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Letters to the Editor

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VARIABILITY IN DROUGHT INCIDENCE OVER DISTRICTS OF MAHARASHTRA

1. Various studies on drought have been made for a large spatial scale such as subdivision, state or country as a whole. Bhalme and Mooley (1980) studied large scale droughts over India. Mooley *et al.* (1984) identified droughts over peninsular India. Chowdhury *et al.* (1989) worked on variability of drought incidences over India. Recently Sen and Sinha Ray (1997) studied trends in drought affected areas in India.

Very few studies have been undertaken to study droughts over smaller scale like district. In this paper authors have studied occurrence of drought over Maharashtra in smaller spatial scale. Epochal nature of drought and the relation with El nino has also been dealt in this paper.

The State of Maharashtra consists of 30 districts at present. The districts from west coast *viz*. Thane, Mumbai, Raigarh, Ratnagiri are from humid region, where annual rainfall is more than 200 cms. The extreme western parts of Nasik, Pune, Kolhapur, Satara and northern & eastern parts of Vidarbha are under sub humid region, where annual precipitation is more than 100 cms. Most of the central parts of the state *viz*. eastward portion of Nasik, Pune, Satara, Kolhapur are under semi arid region. The districts Aurangabad, Jalgaon, Dhule, Solapur, Sangli, Parbhani, Osmanabad, Ahmednagar, Beed, Nanded, Jalna, Latur, Akola, Buldhana, western parts of Yeotmal are also under semi-arid type. The annual rainfall in these regions are 50-90 cms. The central parts of the state are with very low rainfall and high potential evapotranspiration. The rainfall in monsoon season covers about 84-94% of the annual rainfall over the districts of Maharashtra.

2. The daily rainfall data for the period 1901-98 for 30 districts of Maharashtra has been considered and is taken from National Data Centre, Office of the Additional Director General of Meteorology (Research),Pune. Table 1 gives information on rainfall statistics for the 30 districts in Maharashtra.

A meteorological drought over an area is defined as a situation when rainfall over that area is less than 75% of the climatological normal. By using seasonal rainfall departure for southwest monsoon season for the period 1901-98, the years with deficit rainfall more than 25% for different districts in Maharashtra, have been identified as drought years for districts. These are further classified as moderate when the percentage rainfall deficit is 26 to 50% and severe if deficit is more than 50%. The probabilities

TABLE 1

Normal rainfall and variability over Maharashtra

S. No.	Name of sub-division/ district	No. of stations	Seasonal normal rainfall (cm)	C.V. (%)
	Konkan & Goa			
1.	Bombay	8	200	20-30
2.	Raigarh	20	305	20
3.	Ratnagiri	21	305	20
4.	Thane	14	240	20
5.	Sindhudurg	8	280	20
	Madhya Maharashtra			
6.	Ahmednagar	14	44	30-40
7.	Dhule	14	64	30
8.	Jalgaon	13	64	30
9.	Nasik	21	87	30
10.	Kolhapur	19	163	20-30
11.	Sangli	16	47	30-40
12.	Satara	17	107	30-40
13.	Pune	24	90	30
14.	Solapur	12	46	30-40
	Marathwada			
15.	Aurangabad	14	61	30
16.	Parbhani	11	69	30
17.	Osmanabad	11	76	30-40
18.	Nanded	11	70	30
19.	Bhir	10	56	30-40
20.	Latur	6	64	30-40
21.	Jalna	5	59	30
	Vidarbha			
22.	Akola	14	72	20-30
23.	Amraoti	16	81	20-30
24.	Bhandara	14	123	20-30
25.	Buldhana	14	67	20-30
26.	Nagpur	11	104	20
27.	Wardha	07	92	20-30
28.	Yeotmal	11	87	20-30
29.	Chandrapur	23	119	20-30
30.	Gadchiroli	8	119	20-30

