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Areal extent of southwest monsoon droughts in India

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ABSTRACT. Areal extent of droughts in India is studied by computing linear correlation between the southwest monsoon rainfall of a particular station (master station), when it gets below-median rainfall, and the corresponding monsoon rainfall of each of 120 other stations forming a well distributed network over the country. This is done for 12 master stations selected over different parts of the country. The study shows that droughts in the western parts of the country have comparatively greater areal extent.

1. Introduction

Fluctuations in the southwest monsoon rainfall in India are well known. It is a feature of considerable significance in the agricultural production of the country. The coefficient of monsoon rainfall variation ranges from 20 per cent (west coast, east Madhya Pradesh) to 60 per cent (west Rajasthan, Tamil Nadu). In some years, when rain is plentiful over some areas, there are other areas which receive insufficient rain rendering normal agricultural and other rain-based activities difficult. Spatial correlation study of rainfall is of interest in this context, as it brings out the extent of high and low rainfall association between different areas. Studies of this type have been carried out in the United States by Yevjevich (1967) and in Australia by Maher (1968). They computed linear correlation between rainfall of a particular station (called master station) and other stations in the country.

In recent years, occurrences of severe droughts in India (in Bihar in 1965 and 1966 and in Maharashtra and other areas in 1972) have caused considerable concern. Features leading to non-occurrence of rain or its poor distribution have evoked scientific interest. One aspect of the problem to be studied in this connection is the areal extent of drought, because the greater the areal extent, the greater is the resulting distress. This feature of drought can be studied by the technique of rainfall correlation when the master station experiences drought. When a station receives low rainfall, say below median or less than a specified percentage of the normal in a period, it does not necessarily mean prevalence of drought conditions. This rain may be sufficient to meet the needs of vegetation and other established normal activities of the place. When rainfall is not adequate to meet these requirements and water shortage begins to affect the region adversely, then only drought commences. This rainfall requirement will vary from place to place depending on the type of soil, evapotranspiration loss etc, and hence it is difficult to specify rainfall deficiency on a uniform basis for drought incidence. So, for the purpose of the present study, below-median rainfall at the master station is taken only in a very broad sense, as the drought criterion, this representing the lower drought-half of the rainfall spectrum.

2. Methodology

Over most areas of the country, the southwest monsoon (June-September) rainfall accounts for more than 80 per cent of the annual. Tamil Nadu is however an exception. This principal rainy season of the country has, therefore, been studied. Rao *et al.* (1972) have shown that by and large, the southwest monsoon rainfall of India is normally distributed. No transformation of the monsoon rainfall series was, therefore, done for applying the statistical technique of correlation.

A well distributed network of 120 rain recording stations located over different parts of India and having data for about 60 years (1901-1960) was selected for the study. In this network, 12 stations located in different States were chosen as master stations. These are shown in Fig. 1. Taking Trivandrum as the master station, years when Trivandrum received below-median southwest monsoon (June-September) rainfall were found out Linear correlation was computed between monsoon rainfall of Trivandrum and each of the other network stations (Fig. 1) of these years. Correlation coefficients were plotted and isopleths drawn for

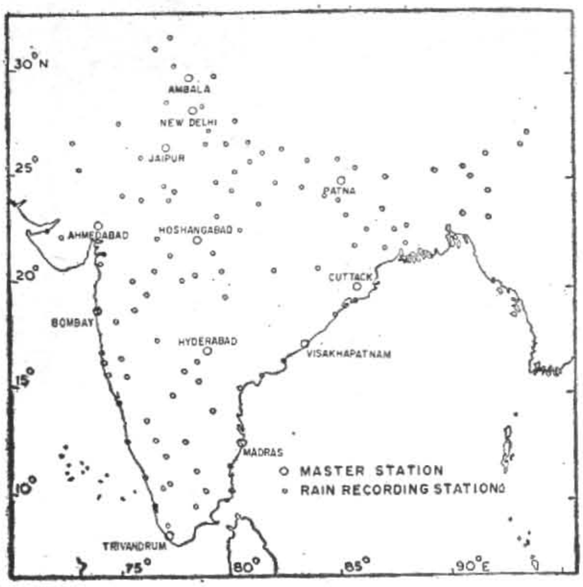

Fig. 1. Locator map

values of 0.6, 0.4 and 0.0. Isopleth marked zero delineates areas of positive and negative correlation. This was done for each of the master stations selected.

