CHAPTER IV

Droughts in India: Problems of Definition

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Introduction

The northern hemispheric summer monsoon is a unique phenomenon anywhere in the world. It is a regional atmospheric system with cyclonic circulation in the lower levels overlain by a mighty anti-cyclonic field aloft. The southwest monsoon brings copious rains between June to September to various parts of India. There is a misconception that the southwest monsoon is a meteorological phenomenon of Asian tropics that repeats year after year with great regularity and in almost identical manner. The fact is that large variations from year to year occur not only in date and manner of its initial onset but also in the spatial and temporal distribution of rainfall. Inadequacy and uncertainty in the monsoon rainfall often cause partial or complete failure of crops leading to periodic scarcity or sometimes even famine conditions. It is, therefore, not surprising that agriculture in India is often seen as a gamble of southwest monsoon rainfall. Vagaries of rainfall resulting in serious deficiency, famines or drought have received attention from Indian meteorologists and hydrologists including irrigation engineers since very early times. Legends of worship of the rain God for averting a famine and offering prayers are well known in India.

Considered as a natural phenomenon drought constitutes dryness, want of rain or a dry spell, specially protracted(Webster) affecting or preventing plant growth. Weather glossary, on the other hand, defines drought as a dry spell sufficient in length and severity to cause at least partial crop failure. A dry spell is nothing but a period of moisture deficiency. Considered as an economic phenomenon, drought may be said to prevail whenever rainfall is insufficient to meet the established human activity.

Problem of Drought Definition

One difficulty in defining drought stems from the fact that a period of moisture deficiency could be caused by factors other than a rainfall deficiency e.g., excessive transperative loss, high temperature, low soil holding capacity, etc. Each of these factors has a role in the establishment of drought conditions.

The drought problem can be considered as an integral part of the large problem of the management and use of limited water resources (WMO, 1975). It is essentially a "supply and demand" problem. Any definition which does not include a reference to water need or "demand" must be regarded as inadequate. Though it is rather difficult to define drought precisely, in general terms, drought may be said as a condition when there is "lack of sufficient water to meet normal human and biological requirements"

In addition to these complications in defining drought the interpretation of moisture deficiency also poses a problem since moisture deficiency depends on the type of activity which it affects. Many activities have their own threshold of water requirement. For this reason it is rather difficult to come up with a unified treatment of the phenomenon or to assign a universal definition which satisfies all human activities. Another major problem in drought definition is what should be considered as a drought situation. This is because drought could be of various kinds.

Drought Types

At least three types of drought as mentioned below are recognised in India:

(i) Meteorological drought - It is a situation when there is a significant decrease from climatologically expected and seasonally normal rainfall over a wide area.

(ii) Hydrological drought - Meteorological drought, if prolonged would result in hydrologic drought with marked depletion of surface water and consequent drying up of reservoirs, lakes, streams and rivers and also fall in ground water table.

(iii) Agricultural drought - It occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity causing extreme crop stress, (even wilting) and drastic fall in yields.

Related to agricultural drought we may have

(i) atmospheric drought which is frequently caused by low air humidity and hot dry dessicating winds.

(ii) soil drought, which occurs when soil moisture lags behind evapotranspiration. This type of drought is usually gradual and progressive and hence plants are able to adjust to increased moisture stress.

As deficiency in rainfall is considered the prime cause of drought, most definitions of drought are based on annual, seasonal or monthly rainfall departures. It is, however, difficult to set a limit or threshold for rainfall above which rainfall does not lead to drought. Consequently there is no definite statistical index that could be uniquely used for all categories of drought.

Drought definitions in India could broadly be categorised into two branches:

(i) based on rainfall deficiency
(ii) based on hydrologic accounting technique.

Drought Definitions from Rainfall

In the early studies, no distinction was made to define or distinguish between different types of drought. Rainfall whether monthly, seasonal or annual has often been used as a simple index of drought (agricultural, hydrological or meteorological). In spite of certain shortcomings, particularly in indicating an agricultural drought, one great advantage of using rainfall in drought delineation is that data for long and accurate rainfall are available in India, sometimes extending to more than 100 years for many locations. In most of the studies in India, rainfall has been used as an indicator of drought.