TABLE 2

Decadal frequencies of district wise droughts over Maharashtra

S. No.	Name of sub-division/ district	1901 to 1910	1911 to 1920	1921 to 1930	1931 to 1940	1941 to 1950	1951 to 1960	1961 to 1970	1971 to 1980	1981 to 1990	1991 to 1998	Average decadal frequency
						Konkan & Goa						
1.	Bombay	2	4	3	2	1	-	1	-	1	1	1
2.	Raigarh	2	2	1	-	1	1	-	1	-	1	1
3.	Ratnagiri	1	3	1	-	1	-	2	1	-	-	1
4.	Thane	2	4	2	-	2	1	-	-	1	1	1
5.	Sindhudurga	-	-	-	-	-	-	-	2	1	-	1
						Madhya Maharashtra						
6.	Ahmednagar	3	4	2	1	1	1	1	3	5	1	2
7.	Dhule	3	3	1	2	-	2	-	1	3	-	1
8.	Jalgaon	-	4	2	-	1	1	-	2	3	-	1
9.	Kolhapur	1	1	-	-	-	-	1	1	1	1	1
10.	Nasik	2	2	-	-	-	-	-	3	4	1	1
11.	Pune	4	3	3	-	-	-	-	-	4	3	2
12.	Solapur	3	5	2	3	-	1	-	2	2	2	2
13.	Sangli	4	3	4	-	-	2	-	1	3	-	2
14.	Satara	2	2	-	-	-	1	-	1	-	-	1
						Marathwada						
15.	Aurangabad	2	3	1	1	-	-	-	2	3	3	1
16.	Bhir	2	3	3	3	2	1	1	4	2	3	2
17.	Nanded	-	2	2	-	1	-	-	4	4	4	2
18.	Osmanabad	4	4	5	4	2	-	-	3	1	3	3
19.	Parbhani	-	2	3	1	1	1	-	5	4	1	2
20.	Latur	-	-	-	-	-	-	-	2	1	5	3
21.	Jalna	-	-	-	-	-	-	-	2	3	3	3
						Vidarbha						
22.	Akola	-	3	2	-	1	1	1	2	2	1	1
23.	Amraoti	1	3	2	-	-	1	2	1	2	-	1
24.	Bhandara	2	1	-	-	1	-	1	3	3	1	1
25.	Buldhana	-	4	1	-	1	1	1	3	3	3	2
26.	Chandrapur	2	2	-	-	1	-	1	2	5	1	1
27.	Nagpur	2	2	2	-	1	1	1	1	-	2	1
28.	Wardha	2	1	2	1	1	1	2	3	3	2	2
29.	Yeotmal	1	3	1	-	1	1	-	3	4	2	2
30.	Gadchiroli	-	-	-	-	-	-	-	3	2	1	2

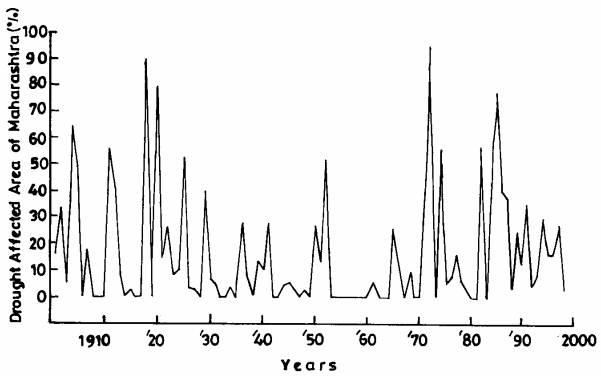


Fig. 1. Percentage drought affected area of Maharashtra during 1901-98

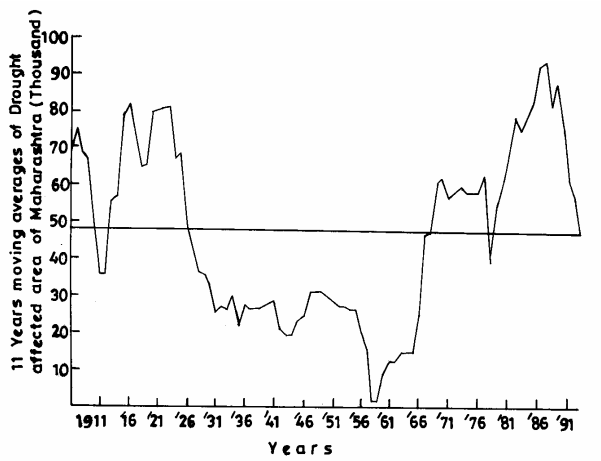


Fig. 2. 11 years moving averages of drought affected area of Maharashtra for the period 1901-98

of moderate and severe droughts have been computed for various districts for the period 1901-98. If in a year 25% or more of the area of the state is affected by drought, then that year is considered as one in which the state suffered from large scale drought. The worst drought affected years were demarcated (marked with star) out of the large scale drought years, when the area affected by drought exceeded 50% of the area of the state. A drought for the country as a whole is defined when total area of the country affected by drought is exceeded by 20% of the country's area.

