
3	Rainy	19	0.576
4	Good rainy	23	0.697

Further it is seen that, the probability of two consecutive droughts is 0.0213 (Class 2 &2).

CONCLUSIONS

The semi-arid region of Chittoor district in southern Rayalaseema in Andhra Pradesh is subjected to relatively less frequent incidence of drought than other districts of Rayalaseema. To facilitate proper planning and effective utilisation of the limited available water resources, a frequency analysis of drought occurrence has been carriedout. The rainfall data for Chittoor district fitted well with the Log-Pearson Type-III distribution. Classification of drought based on ranges of rainfall has been proposed for Chittoor District instead of rainfall deficit as defined by IMD. The study indicates the frequency of occurrence of droughts based on the proposed frequency analysis for Chittoor District is about 5 and agrees well with the frequencies of drought incidence obtained as per IMD definition for Chittoor District. Further study is under progress to assess the application of the proposed ranges of rainfall for classifying droughts for other regions in the district. The application of IMD definition of drought tends to show drought periods even in regions of high rainfall and requires careful interpretation when applying to such areas. The chance of two droughts occuring together on successive years for Chittoor district is 0.0213.

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