Probability of occurrence of drought in various sub-divisions of India

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सार – भारत में वर्षा की अतःवार्षिक विभिन्नता से संबंधित अनेक अध्ययन किए गए हैं। भारत में सूखे के विभिन्न वर्षों के दौरान खाद्यानों के उत्पादन में कमी से संबंधित भी अनेक अध्ययन किए गए हैं। अतः आने वाले वर्ष के सूखे का वर्ष होने की संभावना के बारे में जानने की काफ़ी समय से आवश्यकता अनुभव की जा रही है। यह भी देखा गया है कि पिछले 11 वर्षों के दौरान जब समूचे देश में वर्षा सामान्य रही तब भी कुछ मौसम वैज्ञानिक उपखंडों ने प्रायः प्रति वर्ष सूखे की स्थिति का सामना किया है। इस शोध-पत्र का उद्देश्य लगभग 125 वर्षों के आँकड़ों की सहायता से भारत के विभिन्न उपखंडों में सूखा पड़ने की संभावना और उपखंडों में दो अथवा दो से अधिक वर्षों में लगातार सूखा पड़ने की संभावना का पता लगाना है। अनेक अध्ययनों में अखिल भारतीय ग्रीष्मकालीन मानसून वर्षा में पाई गई कमी और इसके एल निनों के साथ संबंध की चर्चा की गई है। इस शोध-पत्र में प्रशांत महासागर की एल निनों की घटना और भारत के विभिन्न उपखंडों में मौसम वैज्ञानिक सूखे के मध्य के संबंध का पता लगाने का प्रयास किया गया है। इससे यह पता चला है कि भारत के प्रत्येक उपखंड में एल निनों का प्रभाव भिन्न होता है।

यह भी देखा गया है कि एल निनों वाले सभी वर्ष सूखे के वर्ष नहीं होते हैं और सभी सूखे के वर्ष एल निनों वर्ष भी नहीं होते हैं। पिछले 124 वर्षों में से 29 वर्ष एल निनों के थे जिसमें से सूखे के केवल 14 वर्ष ही थे। इसी प्रकार पिछले 124 वर्षों में 25 वर्ष सूखे के थे। सूखे के इन वर्षों में से 11 वर्ष एल निनों से संबंधित नहीं थे।

ABSTRACT. There are many studies dealing with interannual variability of rainfall in India. There are also studies available dealing with the reduction of food grain production during various drought years in India, Hence, there is a long felt need to know about chances whether the next year will be a drought year. It is also seen that during last 11 years when the country as a whole experienced normal rainfall, there were few sub-divisions almost in each year facing a drought situation. The objective of this paper is to find out with the help of nearly 125 years data the probability of occurrence of drought in various sub-divisions of India and the probability of a sub-division facing two or more consecutive droughts, many studies deal with deficiency in all India summer monsoon rainfall and their linkage with El Nino. Effort has also been made in this paper to find out if there is any linkage between El Nino events in Pacific and meteorological drought in various sub-divisions of India. It is seen that effect of El Nino on each sub-division of India is different.

It is also noticed that all El Nino years are not drought years and all drought years are also not El Nino years. During last 124 years there were 29 El Nino years. Out of these only 14 were drought years. Similarly there were 25 drought years during last 124 years out of which 11 drought years were not connected with El Nino.

Key words – Drought year, El Nino, Probability.

1. Introduction

India is mainly an agricultural country with limited irrigation and large dependence on the monsoon rainfall. Hence, the role of monsoon on Indian economy is very crucial. Drought is one of the major natural disasters which affects agriculture, industry and hydroelectric power generation. There are various definitions of drought. It is generally understood as the prolonged deficiency in rainfall over a place. Here we will consider meteorological drought which is defined by the India Meteorological Department as seasonal rainfall deficiency by more than 25 percent of the long term average value of rainfall. Further it is classified as moderate drought when

deficiency is between 26 to 50 percent and severe drought when the deficiency is more than 50%. A year is considered as a drought year, in case the area affected by drought is more than 20 percent of the total area of the country.

