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551.577.38 : 551.582 (540)

On some climatological aspects of drought in India

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सार — इस लेख में 1975 से 1980 तक के आंकड़ों को आधार मानकर भारत में सूखा संबंधी जलवायु विज्ञान के संकलन और संयोजन का प्रयास किया गया है । इस लेख में मौसम वैज्ञानिक सूखा अर्थात् वर्षा में सामान्य से 25% से अधिक कमी पर ही विचार किया गया है । विभिन्न मौसम विज्ञान उपमण्डलों में कितनी बार और कब-कब सूखा पड़ा, इसकी सूचना प्राप्त कर ली गई है, जिसका उपयोग एक सूखे से दूसरे के बीच में पड़ने वाले अन्तराल को निश्चित करने के लिए किया गया है । सूखे को मध्यम व भीषण, इन दो वर्गों में वर्गीकृत किया गया है और इस किस्म के सूखों की विभिन्न उपमण्डलों में संभावनाओं को अभिकलित किया गया है तथा उन पर चर्चा की गई है । देश में सूखे से प्रभावित क्षेत्रफल को ध्यान में रखते हुए सूखे को आगे भी विभिन्न वर्गों में वर्गीकृत किया गया है, यथा स्थानीय, अर्ध-विस्तृत, विस्तृत, व्यापक और अनर्थकारी । प्रत्येक वर्ग की प्रेक्षित बारंबारता भी मालूम की गई है । सूखे की घटनाओं का दशकीय आंकलन कर लिया गया है और किसी भी दशक में सूखे की प्रागुक्ति के लिए इसका उपयोग किया गया है । सूखे की शृंखला का शक्ति स्पेक्ट्रम विश्लेषण भी किया गया है और महत्वपूर्ण चरम स्थितियां मालूम करके, उनके बारे में विचार-विमर्श किया गया है ।

कोई वर्ष पूरे देश के लिए एक अच्छी मानसून वाला वर्ष रहा या बुरी मानसून वाला वर्ष था, यह निश्चित करने के लिए चूंकि अभी कोई संगत मापदंड नहीं है इसलिए इस समस्या के समाधान के लिए एक वस्तुपरक और व्यावहारिक प्रयास किया गया है । सूखा वर्ष पर विचार करने के लिए निम्नलिखित दो वर्गों पर अलग से भी चर्चा की गई है :

(1) जब प्रभावित क्षेत्र की प्रतिशतता 20 प्रतिशत से अधिक हो,

(2) जब क्षेत्र की प्रतिशतता 25 प्रतिशत से अधिक हो ।

सूखा-वर्ष अथवा प्रचुर मानसून वर्ष के अनुक्रम मालूम कर लिए गए हैं । इनके आधार पर (क) तीन लगातार अच्छे वर्ष, (ख) 4 अच्छे वर्ष और (ग) 5 अच्छे वर्षों के बाद एक सूखा वर्ष की संभावनाओं का पता लगाने के लिए जांच की गई है । इसी प्रकार प्रत्येक 3, 4 और 5 लगातार अच्छे मानसून वर्षों के बाद लगातार सूखा वर्षों की संभावनाओं का पता लगाया गया है । अच्छे अथवा बुरे मानसून वर्षों की संभावना में स्थायित्व का पता लगाने के लिए भी इन अनुक्रमों का उपयोग किया गया है और उनका परीक्षण करके उनकी सांख्यिकीय सार्थकता का पता लगाया गया है ।

ABSTRACT. Based on data from 1875 to 1980, an attempt has been made in this paper to compile and collect drought climatology of India. Only "meteorological drought", *i.e.*, rainfall deficiency exceeding 25 % of the normal has been considered. Frequency of occurrence of drought in different meteorological sub-divisions has been obtained which has been used to determine its recurrence period. Drought has been classified into moderate and severe categories and the probability of occurrence of these types in different sub-divisions computed and discussed. Depending upon the area of the country affected, drought has been further classified into different categories, *viz.*, localised, semi-vast, vast extensive and calamitous, observed frequency of each type determined. Decadal representation of the drought incidence has been obtained and used to predict its occurrence in any 10-year period. The series is also subjected to power spectrum analysis and significant peaks obtained and discussed.

Since no rational criteria to define an year as a good or bad monsoon year for the country as a whole exists at present, an objective and pragmatic approach to solve this problem has been attempted. The following two categories were separately adopted to consider a year as a drought year, *viz.*,

(*i*) When the percentage area affected exceeds 20%,

(*ii*) When the area exceeds 25%.

Sequences of a drought year or a good monsoon year have been obtained. This has subsequently been examined to obtain probabilities of a drought year following (a) 3 consecutive good years, (b) 4 good years, and (c) 5 good years. Similarly chances of two consecutive years of drought after each of 3, 4 and 5 consecutive good monsoon years have been determined. These sequencies have also been utilised to find persistence in occurrence of good or bad (drought) monsoon years and subjected to χ^2-test to determine its statistical significance.