For the data series considered, the 2 per cent significant value of correlation coefficient is 0.4. The areal extent of drought for the purpose of discussion is taken as the area covered by the isopleth of the correlation coefficient of this value.

3. Areal extent of drought

3.1. *Stations showing belts of high correlation* (0.6)

(*i*) *Trivandrum* (*master station*) Fig. 2(a) — The belt of high correlation (0.6) in the proximity covers most of south Kerala and that of 0.4 correlation extends well northwards, along west coast, to south Maharashtra and then eastwards. Correlation decreases rapidly east of Western Ghats. Over the central parts of the country, correlation is small and insignificant. Negative correlation is seen over northeast India.

Over northwestern parts of Uttar Pradesh, there is a second belt of significant correlation (0.4).

(*ii*) *Hyderabad* (*master station*) Fig. 2(b) — There is an elliptical belt of high correlation (0.6) in the proximity extending in a general east-west direction. Surrounding this, there is a belt of correlation (0.4). Outside the above areas correlation is small becoming negative over Gujarat and northwest India.

(*iii*) *Bombay* (*master station*) Fig. 2(c) — The belt of correlation (0.6) in the proximity extends over Konkan and that of 0.4 in northnortheasterly direction to a distance of 1000 km.

A second belt of significant correlation (0.4) is seen over the Punjab and adjoining areas of Himachal Pradesh. There are two belts of negative correlation; an extensive one over northeast India and a small one over interior south Tamil Nadu.

(*iv*) *Ahmedabad* (*master station*) Fig. 2(d)— The belt of high correlation (0.6) covers most of Gujarat and that of 0.4 extends northwards to Punjab. Outside this area, correlation is small with negative correlation over northeast India.

3.2. *Stations showing belts of moderate correlation* (0·4)

(*i*) *Hoshangabad* (*master station*) Fig. 3 (a)—The belt of correlation (0.4) is mostly to the south of the station and is more or less elliptical in shape. Outside this area, correlation is small becoming negative over a small belt of southwest Uttar Pradesh, northeast India and southern tip of Kerala.

(*ii*) *Jaipur* (*master station*) Fig. 3(b) — There is a fairly large area extending in a general east-west direction around the station having correlation 0.4. Over the Punjab and adjoining areas, as well as over the coastal areas of Maharashtra and Gujarat, correlation values of the same order are seen.

(*iii*) *Ambala* (*master station*) Fig. 3(c) — The belt of correlation 0.4 in the proximity covers a narrow north-south belt extending from Punjab (Ludhiana) to northwest Madhya Pradesh (Gwalior). There are two other belts of significant correlation; one over Maharashtra and Gujarat and the other over north Tamil Nadu and adjoining areas.

(*iv*) *New Delhi* (*master station*) Fig. 3(d) — The belt of high correlation (0.6) is small in extent, while the 0.4 correlation belt extends northwards as well as to a considerable distance to the south.

3.3. *Stations showing large areas of small or negative correlation*

Fig. 4 shows correlation field in respect of 'master station' Patna, Cuttack, Visakhapatnam and Madras. For all these stations, no belt of significant correlation is seen in the proximity. Correlation is small or negative all over the country. The only exception is in the case of Madras (master station) where a small belt of correlation (0.4) is seen not in the proximity but some distance away, *i.e.*, over the Raichur-Sholapur area.

4. Conclusions

The above correlation analysis of southwest monsoon rainfall reveals that droughts in some parts of the country cover wide areas, while in some other parts the areal extent is not appreciable.