3. Table 2 shows decadal frequencies of district wise droughts for 30 districts over Maharashtra for the period 1901 to 1998. Most of the districts show 2 to 4 incidences of drought during first 3 decades from 1901 to 1930. The decadal frequency of droughts for most of the districts has been reduced during the years 1931 to 1970. Some of the districts show 1 to 2 incidences of drought during each decade of 1931-70. Most of the districts from Vidarbha experienced no drought during years 1931-40. A single occasion of drought incidence during 1931-40 was shown by only Wardha district. Also most of the districts except Bombay in Konkan experienced no drought during 1931-40. The district Bombay showed 2 incidences of drought during this period. The decadal frequencies of drought have been increased a little after 1970 to 1990 except Konkan. The districts in Madhya Maharashtra and Vidarbha experienced about 2 to 5 incidences of drought during 1981-90. While, the districts in Marathwada experienced 2 to 5 incidences of drought during 1971-1980. The frequencies of drought have reduced a little during the decade 1991-98 except Marathwada.

Fig.1 shows percentage of the area of the state showing drought conditions during southwest monsoon season (June-September) for the period 1901 to 1998 over Maharashtra. There are 26 large scale drought years identified over Maharashtra during 1901-98 and out of them 11 drought years are worst droughts (marked with star). They are :

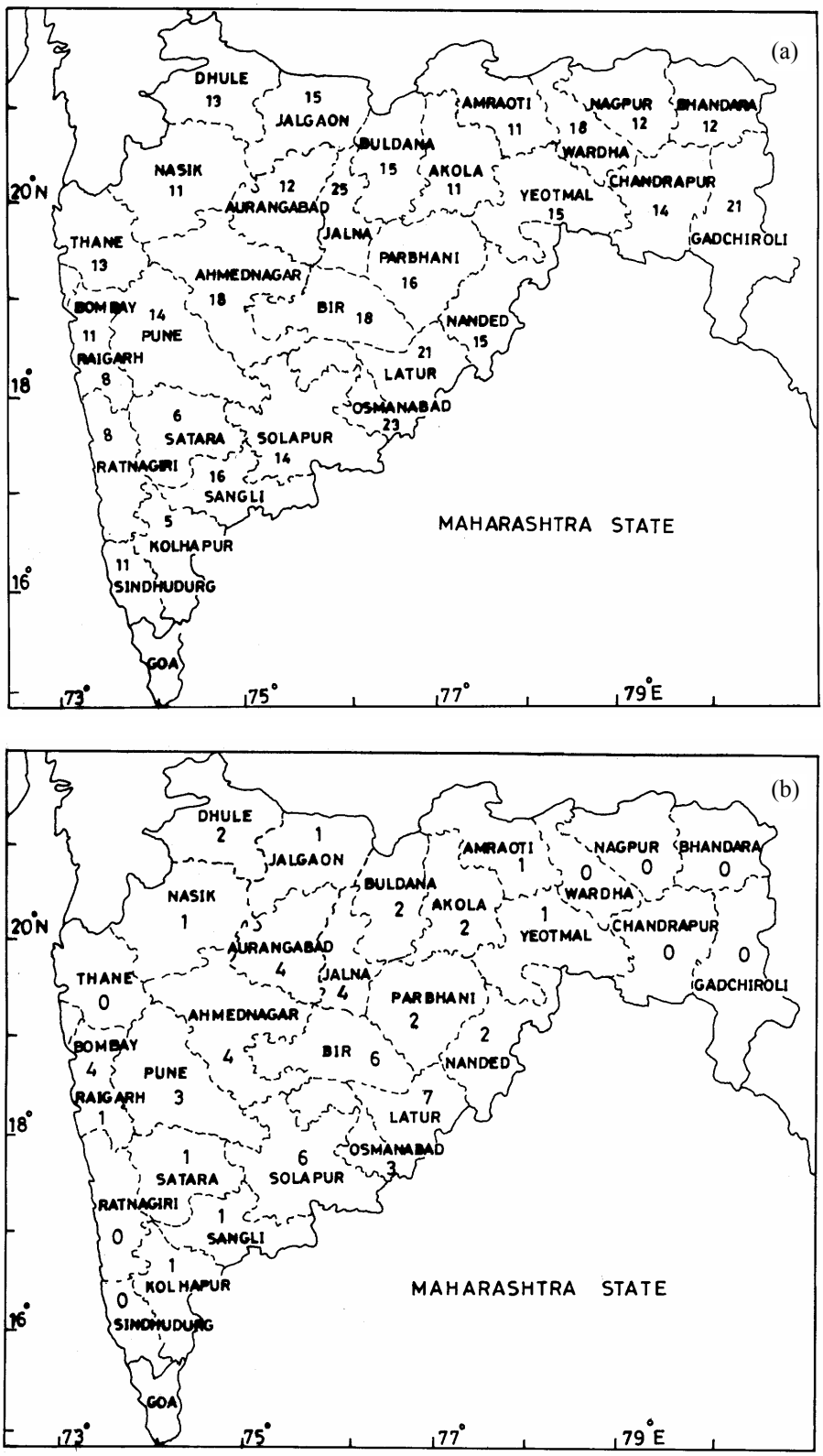
Decadal variability of large scale droughts over Maharashtra

