Meteorological Drought

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1. Introduction

In simplistic terms, drought is referred to as a period of dryness due to lack of rain. Any condition that leads to reduction in "available water" for "actual use" which need to be further defined, may be considered a drought producing one. To the meteorologist, drought is a rainless situation for an extended period during which some precipitation should have been normally received depending on the location of the place and the season. Aridity should not be confused with drought because arid regions can also be affected by drought since rainfall amounts far below the normal would constitute a drought condition. As soon as daily activity in any sphere of life due to lack of water is restricted, occurrence of drought is felt. One fact that should be recognised is that with the growth of industries, agriculture and other activities, fresh demands for more water than that is normally received through rainfall are created, and the requirements grow while normal rainfall may remain more or less the same.

Severe and prolonged water shortage due to absence of rainfall for prolonged periods with reference to normal rainfall expectation is apt to decribe a meteorological drought in general terms. In fact the meteorological drought precedes the agricultural drought, soil drought, hydrological drought etc. as the latter need to be defined *not with respect to normal rainfall expectancy, but on the failure to meet specific and immediate* needs for water supply. Consequently, agricultural, hydrological and other droughts need not occur simultaneously, but occur subsequent to a meteorological drought, and hence the necessity of studying the characteristics of meteorological drought,

2. Drought Characterization :

Different methods have been proposed from time to time for characterization of a meteorological drought. The present discussion is confined to meteorological drought which is solely determined by rainfall and methods depending on soil moisture, water balance etc. are not detailed here. Since drought condition is related to normal expectancy of rainfall, departures from normal at different percentage levels have been used to describe rainfall deficiency at a place or over a region. Being a percentage, it is purely qualitative and descriptive in nature which is useful as a first estimate of the drought condition. The magnitude of the severity in terms of the amount of rainfall deficiency is not reflected in such an analysis and thus, based on this information alone, a guess cannot be made about which sphere of activity would be affected due to such a situation. However it is easy to analyse and provide a overall view about the extent of deficiency from the normal and enables one to make spatial comparisons about the rainfall situation for a given period.

In India, the meteorological department uses the following criteria for describing the meteorological drought. If a meteorological sub-division receives total seasonal rainfall or weekly rainfall less than 25 percent of the normal, it is considered as drought. Rainfall deficiency in the range 26-50 per cent is described as moderate drought and beyond 50 per cent as severe drought. Based on these criteria using long series of rainfall data recurrence intervals of drought conditions during south-west monsoon season have been worked out (Koteswaram, 1970) as follows :

Meteorological sub-division	Recurrence period of highly deficient rainfall
Assam	Once in 15 years
West Bengal, coastal A.P. Madhya Maharashtra Kerala, Bihar and Orissa	Once in 5 years
South Interior Karnataka, East U.P., Vidarbha	Once in 4 years
Gujarat, East Rajasthan, West U P., Tamilnadu, Kashmir, Rayalaseema, and Telangana	Once in 3 years
West Rajasthan	Once in $2\frac{1}{2}$ years

Ramdas (1958) suggested that the season in a sub-division where the actual rainfall is in excess of the normal by twice the mean deviation may be defined as a flood and when the actual rainfall is less than normal by more than twice the mean deviation as a drought period; he identified both flood and drought years of the past and concluded that there was no regularity in the occurrence of widespread abnormalities or rainfall.

3. The Decile technique

Gibbs and Maher (1967) gave a comprehensive account of the calculation and use of the deciles to describe the distribution of a series of discrete values of the variate. They state that by stating the values of nine deciles of annual or seasonal rainfall, it is possible to have a reasonably complete picture of a particular rainfall distribution over a region. By determining the decile range into which a particular total falls, one may obtain a useful indication of departure from the normal. The classification given by them is as follows :

Decile range value	Description
1	Very much below 'Average'
2	Much below average
3	Below average
4-7	Average
8	Above average
9	Much above average
10	Very much above average

"Average" in this context refers to the most frequently occurring values grouped around the median rather than the arithmetic average. By carrying out the analysis for groups of months starting from the water year in Australia, to obtain frequencies of runs of dry weather in the past, Maher (1968, 1973), attempted to estimate feasibility of crop growth. The maps drawn using these data indicate the rainfall anamoly and the spatial distribution of the areas which were "very dry" or "very wet" in a particular year. Quantile rainfall amounts for some Indian stations were reported by George et. al. (1974).