From rainfall deficiency point of view pioneering work has been done by Walker (1919). He used seasonal rainfall data from 1841-1908 as an indicator of drought in India. He worked out rainfall departures from long term means and identified bad monsoon years. However, he had some doubts about the degree of accuracy of the data.

Drought concept was applied for the first time to agriculture in India by Ramdas (1950). He defined drought to have occurred if the weekly rainfall is less than twice the mean deviation. He could identify 1877 and 1899, the two worst drought years then in India. However, the method also considered 1913 and 1920 as years of outstanding agricultural drought though in these two years the areally averaged rainfall over India computed from tables given by Parthasarthy et al. (1987) were respectively 99.6 and 95.2cm, much above normal of 85.3cm given by Mooley and Parthasarthy (1984). Thus rainfall in these two years does not appear to be so bad as to be categorised as drought.

Mallik (1958) adopted the following criteria while discussing the drought problems of India in relation to agriculture:

(i) a wet season consists of weeks with a normal rainfall of more than 5 mm
(ii) a week of 'drought' is one with actual rainfall equal to half the normal rainfall or less and
(iii) 'drought' has really serious repercussions on crop growth only when it extends over four or more consecutive weeks.

Gibbs and Maher (1967) developed a system which uses the limit of each 10% or deciles of the rainfall distribution. The approach was used by George and Kalyansundram (1969) for assessing agricultural droughts with respect to winter rice yields. The method was found to furnish critical values of rainfall for different months that would result in agricultural drought. However, in certain years the criteria was not found to hold good. Similarly Kalyansundram and Ramasastry (1969) modified Van Rooy's (1965) anomaly index by using 25% rainfall departure instead of the mean departures of ten lowest values. They claim that this drought index could be used as a rough indicator of the crop yield, when cumulated on monthly basis during crop season. The index however, could not identify some of the worst drought years. The basic difficulty in these studies were that though they were aimed at defining agricultural drought, the water need of the plants in relation to demand was never considered.

Bhalme and Mooley (1980) developed an index called Drought Area Index utilising monthly rainfall deficiency for defining large scale drought. The index is based on the assumption that agriculture in a region is adjusted to average rainfall variability. The criteria evolved was found to agree well with the actual conditions.

Analogous to decile method, Mooley et al. (1981) adopted percentile method for drought studies. They considered a year as drought when the rain water deficiency was below the tenth percentile of the normal distribution. With a view to assessing deficiency in monsoon rainfall of India, an index termed as Monsoon Deficiency Index was developed by Mooley and Parthasarthy (1982). This index was obtained by expressing the area of the country receiving 80% of the seasonal normal rainfall as a fraction of the total area of the country. The most important aspect of their data series of 1871 to 1978 period was that they considered a fixed number i.e., 306 stations throughout the data period and thus assured homogeneity of the rainfall series. The method enabled them to identify some of the years of the worst monsoon failures; however, some differences were noticed owing to criterion. Moreover, in their methodology, they had ignored year to year variations in the area affected. Using the same set of data i.e., 306 stations Mooley and Parthasarthy (1983) proposed another criteria based on rainfall expressed as a standard deviate, Yi given by

$$Y_i = (X_i - \bar{X})/\sigma$$

Where Xi is the rainfall of ith year, $\bar{X}$ the normal rainfall and σ the standard deviation. They considered drought to have occured when Yi < -1.28, the value 1.28, being 10% value of the Gaussian distribution. Since district was used as a basic unit instead of meteorological subdivision (which are far larger in area) these approaches definitely give a better representation of subnormal rainfall. But, it is felt that a data of a mere 306 stations is inadequate to represent a vast country like India. Another shortcoming is the assumption that the rainfall is normally distributed. As is well known rainfall over many parts in India is not normally distributed.

Similar to the index developed by Mooley and Parthasarthy (1982), Chowdhury and Abhyankar (1984) developed a criteria for defining drought, using 25% as the limit, which is widely assumed as the threshold to initiate drought conditions. This study also does not take the interannual variability into account. Sarkar (1988) considered the whole country as affected by drought when the departure of rainfall from normal is -11% or less. The value of -11% adopted in the study appears arbitrary. Also the approach does not take into consideration the statistical distribution of the departures nor the interannual variability.

Recently, Chowdhury et al. (1989) proposed a criteria of drought by taking into account rainfall deficiency 25% or more and the year to year variations by computing standard deviate of the area affected. Their definition of drought, however, is based on meteorological subdivisional data. A subdivision comprises of a number of districts and working out mean for such a vast area (where rainfall is highly spatially variable), does not appear justified.

