OCCURRENCES OF DROUGHTS AND FLOODS ASSOCIATED WITH RAINFALL PATTERN OVER INDIA

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1.0 INTRODUCTION

The monsoon period is not one of continuous rain in any part of India. There may be prolonged breaks in the rain or the rains may terminate considerably earlier or persist longer than usual. The rainfall may be unevenly distributed in space and time being excessive in one part of the country and deficient in another part resulting in flood/drought situations.

One who examines the past records in India cannot help noticing that, in many years, parts of the country have been subjected to "drought" owing to the failure of rains and that occasionally, the entire country had to suffer this calamity. On the other hand, when heavy rainfall occurs consecutively on a number of days and particularly over the entire catchment areas of rivers, the magnitude of the ensuing floods is enormous. Flood and drought hazards are very common in all parts of India. They disrupt human lives, cause death and destruction, loss of property and wealth. Floods in Gangetic and Brahmaputra basin occur almost every year and work havoc on local population. Perennial shortage of rainfall and overusage of water bring in drought like situations every year in some parts of the country. For such phenomena like "drought" and "flood", the remedies depend on large scale planning and operative measures. Therefore, the study of "floods" and "droughts" have occupied and continues to occupy an important place in national programmes of many countries.

Accordingly, in this paper an attempt has been made to understand the characteristics of rainfall of various meteorological sub-divisions with particular reference to the drought and flood situations. Variability of rainfall has been discussed and areas of high and low rainfall identified.

2.0 DATA USED

The present study utilises data of 35 sub-divisions in which the country is divided for meteorological purposes. For most of the sub-divisions 116 years data (1875-1990) has been used. Based on data of over 500 surface observatories and over 5000 state rainguage stations, the total rainfall for the monsoon season has been computed. June to September months are supposed to constitute the summer monsoon season in India.

3.0 CRITERIA FOR DROUGHT/FLOOD

Depending upon the aim of the study, drought can be defined in various ways. Palmer (1965) defined drought as a prolonged and abnormal moisture deficiency. Palmer's drought severity index (PDSI) has been extensively applied in drought delineation (Frere and Popov, 1979; Bhalme and Mooley, 1980; Chowdhury and Gore, 1989 etc.). Based on seasonal rainfall deficiency, Parthasarathy et al. (1987) and Chowdhury et al. (1989) studied various facets of droughts in India.

In the present study, years in which, 20 percent or more of the sub-divisions experienced rainfall deficiency –26 percent or more were categorised as drought years for the country as a whole. The droughts were further classified as moderate drought when seasonal rainfall departure was –26 to –50 percent and severe drought when the departure was –51 percent or more.

Similarly "floods" were defined when a sub-division received seasonal rainfall 25 percent or more of normal. Rainfall departure between 25 to 50 percent were termed as moderate flood and that above 50 percent as severe floods. For the country as a whole, the same criteria of number of sub-division as in case of drought was adopted.

4.0 RAINFALL CHARACTERISTICS

Vagaries of monsoon are now proverbial. Excess rainfall leads often to floods in some parts while scanty rains in other part brings in its wake drought and famine, resulting an acute distress to millions. Fluctuations of rainfall have engaged the attention of Indian meteorologists from very early times.

A feature of considerable interest is the variability of monsoon rainfall. Mean rainfall and its variability is shown in Table 1. There are some parts of India e.g. NE India where the pattern of monsoon rainfall show fluctuations from year to year. The rainfall in these areas is usually within 20 percent of its long term normal value. On the other hand variability of rainfall in NW India is quite large, nearly 40-50 percent. These are also the regions which receive smallest amount of rainfall. In Maharashtra, whereas in Konkan the C. V. is less than 20 percent over the rest of the regions it is about 30 percent of the normal value.