1. Introduction

Drought rank as one of foremost serious natural tragedy for mankind. Inspite of spectacular scientific advances, drought remains a formidable and unsolved riddle. There is hardly any region which in one year or the other does not experience drought in this country. In recent years the vagaries of monsoon have

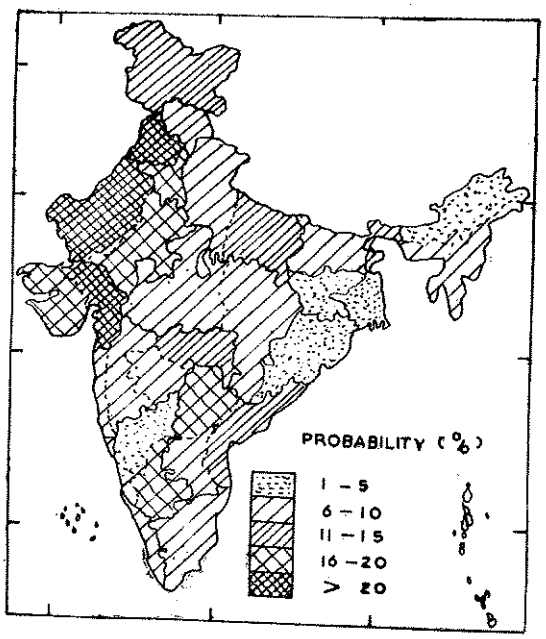

Fig. 1. Probability of drought in India

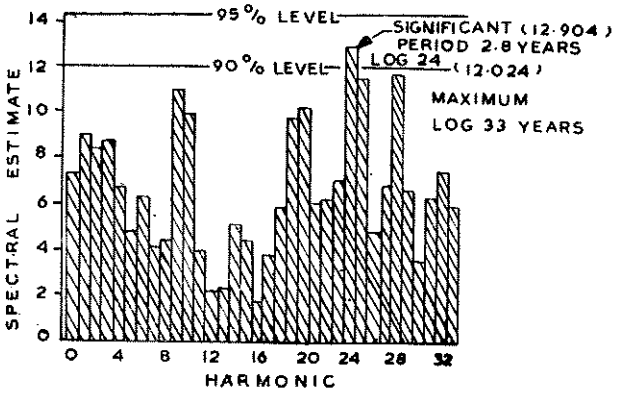

Fig. 2. Power spectrum analysis of drought

often resulted in frequent drought incidence, producing far reaching economic consequences. Knowledge of drought is essential for short and long term advance planning especially in the field of agriculture. Agricultural planners require, well in advance, chances of a year being good in order to reap maximum benefit and to prepare plans for minimising distress in years of bad monsoon.

Drought climatology has thus emerged as a discipline of immense practical and potential value. Some of the economically important decisions involve periods of time which are beyond the capability of meteorologists to produce conventional forecasts. For the weather sensitive policy decisions intended to remain in use for a long time, as such, recourse has to be taken to the information in the climatological form. In this paper an attempt has been made to compile and collate drought climatology of India.

2. Data

Rainfall data for 31 sub-divisions from 1875 to 1980 have been used in the study. The data pertains to June to September months, during which over 80% of rainfalls in the country. Droughts have been classified as those in which seasonal rainfall departures were less than or equal to —25%, which have been further classified as moderate (departures between —26 and —50%) and severe (departures less than —50%) droughts.

3. Drought probability

3.1. The probability of drought in different meteorological sub-divisions is shown in Fig. 1.

Areas of high probability, *i.e.,* greater than 20% are located in northwest India, the sinking limb of the monsoon cell (Das 1962). Areas where it lies between 15 & 20% are Saurashtra and Kutch, east Rajasthan, Haryana, Telangana and south interior Karnataka. Over northeastern region and the west coast the probability is low.

The following recurrence period of drought emerged from this analysis :

Recurrence period	*Sub-divisions*
Once in 4 to 5 years	Rajasthan Punjab, Gujarat and Telangana
Once in 6 to 8 years	Haryana, Jammu & Kashmir, Uttar Pradesh (east), Sub-Himalayan West Bengal, Vidarbha, interior Karnataka (south) and coastal Andhra Pradesh
Once in 10 years	Himachal Pradesh, Uttar Pradesh (west), Madhya Pradesh, Bihar Plains, Marathwada, Konkan, Rayalaseema & Kerala.
Once in 15 - 20 yr	Madhya Maharashtra, south Assam, Tamil Nadu, interior Karnataka (north) and Orissa.
Very rare	Coastal Karnataka, Bihar Plateau, north Assam and Gangetic West Bengal

TABLE 1

S. No.	Sub-division	Ratio of moderate and severe drought
1	Saurashtra and Kutch	1 : 1
2	Gujarat region	2 : 1
3	Rajasthan (west and east)	2 : 1
4	Madhya Maharashtra	3 : 1
5	Interior Karnataka (south)	3 : 1
6	Haryana	4 : 1
7	Punjab	6 : 1