Appa Rao (1986) studied probability of drought in various sub-divisions of India on the basis of rainfall data for the period 1975 to 1985. Considering the epochal nature of rainfall it is desirable to study probability of the occurrence of drought using data for long period so that the results may be unbiased. Mooley & Paolino (1989) have identified years of Pacific warming under two categories which was extended by De (1997) using recent
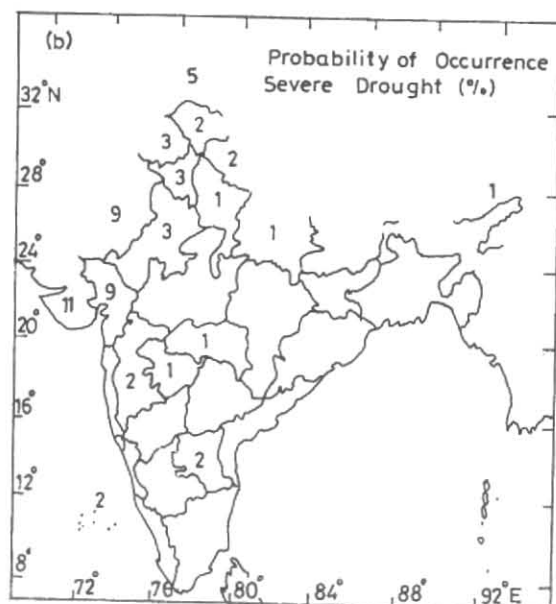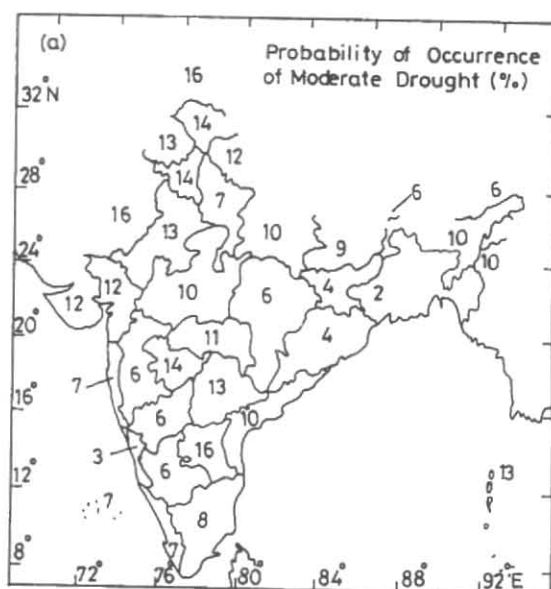
TABLE 1

Drought years with percentage area of the country affected by drought

S.No.	Year	Area affected in percentage of total area of the country by		
		Moderate drought	Severe drought	Total
1.	1877	30.6	28.9	59.5
2.	1891	22.4	0.3	22.7
3.	1899	44.1	24.3	68.4
4.	1901	19.3	10.7	30.0
5.	1904	17.5	16.9	34.4
6.	1905	25.2	12.0	37.2
7.	1907	27.9	1.2	29.1
8.	1911	13.0	15.4	28.4
9.	1913	24.5	0.0	24.5
10.	1915	18.8	3.4	22.2
11.	1918	44.3	25.7	70.0
12.	1920	35.7	2.3	38.0
13.	1925	21.1	0.0	21.1
14.	1939	17.8	10.7	28.5
15.	1941	35.5	0.0	35.5
16.	1951	35.1	0.0	35.1
17.	1965	38.3	0.0	38.3
18.	1966	35.4	0.0	35.4
19.	1968	21.9	0.0	21.9
20.	1972	36.6	3.8	40.4
21.	1974	27.1	6.9	34.0
22.	1979	33.0	1.8	34.8
23.	1982	29.1	0.0	29.1
24.	1985	25.6	16.7	42.3
25.	1987	29.8	17.9	47.7

Figs. 1 (a&b). Probability of occurrence of (a) moderate drought (%) and (b) severe drought (%)

data. The authors have defined events when warming started in the eastern equatorial Pacific as EW and without eastern equatorial Pacific as E event. Their study indicated that occurrence of drought over the Indian sub-continent was more frequent during the years of EW events as compared to those occurring during E events. Mooley (1997) studied the variation of monsoon rainfall over India in El Nino years. His study shows that the rainfall over the country as well as over westernmost sub-divisions were affected more during EW events compared to that of E events.

In this paper authors have studied drought over 35 sub-divisions of India during 1875 to 1998. Probability of occurrence of drought in each sub-division has been discussed. There are a few sub-divisions in India where there are chances of occurrence of two or more consecutive droughts. These have also been highlighted. The information will help the planners to take proper steps regarding food grains storage for those frequent drought affected areas and if possible, to plan for supplementary irrigation.

2. Data used

Rainfall data for the period 1875 to 1998 (June to September) for each sub-division of India have been considered. Proper care has been taken for reconstructing the data of Arunachal Pradesh, Assam and Meghalaya, Nagaland, Manipur, Mizoram and Tripura and hills of west Uttar Pradesh which are recently formed sub-divisions.