The mean value on inter-annual variation (i.e. variation from one year to another) of the seasonal rainfall is also given in Table 1. The value exceed 10 percent in almost all sub-divisions in NW India. It is nearly 55 percent in coastal Karnataka, 40 percent over Kerala, sub-Himalayan, west Bengal and is lowest i.e. 10 percent in North Interior Karnataka. On individual occasions, the variation from one year to the next can be as high as 215 percent in arid regions and over 100 percent in the rest of India (Banerjee et al., 1978).

5.0 INCIDENCE OF DROUGHT/FLOODS

Years when country was affected by drought/floods, based on the above criteria is given in Table 2. The worst years of monsoon failures appear to be 1899, 1877 and 1987 in decreasing

order of severity. Similarly the best three years of bountiful rainfall appear to be 1961, 1975 and 1988 in that order, all occurring in the past 40 years. Dacade-wise occurrence of droughts is shown in Fig. 1(a). The largest number of drought occurred in 4 years in each of the decades 1901-10, 1911-20 and 1981-90. The 30 year period (1930-60) witnessed the lowest number, (i.e. just 3) of droughts.

Table 1 : Rainfall Statistics

Station	Mean (cm)	S. D. (cm)	C.V. (%)	Inter annual Variability (%)
Arunachal	271.4	76.1	28.1	66.7
North Assam	155.8	20.7	13.3	19.4
South Assam	146.7	30.4	20.7	19.3
Himalayan WB	214.1	38.6	18.1	38.7
Gangetic WB	192.2	56.0	29.2	34.9
Orissa	110.1	17.3	15.7	18.1
Bihar Plateau	109.9	10.1	13.8	18.8
Bihar Plains	102.5	18.6	18.2	21.7
E. Uttar Pradesh	89.3	19.5	21.8	20.6
W. Uttar Pradesh	78.9	19.9	25.2	21.6
W. U. P. Hills	138.3	26.6	19.3	29.7
Haryana, Delhi Chandigarh	48.0	16.0	33.2	18.0
Punjab	51.3	19.3	38.7	19.1
Himachal	128.9	39.3	30.7	36.6
Jammu and Kashmir	38.3	24.1	62.8	13.8
W. Rajasthan	27.7	11.6	41.8	12.3
E. Rajasthan	61.8	16.5	26.7	19.5
W. Madhya Pradesh	95.0	17.9	18.9	19.8
E. Madhya Pradesh	117.8	18.3	15.5	20.8
Gujrat Region	90.1	28.4	31.6	31.8
Saurashtra and Kutch	48.9	18.7	38.3	21.6
Konkan and Goa	277.3	48.7	17.5	53.3
Madhya Maharashtra	87.3	26.2	30.0	17.3
Marathwada	70.5	19.4	27.5	20.8
Vidarbha	83.6	24.0	28.7	20.2
Coastal Andhra Pradesh	57.0	12.0	21.1	14.2
Telengana	73.6	18.4	25.0	18.2
Rayal seema	39.9	11.5	28.9	12.9
Tamil Nadu	34.5	16.7	48.2	10.4
Coastal Karnataka	293.7	48.8	16.6	54.3
N. I. Karnataka	48.9	10.4	21.2	9.9
S. I. Karnataka	67.9	22.1	32.5	15.6
Kerala	197.8	41.5	21.0	41.9

Table 2 Drought and Flood years (1875-1990)

Drought years	No. of sub-divisions affected	Flood years	No. of sub-divisions affected
1877*	18	1878	15
1891	9	1884	9
1896	7	1886	8
1899*	20	1889	8
1901	8	1890	7
1904	11	1892	12
1905	13	1893	7
1907	10	1894	10
1911*	8	1909	7
1913	7	1914	11
1916	7	1916	12
1918*	12	1917	15
1928	7	1924	7
1941*	9	1933	11
1951*	10	1938	9
1952	7	1942	7
1965*	11	1956	8
1968	8	1958	9
1972*	14	1959	13
1974	8	1961	16
1979	12	1964	8
1982	9	1975	15
1985	8	1983	12
1986*	7	1988	15
1987*	15		

* *El-Nino Years*

Similar information on floods is given in Fig. 1(b). The decade of well distributed rainfall was perhaps 1980-90 which had a frequency of 4 flood year followed by 1911-20 and 1951-60 in which 3 years had floods. It is obvious from above that in a decade the occurrence of drought or flood have equal chances of their occurrence.