1901-1910	*1911-1920*	*1921-1930*	*1931-1940*	*1941-1950*	*1951-1960*	*1961-1970*	*1971-1980*	*1981-1990*	*1991-1998*
1902	1911*	1922	1936	1941	1952*	1965	1971	1982*	1991
1904*	1912	1924		1950			1972*	1984*	1994
1905	1918*	1925*					1974*	1985*	1997
	1920*							1986	
								1987	
Worst Droughts									
1	3	1	-	-	1	-	2	3	-

The above Table shows that (*i*) Least number of droughts are in decades 1931-40, 1951-60 and 1961-70. (*ii*) There are three worst droughts in decades 1911-1920 and 1981-1990. (*iii*) On an average one worst drought is noticed in each decade.

Successive years of either large scale or worst drought are 1904/1905, 1911/1912, 1924/1925, 1971/1972, 1984/1985, 1986/1987.

The moving averages of 11 years of the area affected by drought were taken to eliminate cycles up to 11 years. Mann Kendall Rank Statistic test (WMO, 1966b) has been applied to the smoothened series of drought affected area. Fig. 2 shows 11 years moving averages of drought affected area of Maharashtra for the



Figs. 3(a&b). Percentage probability of occurrence of (a) moderate drought and (b) severe drought

period 1901 to 1998. It shows that there is no significant trend in area affected by drought, but epochal behavior of the occurrence of drought can be seen. It can be seen from Fig.2 that the 11 years moving averages of the area affected by drought from the years 1906 to 1910 and 1913 to 1926 are above the average line (48,000 sq. km.). While 11 years moving averages of area affected by drought from 1927 to 1967 are below the average line and is the 40 years period when the area of the state affected by drought is minimum. While those from 1968 onwards are above the average line. It may be noted that these years represent middle year of the group of 11 years. During the years 1918, 1920, 1972, 1985 more than 2 lakhs sq. km. area has been affected by drought. The years 1908-1910, 1916-1917, 1942-1943, 1953-1960, 1962-1964, 1969-1970, 1980-1981 were very good years with no area under drought. There were few isolated years *viz*. 1906, 1914, 1919, 1928, 1932, 1935, 1938, 1947, 1949, 1967, 1973 and 1983 with no area under drought.

In June few of the depressions which originate in the Bay of Bengal travel westnorthwest (WNW) and affect the weather in the east or northeast of Vidarbha. In July and August, systems continue to move in WNW direction and tracks are continued between latitudes 20-25° N. During September the depressions originate in the area north of 15° N, move in WNW direction before recurving to NE and cause heavy and prolonged spells of rain in Vidarbha and Marathwada. The information in respect of storms/depressions contained in the publication "Tracks of Storms and Depressions in the Bay of Bengal and Arabian Sea" by the India Meteorological Department (1979) and (1996) for the period of 1877-1970 and 1971-1990 respectively were utilised for the study. These systems were studied in respect of their frequency formation and their tracks in drought years and flood years affecting Maharashtra for the area 14° - 23° N and 73° - 83° E. The flood year was considered in which 25% or more area of the state received seasonal rainfall more than 125% of the normal. The mean frequency of the depressions in such years is given in Table 3. It is seen from the table that frequency of the systems in flood years is more in the months July, August and September. The month August shows the maximum difference in frequency. The difference in frequency in month September follows August. The total frequency of the season being more in flood years.