Definition Based on Water Balance

The above mentioned studies are purely based on rainfall deficiency in some way or the other. So far as meteorological/hydrological drought is concerned, these definitions may perhaps be quite adequate. But if the emphasis is on agricultural drought, they are, by and large, of limited use. Beginning of the drought period depends upon the moistness of the soil at the start of the dry spell. Agricultural drought, therefore, begins when the vegetation cannot absorb water from the soil rapidly enough to replace the moisture loss by respiration. It persists when there is no continued replenishment of the water in the soil. In other words, in any definition of agricultural drought unless water supply in relation to water need is taken into account, the whole exercise becomes meaningless. This aspect can well be solved by hydrological accounting procedure.

Earlier investigations in India used the water balance technique, mostly Thornthwaite and Mather (1957), to develop drought indices. For example, Subramanyam and Sastry (1969) have computed aridity index to define droughts in India. The yearly march of the index was graphically plotted and the amplitude of the departure of the index from its normal value was taken to represent severity of drought on annual basis. Employing a purely statistical technique drought years were classified as moderate, large, severe or disastrous according as the departure of the aridity index from the normal value was less than $1/2\ \sigma$, between $1/2\ \sigma$ to σ, between σ and $2\ \sigma$ or above $2\ \sigma$ respectively, σ being the standard deviation.

The water balance technique was also adopted by George and Ramchandran (1969) in drought identification. The date when soil moisture storage falls below half the field capacity after cessation of monsoon rains was found to give a good indication of whether drought has occurred.

In this study however, soil moisture storage value was arbitrarily chosen. Also loss due to evapotranspiration was done on monthly basis and estimated using approximate empirical relationship. Use of shorter time periods e.g a week would have given realistic values of the evaporation with better results.

Water availability periods like preparatory, intermediate, humid and moist, as suggested by Cocheme and Franquin (1967), also provide indication of crop drought. Agricultural drought has been studied by George and Alda (1969) using this technique in relation to rice yield for one location. It was found that a significant shortening of humid period and its early termination lead to shortfall in rice yield and both rice and wheat yields are low with the shortening of moist period. Both these studies however, provide mainly a qualitative idea of drought.

A vigorous and comprehensive mathematical treatment to the drought definition was given by Palmer (1965), on the basis of hydrologic accounting. In this technique moisture supply is in the form of rainfall and soil moisture storage and moisture demand by way of evapotranspiration, current and antecedent weather. He uses CAFEC (Climatologically Appropriate for Existing Conditions) rainfall for obtaining rainfall anomaly. The CAFEC precipitation $\hat{P}$ is an imaginary amount of a place that will maintain at normal level all established human activities. It is given by

$$\hat{P} = \alpha\, ET + \beta R + \gamma RO - \delta L$$

Where ET =evapotranspiration

R = soil recharge

RO = run off

L = loss

α, β, γ and δ being constant.

This technique was adopted by George et al. (1973) to different meteorological subdivisions of India to identify drought periods and their intensities. The study, no doubt identified some of the severe dry spell periods but it could not be considered fully realistic. Computation on the basis of point data could have brought out a better picture of the drought situation. The methodology has the following limitations:

(i) It is a systematic approach for drought problem as it takes into account abnormalities in all major factors in drought developments viz., evapotranspiration, soil moisture, run off etc. It does not however, indicate which particular aspect of the moisture balance is affected more.

(ii) It does not distinguish between agricultural and hydrological droughts; it indicates meteorological droughts.

(iii) In moist sub-humid areas it represents hydrological drought and in arid and semi-arid regions, the agricultural drought.

For a few selected locations over India, Bhalme and Mooley (1979) applied Palmer's Drought Index and also found it inadequate to describe the drought conditions realistically. They modified the weighting factors in Palmer's index and observed that the performance of the model improves significantly. However, the modified model was based on a smaller sample, i.e., arid, semiarid and dry sub-humid locations, ignoring the moist side of the climatic spectrum. It could not be applied for the whole country and the moist locations would perhaps need a separate model.