The probability of drought/flood in different sub-divisions is shown in Table 3. Low probability of drought i.e. less than 10% is noticed over NE India, west coast and nearly whole of Maharashtra. Over NW India, however, the chances of drought incidence is rather high, often exceeding 20%. Surprisingly in major part of India, probability of floods is also quite large.

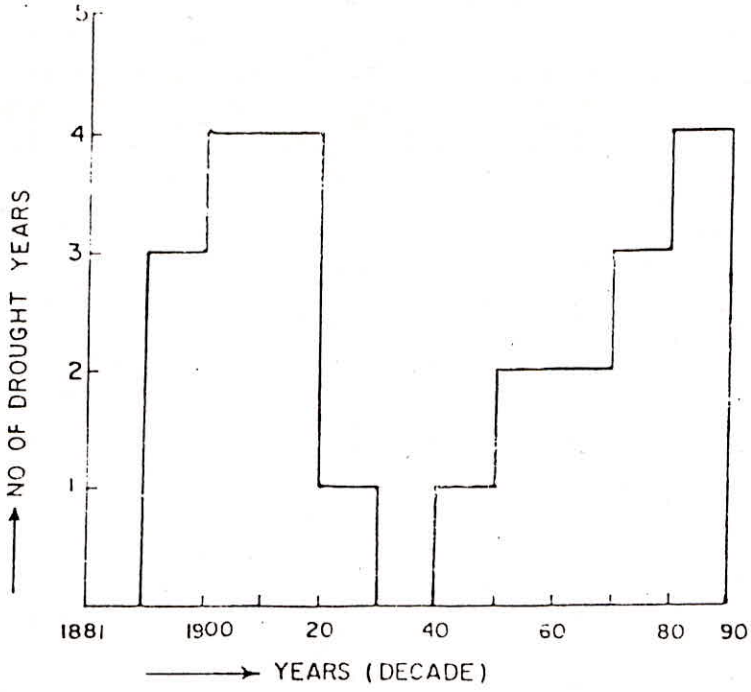

Fig. 1 (a) : Decadal Distribution of Drought

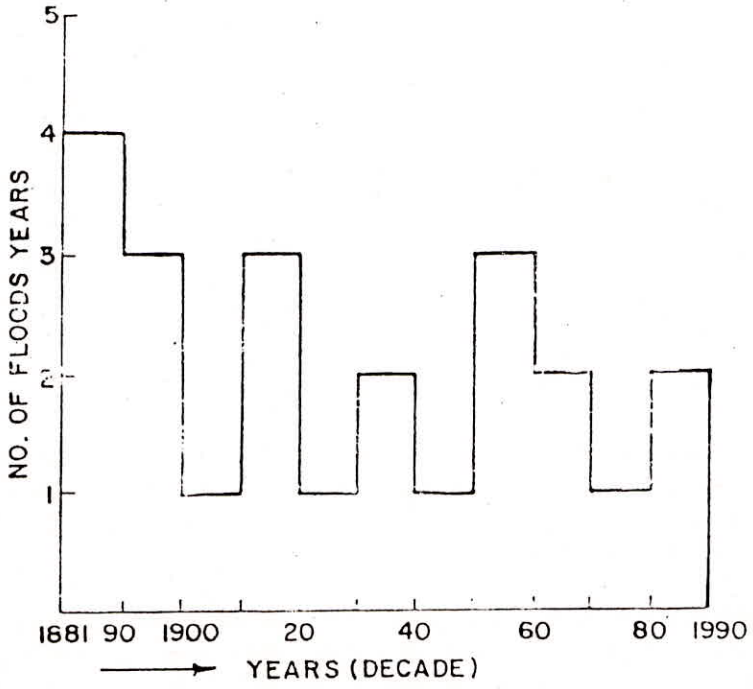

Fig. 1 (b) : Decadal Distribution of Floods

Table 3 also contain years of worst and best monsoon and the corresponding departure.