There were all India droughts and large scale droughts over Maharashtra in 1972 and 1987 where, 40% and 48% area of the country respectively were under drought. In 1972 all the subdivisions of Maharashtra were badly affected by deficit rainfall. The monsoon activity was normal in northeast India, extreme northwest India,

TABLE 3

Mean frequency of storms/depressions forming in the Bay of Bengal and Arabian Sea in each of the monsoon months for years in large scale drought/flood affecting Maharashtra

	June	July	August	September	Season
Drought	0.2	0.2	0.15	0.4	0.95
Flood	0.2	0.3	0.6	0.7	1.8

Madhya Pradesh and the south peninsula but weak in north peninsula, Rajasthan and Bihar Plains. The delayed onset of the monsoon in June and a prolonged break in the second half of July to 4 August and first week of September led to droughts in many parts of north India and north peninsula. The tracks of three cyclonic storms and six depressions were mostly confined in northerly latitudes and away from Maharashtra. The monsoon was generally weak in many parts of peninsula during the first fortnight and during the last week of August, leading to deficit or scanty rainfall in 1972.

In 1987, the seasonal trough at 0.9 km a.s.l. was mostly to the east of 80° E during June and September. There was break in end of July and first fortnight of August. The southwest monsoon was set in over south Kerala on 2 June. The advance of monsoon delayed by 4 to 7 days over Madhya Maharashtra, Marathwada, Vidarbha. The tracks of cyclonic storm and the three depressions developed during the season were in northern and north eastern region and mostly confined to beyond 80° E. These synoptic conditions led the deficit situation in Madhya Maharashtra and Vidarbha in 1987. Marathwada was marginally normal but below normal. Konkan and Goa was just normal.

The Figs. 3(a&b) show probability maps for the period 1901-1998 for district wise moderate and severe drought over Maharashtra. The moderate drought probability in various districts is 5 to 24%. The severe drought probability is 1 to 7% in major parts. The severe droughts were not experienced in districts Ratnagiri, Thane, Sindudurga, Bhandara, Chandrapur, Gadchiroli, Wardha and Nagpur during last 98 years.

The drought years in India since 1901 are 1901, 1904*, 1905*, 1907,1911*, 1913, 1915, 1918*, 1920*, 1925*, 1939, 1941*, 1951, 1965*, 1966, 1968, 1972*,1974*, 1979, 1982*, 1985* and 1987*. The 13 years marked with star are large scale drought years over Maharashtra. Therefore, about 59% probability of large scale drought over Maharashtra is noticed during drought over the country.

The El Nino years since 1900 noted by Rasmusson and Carpenter (1983) and Fredric and Miller (1992) are

1902*, 1905*, 1911*, 1914, 1918*, 1923, 1925*, 1930, 1932, 1939, 1941*, 1951, 1953, 1957, 1965*, 1969, 1972*, 1976, 1982*, 1986*, 1991*. The latest El Nino event of 1997* has also been considered. De *et al*. (1996) have used El Nino events from 1960 onwards in study of decadal variability of monsoon. The 12 years marked with star are the large scale or worst drought years for Maharashtra state. As such about 55% probability of drought year for Maharashtra is noticed during El Nino years. While, the probability of drought year prior to El Nino year is 36%. In strong El Nino years like 1965, 1972, 1982, 1987 and 1991 the state was affected on cent percent occasions.

The state has a large variety of agro climatic patterns, rainfall, vegetation, soil and crops. Konkan and east Vidarbha have adequate assured rainfall for major crop like paddy. The droughts in the mid-western portions of Dhule, Nasik, Ahmednagar, Pune, Satara, Sangli and northeast Kolhapur may affect the crops like Bajra, Jowar and Groundnuts. In the interior parts of low rainfall of about 50-75 cm, in the regions of eastern portions of Dhule, Nasik, Ahmednagar, Pune, Satara and Sangli, Sholapur, western portions of Aurangabad, Bhir, Osmanabad and Jalgaon, survival of millet also become difficult when these districts are affected by drought.

The study shows the important features as below:

(*i*) There are 26 large scale meteorological droughts identified over Maharashtra during 1901-1998 and out of them 11 years are worst drought years when more than 50% area of the state was affected by drought.

(*ii*) A trend for total area affected by drought over Maharashtra did not show a significant trend but epochal behavior of the occurrence of drought is depicted.

(*iii*) The frequency of depressions forming over the Bay of Bengal and the Arabian Sea, affecting Maharashtra is significantly less during drought years compared to that of flood years.

(*iv*) The severe drought probability is 1 to 7% for most of the districts. The severe droughts were not experienced in some of the districts of Vidarbha and Konkan for last 98 years.

(*v*) The probability for large scale drought years for Maharashtra is 59% during the drought over the country and is about 55% during El Nino years.

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