TABLE 2

Classification of frequency of areal extent of drought

S. No.	Category	Percentage of the area affected	Observed frequency
1	Localised drought	(1-10%)	41
2	Semi-vast drought	(11-20%)	16
3	Vast drought	(21-30%)	8
4	Extensive drought	(31-50%)	8
5	Calamitous drought	(>50%)	3

TABLE 3

Current year	Preceding year: Good (G)	Preceding year: Bad (B)	Total
	Category I		
Good (G)	68	17	85
Bad (B)	17	3	20
Total	85	20	105
Fraction of G to total	0.80	0.85	
Fraction of B to total	0.20	0.15	
	Category II		
Good (G)	76	13	89
Bad (B)	13	3	16
Total	89	16	105
Fraction of G to total	0.85	0.81	
Fraction of B to total	0.15	0.19	

It is evident that for every drought of moderate intensity a severe drought is expected over Saurashtra and Kutch, while in Gujarat region and Rajasthan for every two cases of moderate droughts, an incidence of severe drought occurs. This ratio comes down to 6 : 1 for Punjab, *i.e.*, out of 7 years of droughts, in only one year the drought is of severe intensity, *vide* Table 1.

3.2. *Areal extent*

The extent to which the country is subjected to drought hazard during different years has been examined. It was observed that more than 50% of the sub-divisions experienced drought during 1877, 1899, 1918, 1972 and 1979 while in 1904, 1965 and 1974 over a third of them experienced drought. In 30 years not a single sub-division experienced drought, notable amongst them are 1953-1956, 1958, 1961, 1970 and 1975. Areas of all sub-divisions experiencing drought in any year were added together and expressed as a percentage of the total area of the country. The following classification was adopted to describe areal extent of drought (*cf.* Subrahmanyam 1967) — Table 2.

According to the above mode of classification, years of vast drought were 1901, 1904, 1907, 1911, 1939, 1941, 1966 and 1971. Extensive drought occurred in the years 1891, 1904, 1920, 1951, 1965, 1972, 1974 and 1979 while India witnessed calamitous drought in three years, *viz.*, 1877, 1899 and 1918.

3.3. *Power spectrum analysis*

The nature of relationship in a time series of drought becomes more clear through a spectral analysis. The area experiencing drought was subjected to the power spectrum analysis with a lag upto 33 years. The results are shown in Fig. 2. None of the peak was found significant at 95% level. However, a peak of 2.8 years cycle is found significant at 90%. This possibly could be associated with a quasibiennial oscillation.

3.4. *Drought sequence*

We do not appear to have any rational criteria to categorise an year as a good or bad from monsoon rainfall point of view for the country as a whole. Each research worker has adopted his own method to suit his line of research. A more objective and pragmatic approach to solve this problem has been attempted. The following two categories were separately adopted to consider a year as a bad year, (B), *viz.*,

(*i*) When the percentage area affected exceeds 20%,

(*ii*) When the area exceeds 25%.

All those years which were not bad years were assumed to be years of good monsoon (G). A perusal of occurrence of good/bad years showed that sequences for both categories were rather random. The interval between good and bad years varies from 1 year to a maximum of 18 years (1921-1939) for the first cate-

gory and 30 years (1921-1950) for the second category. Consecutive two bad years appear to be less frequent and were observed only on three occasions, *viz.*, 1904-1905, 1965-1966 and 1971-1972, while there was no situation when the country experienced 3 consecutive bad years. Frequency of one or two bad years succeeding 3 or more good years alongwith their probabilities are given below :

	A bad year following			Two bad years following		
	3 good years	4 good years	5 good years	3 good years	4 good years	5 good years
	Category I					
Frequency	10	9	7	2	2	1
Probability %	17	18	19	4	4	3
	Category II					
Frequency	6	6	5	2	2	1
Probability %	9	10	11	3	3	2

From the above it is observed that probability of occurrence of bad years, following 3 or more good years is less than 20% in the first category and nearly 10% in the second category. Chances of two bad years succeeding 3 or more good years are, however, less than 5% for both categories.

3.5. *Persistence in good or bad monsoons*

Sequence of good/bad years have been used to examine persistence in years of good or bad monsoons. Out of 106 there were 86 and 90 good years for the two categories respectively and 20 and 16 were respective occasions of bad monsoon. For any tendency for the good year to occur successively, the probability of good year has to be greater if the preceding year was good than when the preceding year was bad. This hypothesis has been tested by preparing 2×2 contingency tables (*see* Table 3).

The χ^2 values were low and insignificant, indicating absence of dependence. Chance of G following G were 0.80 and 0.85 for the two categories while B succeeding B were 0.15 and 0.19. These values were not significantly different from their probabilities. It, therefore, means that occurrence of good or bad monsoon, is a random phenomenon, though there is weak tendency for a good monsoon year to recur in the following year.

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