Table 3 : Probability of drought floods in the best and worst monsoon year

Station	Probability of		Worst		Best percentage	
	Drought	Flood	Year	Percent Dep.	Year	Percent Dep.
Arunachal	3.3	5.5	1961	-33	1987	56
North Assam	5.2	3.4	1896	-39	1878	47
South Assam	4.4	5.5	1972	-29	1961	83
Himalayan WB	6.0	4.3	1975	-45	1878	39
Gangetic WB	6.0	5.2	1975	-45	1880	40
Orissa	3.4	5.2	1974	-34	1961	36
Bihar Plateau	2.6	3.4	1966	-32	1971	39
Bihar Plains	10.3	6.0	1966	-46	1987	63
E. Uttar Pradesh	12.9	11.2	1877	-65	1980	65
W. Uttar Pradesh	10.3	18.1	1877	-73	1936	57
W. U. P. Hills	13.3	6.9	1979	-47	1917	42
Haryana, Delhi and Chandigarh	20.0	27.8	1987	-63	1988	83
Punjab	16.8	28.0	1987	-66	1988	98
Himachal	15.2	13.0	1987	-54	1894	74
Jammu and Kashmir	22.8	20.2	1889	-80	1957	195
W. Rajasthan	26.7	12.9	1877	-83	1917	139
F. Rajasthan	15.5	15.5	1877	-65	1917	82
W. Madhya Pradesh	8.7	7.8	1899	-49	1973	47
E. Madhya Pradesh	2.6	7.8	1965	-40	1961	38
Gujrat Region	22.7	17.4	1899	-79	1976	31
Saurashtra and Kutch	21.7	28.7	1987	-81	1878	120
Konkan and Goa	7.7	10.3	1899	-48	1958	50
Madhya Maharashtra	7.7	8.6	1918	-55	1988	41
Marathwada	10.1	25.9	1899	-56	1988	84
Vidarbha	9.5	13.9	1899	-62	1964	39
Coastal Andhra Pradesh	7.8	18.3	1920	-38	1983	54
Telengana	11.2	15.5	1877	-46	1893	60
Rayal seema	15.5	13.7	1922	-55	1983	78
Tamil Nadu	8.6	13.7	1891	-44	1985	46
Coastal Karnataka	1.7	6.0	1918	-46	1878	47
N. I. Karnataka	0.0	11.2	1918	-41	1964	54
S. I. Karnataka	8.6	11.2	1918	-44	1897	59
Kerala	8.6	6.0	1918	-47	1924	64

6.0 SUCCESSIVE DROUGHT/FLOOD INTERVALS

Occurrence of drought/flood is a random phenomenon. Yet it is seen that drought has occurred in three consecutive years i.e. 1985-87 and on two consecutive years in 1904-05 and 1951-52. It occurred after a maximum interval of 13 years after 1877 and 12 years after its incidence in 1941 and 1952.

Similarly, floods have occurred in 3 consecutive years between 1892-94 and two consecutive years in 1889-90 and 1916-17. It took as much as 14 years for the flood situation to occur which took place after 1894 and an interval of 13 years between 1942-56. The intervals of occurrence of drought/floods did not follow any known pattern.