Thornthwaite and Mather's (1957) water balance technique was adopted by Chowdhury et al. (1977), Rao and Vijayaraghavan (1983) etc., to define agricultural drought and delineate drought affected areas. These studies have applied the weekly aridity anomaly concept and delineated agricultural drought. The methodology could identify periods and areas in which crops would have suffered growth due to inadequate soil moisture availability.

Concluding Remarks

The problem of defining drought remains an unsolved riddle because of the complexities involved. The water balance seems to be a better approach for the objective than the use of rainfall since it takes into account factors like rainfall, transpiration loss, soil moisture storage and run off. It also attempts to arrive at a balance between water income and water loss.

The need to have universally acceptable standard definition of drought is great. It would also be convenient and of great utility, if definitions for each discipline are evolved for different kinds of drought, depending upon the type of activity they affect and the user's interest.

References

1. Bhalme, H.N. and D.A. Mooley, 1979, *Arch. Met. Geoph.*
2. *Biokl., Ser. B.*, 27, pp. 281-295.
3. Bhalme, H.N. and D.A. Mooley, 1980, *Mon. Wea. Rev.*, 108, pp. 1197-1211.
4. Chowdhury, A. and V.P. Abhyankar, 1984, *Mausam*, 35,pp. 375-378.

5. Chowdhury, A., M.M. Dandekar, and P.S. Raut, 1989, Accepted for publication in Mausam.
6. Chowdhury, A., K.S. Ramasastry, and G.S., Rentala, 1977, Pre. Pub. Sci. Rep. No. 77/4, Ind. Met. Dept.
7. Cocheme, J. and P. Franquin, 1967, *W.M.O. Tech. Note No. 86*, World Meteorological Organisation, Geneva.
8. George, C.J. and K. Alda, 1969, *Sci. Rep. No. 95*, Ind. Met. Dept.
9. George, C.J. and V. Kalyansundram, 1969, *Pre. Pub. Sci. Rep. No. 96*, Ind. Met. Dept.
10. George, C.J. and G. Ramachandran, 1969, *Sci. Rep. No. 94*, Ind. Met. Dept.
11. George, C.J., K.S. Ramasastry, and G.S. Rentala, 1973, *Met. Mon. Agrimet*, No. 5, Ind. Met. Dept.
12. Gibbs, W.J. and J.V. Maher, 1967, *Bulletin No. 48*, Bureau of Meteorology, Melbourne, Australia.
13. Kalyansundram, V. and K.S. Ramasastry, 1969, *Pre. Pub. Sci. Rep. No. 97*, Ind. Met. Dept.
14. Mallik, A.K., 1958, *Proc. hydrol. aspects of floods and drought in India*, New Delhi, pp.65-70
15. Mooley, D.A., et. al., 1981, *Jour. Clim*, 1, pp. 167-186
16. Mooley, D.A. and B. Parthasarthy, 1984, *Climatic Change*, 6, pp. 287-301.
17. Mooley, D.A. and B. Parthasarthy, 1982, *Arch. Met. Geophy. Biokl.Ser. B.*, 30, pp.383-398.
18. Mooley, D.A. and Parthasarthy B., 1983, *Mon. Wea. Rev.*, 111, pp.967-978.
19. Parthasarthy, B., et. al., 1987, *J. Clim.*, 7, 57-70.
20. Palmer, W.C., 1965, U.S. Weather Bureau, *Research Paper No. 45*, Washington.
21. Rao, G.S. and G.S. Vijayraghavan, 1983, *Vayu Mandal*, 13,pp. 35-40.
22. Ramdas, L.A., 1950, *Ind. J. Met. Geophys*, 1.pp. 262- 274.
23. Sarker, R.P., 1988, *Proc. Int. Conf. Tropical Micro- meteorology and Air Pollution*, Delhi, India.
24. Subramanyam, V.P. and C.V.S. Sastry, 1969, *Annals Arid Zone*, 8, pp. 18-23.
25. Thornthwaite, C.W. and J.R. Mather, 1957, *Lab. of Clim.*, Centeron, Vol. X, No. 3.
26. Van Rooy, M.P.,1965, NOTOS, Weather Bureau, South Africa, 14, pp.43-48.
27. Walker, Sir Gilbert, 1919, *Memoir.*, Ind. Met. Dept., pp. 1-21.

28. W.M.O., 1975, *Special Environmental Report No. 5,* World Meteorlogical Organisation, Geneva.

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