Based on the decile technique, drought statements have been issued in Australia since the year 1965 containing a general summary and discussion of the drought situation in the country. Rainfall deficiency maps, information on sequential dry months recorded in the past and possibility of relief from drought are given periodically. Such drought estimates using the decile techniques are approximate and should be regarded as giving preliminary indication of drought risk and the manner in which drought areas cover the country in any given period.

4. Drought characterization using probability studies

Since early times, it had been realized that classification of drought mearly based on departures from normals alone may not have sufficient predictive value. Application of probability distributions to analyse daily, monthly or annual rainfall series to incorporate an element of predictive value through estimation of expected rainfall amounts at different threshold values and confidence limits and for specified periods had been attempted. Since 1940's when this method was probably systematically first applied by Blumenstock (1942), several studies have been reported in literature in the field of rainfall statistics, with reference to both dry and wet spells which are relevant to both flood and drought situations. To mention a few, representing the different techniques, normal frequency distribution and incomplete gamma distributions (Barger and Thom, 1949; Thom 1958, Mooley and Crutcher, 1968, Yao, etal., 1971; Raman et. al. 1972; Krishnan and Kushwaha, 1972)., Markov chain models (Gabriel and Neumann, 1972; Casky, 1963, Weiss, 1964, Wiser, 1965, Fizpatrick and Krishnan, 1967., Sarker et. al 1978., Victor and Sastry, 1979), mixed gamma distribution (Thom, 1966)., had been applied to obtain long term rainfall probabilities. Rainfall series of India have also been subjected to power spectrum analysis (Rao and Raghavendra, 1983, Koteswaram and Alvi, 1969), orthogonal polynomial techniques and time series analysis (Banerji and Chabra, 1963., Rao and Raghvendra, 1973} for studying trends, oscillations or periodicity of rainfall events. Their results did not show any trends or periodicities in rainfall over India.

Gregory (1969) and Jackson (1970) suggested that over short periods say 5 years or less, which are of interest to short term planning, hydrological or agricultural planning, the probabilities reflecting long term average conditions may differ considerably from the actual. They suggested derivation of short term probabilities by application of binomial distribution to the long term probabilities. Such an analysis had been made for the monsoon season in the Delhi region by Victor and Sastry (1983) to obtain short term weekly drought probabilities in 4 out of 5 years, in successive 2 years and in successive 5 years (Table 1). They concluded that year-to-year short period rainfall variability is better reflected in the short term probabilities than in the long term probabilities.

5. Meteorological Drought analysis in relation to crop planning :

It had been mentioned earlier that meteorological drought precedes all other types of droughts (agricultural, soil or hydrological etc.). For direct application to crop planning, information on meteorological drought occurrence if related to some crop character, would enhance its practical value. Though it is conceded that meteorological drought probabilities as derived by the methods enumerated earlier are essential as they form the basic information content, they do not directly meet the requirements of agricultural planning. To meet such needs, for example, Markov Chain technique can be applied, to derive meteorological drought probabilities during different growth stages of any particular crop in the monsoon season by choosing for the analysis suitable intervals related to crop growth phase rather than the calender months as is usually done. On this basis, Victor and Sastry (1979) developed cumulative probability nomograms for dry spell runs during the kharif season at Delhi using (1) calendar months and (b) growth stages of pearl millet. This analysis can easily be extended to other stations to obtain probability maps of meteorological drought on a regional basis. It may be noted that apart from rainfall, the only additional input needed is the dates of different crop phenological events specific to a crop and to a region. Addition of this small but vital input (Table 2) would seem to enhance the value of the probability analysis since drought expectations are presented in a form readily usable by agricultural planners and plant breeders.