7.0 ONSET OF SOUTH-WEST MONSOON IN RELATION TO FLOOD/DROUGHT

Advance of monsoon over Indian regions takes place in two branches (i) Arabian Sea branch and (ii) Bay of Bengal branch. Normally the Arabian Sea branch sets in over extreme S. W. parts of peninsular i.e. over Kerala and Bay of Bengal branch over Assam and neighbourhood around 1st of June. There has been significant variation from the normal and onset has been early or delayed by 2/3 weeks. For instance in 1972 the onset over Kerala occurred on 18th June while 1918, the worst drought year, the onset was as early as 11th May. Late arrival of monsoon in some years can cause shortage of water in dams and reservoirs, affecting thereby hydropower generation and host of other problems. However, an analysis of 1901-1990 years onset data revealed that in 60 out of 90 years, the onset was within ± 7 days of the normal, i.e. within mean ± 1 SD. It is also clear that a late onset does not necessarily mean large scale monsoon failures. Out of 21 droughts that have occurred since the beginning of this century, 14 cases of drought occurred when the monsoon onset over Kerala was within mean ± 1 SD dates. Incidently in one of the worst drought year of 1918, the onset was as early as 11 May. Then there have been cases like in 1983, 1958 and 1940 when the onset was delayed by 12-14 days from the normal. Yet, 1983 was one of very good monsoon years and 1958 and 1940 also received normal or excess rainfall over most parts of the country.

Assuming Maharashtra as a single unit to have experienced drought when at least 2 out of its 4 met. sub-divisions had received, 74 percent or less rainfall, it is seen that between 1875 to 1990, Maharashtra may be deemed to have been drought affected in 11 years. Between 1901-90 such occasions were 9. It is seen that in 6 such events the onset over Kerala was between 28th May to 10th June , while in 1941, the onset was slightly early i.e. 23rd May. However, in the worst drought year 1918, when all the 4 sub-divisions experienced drought and in 1972 when complete Maharashtra (except Vidarbha) experienced deficient rains, the onset dates over Kerala, as stated above, were 11th May and 18th June respectively. This suggest that drought in any part of the country as in the state of Maharashtra is not much linked with the onset date over the southern tip of the country. Dhar et al. (1980) had also observed that, generally, the total rainfall received in Konkan, coastal Karnataka and Kerala during monsoon, is independent of the onset date of monsoon.

8.0 EL-NINO AND ITS ASSOCIATION WITH MONSOON PERFORMANCE

Due to upwelling, lowest sea surface temperature (SST) occurs off Peru and Equador in the tropical Pacific Ocean. However, the SST field over these regions often undergo an episodic warming over and above the seasonal cycle. Such warming is known as El-Nino event.

The warming usually commences during April-May and reaches its peak during following December. During the past two decades the apparent association between El-Nino and the summer monsoon over India has been extensively studied (Bhalme and Jadhav, 1984; Chowdhury and Mhaswade, 1991 etc.). Between 1875 and 1990, 28 cases of El-Nino phenomenon has been observed. During the same period in 25 years monsoon rains, in various degrees have failed in India leading to drought. Not all the drought years were associated with the Pacific warm temperature anomaly nor all El-Nino events have led to droughts, although some of the worst drought years e.g. 1877, 1899, 1982 and 1987 synchronised with the prevailence of El-Nino. It has been observed that 52 percent of the cases when the drought conditions prevailed in India, Pacific Ocean had warmer temperature episodes. Similarly, only 46.5 percent of the El-Nino years could be associated with droughts in India. Excess rainfall or flood is almost never been associated with El-Nino episode. However, there have been some exceptions like 1977 which was a year of good monsoon but El-Nino phenomena also present. On the other hand there were no El-Nino event in 1979 and yet monsoon failed over large parts of the country.

So far as Maharashtra is concerned, it is seen that out of the 11 occasions of drought it experienced in past 116 years, concurrent warm sea surface episodes prevailed in 7 occasions. The probability of drought *vis-à-vis* El-Nino thus works out as nearly 64 percent which is marginally more than the corresponding figure for the country.

9.0 CONCLUDING REMARKS

A close watch on the rainfall pattern week by week over all the meteorological sub-divisions of India can provide an objective assessment of the effect of the rainfall over the whole country, specially with respect to agricultural production. Flood and drought associated with the rainfall pattern cannot be stopped, but by proper planning and taking appropriate measures the loss can be minimised and sometimes the occurrence can also be minimised. This is definitely a positive gain not only towards human civilization but to the environment as a whole.

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