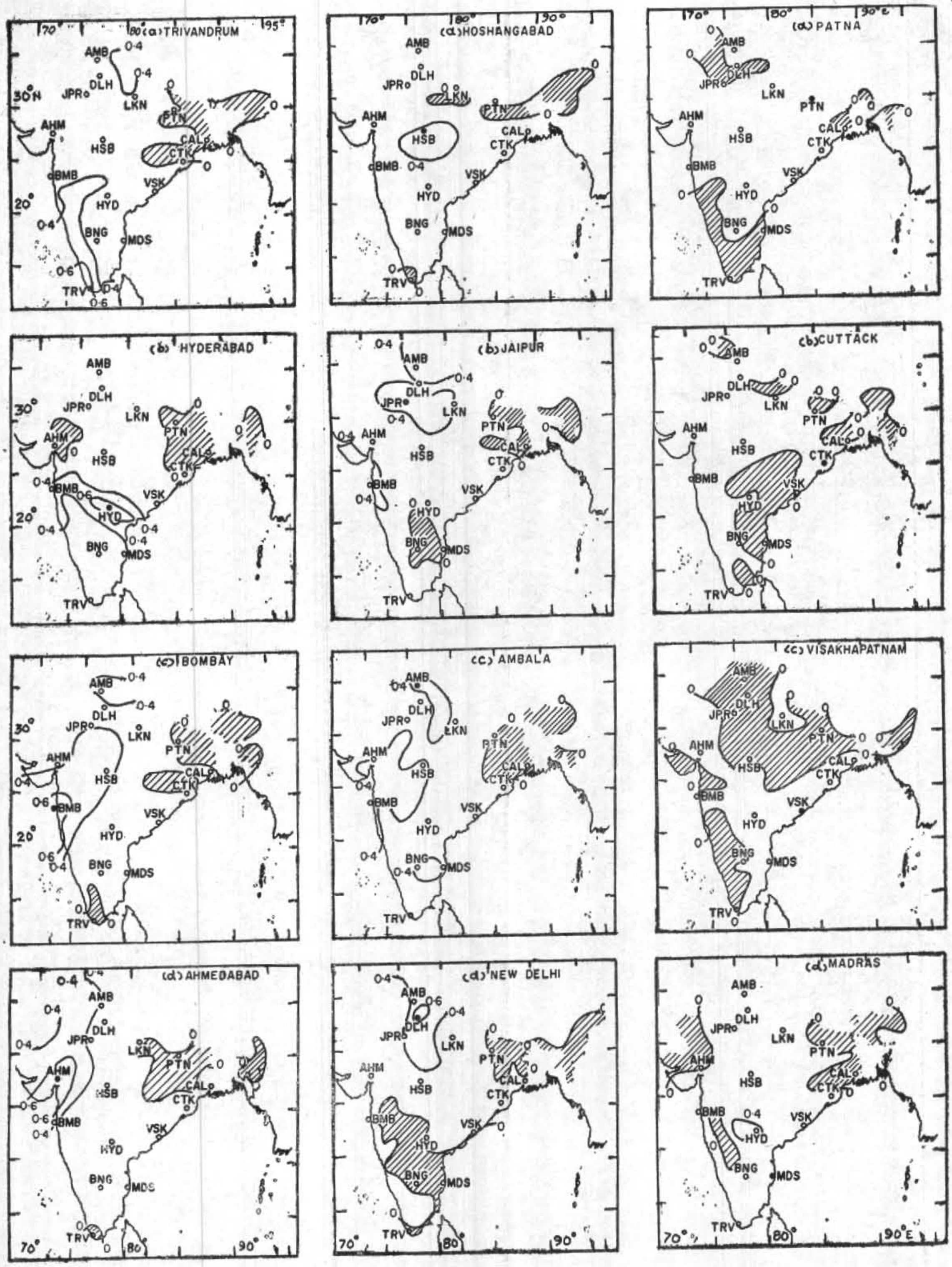

Fig. 2 Fig. 3 Fig. 4

Figs. 2-4. Isopleths of correlation coefficients of southwest monsoon (June-September) rainfall when master station receives below median rainfall in the season

Droughts with great areal extent are seen more in the western part of the country than in the eastern part. Severe droughts have generally large areal extent (Yevjevich 1967). This will mean, as a very broad generalization, that droughts occurring in the western parts of the country are more severe. The study reveals indirectly an important feature of weather systems over the country. Weather systems over the western part of the country causing below-median rainfall in the monsoon season have comparatively greater areal extent.

This difference in the rainfall and weather systems over the western and eastern half of India may result from the cumulative effect of the positioning of 'source/sink' in the zonal wind flow pattern of the monsoon circulation. This aspect, however, requires further critical examination.

Other features brought out are :

(*i*) The belt of high correlation (0.6) is not circular around the master station. However, in some cases this belt is more or less elliptical in shape (Hyderabad and Ahmedabad).

(*ii*) Rapid decrease of correlation to the east of the Western Ghats is seen in the case of Trivandrum.

(*iii*) Some stations have fairly large belts of significant correlation (0.4) in the proximity (Hoshangabad, Jaipur, Ambala and New Delhi).

(*iv*) No belt of significant correlation is seen in the proximity in the case of Patna, Cuttack, Visakhapatnam and Madras.

(*v*) A second belt of significant correlation (0.4) is seen in the case of Trivandrum, Madras, Bombay, Jaipur and Ambala.

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