Meteorological droughts in India are known to occur due to late onset of the monsoon, breaks in the monsoon and its early withdrawal from the different regions (Sastry, 1976). Also the tracks of storms and depressions in any season play an important part in determining the drought occurrence and its spread in a region in any given season. Assessment of meteorological drought related to rainfall distribution pattern within the cropping season and growth phase of the crop assumes importance under these conditions, since meteorological drought in the season could result in temporary enhancement of evaporation rates (Sastry, 1976) leading to higher water requirements and a change in irrigation scheduling. An empirical technique for characterization of meteorological drought based on defining a dry day or a dry week in relation to potential evapotranspiration at different growth stages and their duration was suggested by Sastry (1970) and further examined in relation to soil drought (Sastry and Chakravarty, 1983). Results indicated that disastrous drought conditions are associated with the season where meteorological drought was followed by soil drought which is a consequence of both low rainfall amounts and its erratic distribution. The frequency of occurrence of meteorological drought (Table 3) during the critical phase of corn crop (51%) had been found to be more than that of soil drought (37%). The results reveal that information on meteorological drought with an element of crop character in it would provide a more meaningful base for analysis of drought using rainfall data.

In conclusion, it may be said that the success of the methods of estimation of meteorological drought and its effect on various activities depends on how skilfully we can extract and generate information using rainfall data to represent the observed features from year to year of agricultural, soil or hydrological drought etc. Even if their features can be studied directly using other techniques like soil water balance or hydrological balance, a knowledge of the meteorological drought and its interpretation is the first requisite before other types of drought are taken up for study. In many parts of the country, it is known that the filling of reservoirs which are sources for supply of irrigation, drinking water, hydroelectricity generation etc. also heavily depend on the monsoon activity in any particular year. It is therefore, imperative that since in contrast to other parameters, rainfall data for long periods of time and from a large network of stations are available in our country, they should be analysed by a judicious choice of the techniques and threshold values depending on the purpose and problem on hand. No doubt, data analysis purely from a statistical point of view, describes the general features of the rainfall domain. However, in view of its high spatial and temporal variability, to render the analysis more practical and purposeful, new techniques which allow enough flexibility for incorporating information on other characteristics related to a particular problem, such as growth stage duration, extent of susceptibility of crop to drought, short period variations indicated in some of the techniques discussed above, appears to be the prime need in this field of study.

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Table 1 : Probability of weekly rainfall less than PET/2

Week No.	PET/2 mm/week	Long term probability	Short Term probability		
			4 out of 5 years	Successive 2 years	Successive 5 years
6	24.5	0.44	0.12	0.19	0.02
7	28.0	0.51	0.20	0.26	0.03
8	22.4	0.41	0.09	0.17	0.01
9	20.3	0.29	0.03	0.08	0
10	19.9	0.44	0.12	0.19	0.02
11	18.2	0.21	0.01	0.04	0
12	12.6	0.33	0.04	0.10	0
13	16.8	0.45	0.13	0.20	0.02
14	15.4	0.52	0.22	0.27	0.02
15	16.8	0.54	0.25	0.29	0.05

(Victor & Sastry, 1983)

Table 2 : Rainfall probabilties during development periods of pearl millet crop (Delhi region)

Probabilites	Sowing and germination (2 weeks)	Tillering (4 weeks)	Flowering (2 weeks)	Grain filling and maturity (5 weeks)
x^2 (2df)	2.12	2.74	2.29	33.75*
p_o	0.198	0.205	0.152	0.079
p_1	0.487	0.389	0.400	0.463
p_w	0.279	0 251	0.202	0.128

(Victor & Sastry, 1979)

p_w : probability of a day being wet

p_1 : probability of a wet day preceded by a wet day

p_o : probability of a wet day preceded by a dry day

df : degrees of freedom

* : denotes rejection of null hypothesis at 0.05 level of a significance ($x^2 > 5.99$)

Table 3 : Drought frequency during crop phases of corn (based on data for 1940-1980)

Nature of drought	Frequency in 41 years	
	Tasselling phase	seasonal value
Meteorological drought	21 (51%)	8 (20%)
Soil drought	15 (37%)	14 (34%)
Soil and meteorological drought	12 (29%)	6 (15%)

(Sastry and Chakravarty, 1984)