3. Results and discussion

Table 1 gives the percentage area of the country affected by moderate and severe drought. It may be noted

TABLE 2

Probability of occurrence of drought

S.No.	Name of the sub-division	Probability of occurrence of drought (P_1)	Probability of occurrence of two consecutive drought (P_2)	Probability of occurrence of more than two consecutive drought
1.	Andaman & Nicobar Islands	13	2	0
2.	Arunachal Pradesh	8	0	0
3.	Assam & Meghalaya	2	0	0
4.	Nagaland,Manipur, Mizoram & Tripura	10	3	0
5.	Sub-Himalayan West Bengal	6	1	0
6.	Gangetic West Bengal	2	0	0
7.	Orissa	4	0	0
8.	Bihar Plateau	4	0	0
9.	Bihar Plains	9	0	0
10.	East Uttar Pradesh	10	1	0
11.	Plains of west Uttar Pradesh	8	0	0
12.	Hills of west Uttar Pradesh	14	1	0
13.	Haryana, Delhi and Chandigarh	17	3	0
14.	Punjab	16	4	0
15.	Himachal Pradesh	16	3	2
16.	Jammu & Kashmir	21	6	2
17.	West Rajasthan	25	6	0
18.	East Rajasthan	16	2	0
19.	West Madhya Pradesh	10	1	0
20.	East Madhya Pradesh	6	1	0
21.	Gujarat region	21	2	1
22.	Saurashtra & Kutch	23	3	1
23.	Konkan & Goa	7	0	0
24.	Madhya Maharashtra	7	1	0
25.	Marathwada	15	1	0
26.	Vidarbha	12	1	0
27.	Coastal Andhra Pradesh	10	1	0
28.	Telangana	13	2	0
29.	Rayalaseema	18	1	0
30.	Tamil Nadu & Pondicherry	8	0	0
31.	Coastal Karnataka	3	0	0
32.	North interior Karnataka	6	1	0
33.	South interior Karnataka	6	0	0
34.	Kerala	7	2	0
35.	Lakshadweep	10	2	0

that during the complete 124 years period there were three occasions *i.e.*, in 1877, 1899 and 1918, when the percentage area of the country affected by drought was more than 60%. It may be noted that during last 80 years there was no occasion when the percentage area of the country affected by drought was more than 50%. It also confirms the finding of Sen and Sinha Ray (1997), which showed a decreasing trend in the area affected by drought in the country.

TABLE 3

Sub-divisionwise years of occurrence of drought where drought probability is more than 15%

S.No.	Haryana	Punjab	Himachal Pradesh	Jammu & Kashmir	West Rajasthan	East Rajasthan	Gujarat region	Saurashshtra & Kutch	Marathwada	Rayalaseema
1.	1877	1899	1877	1878	1877	1877	1877	1875	1877	1876
2.	1883	1904	1883	1879	1883	1898	1885	1877	1885	1884
3.	1898	1905	1899	1883	1885	1899	1888	1889	1899	1891
4.	1899	1911	1902	1884	1887	1901	1892	1890	1905	1896
5.	1905	1915	1905	1885	1891	1905	1899	1894	1907	1899
6.	1907	1918	1907	1886	1899	1907	1901	1899	1912	1901
7.	1913	1920	1911	1887	1901	1911	1904	1901	1918	1904
8.	1915	1921	1918	1889	1902	1913	1911	1904	1920	1907
9.	1918	1928	1928	1891	1904	1915	1915	1905	1925	1911
10.	1920	1929	1965	1895	1905	1918	1918	1911	1929	1918
11.	1928	1938	1968	1896	1911	1925	1920	1915	1939	1920
12.	1929	1939	1972	1898	1913	1928	1923	1918	1941	1922
13.	1938	1951	1979	1900	1915	1939	1925	1923	1972	1923
14.	1939	1964	1981	1902	1918	1941	1936	1925	1974	1934
15.	1941	1965	1982	1911	1920	1951	1939	1931	1984	1941
16.	1951	1969	1983	1918	1925	1965	1948	1939	1985	1948
17.	1965	1972	1984	1920	1938	1966	1951	1948	1993	1951
18.	1968	1974	1986	1937	1939	1972	1957	1951	1997	1971
19.	1979	1979	1987	1949	1951	1987	1960	1968		1972
20.	1986	1987	1989	1951	1963	1991	1965	1969		1985
21.	1987			1965	1968		1972	1972		1993
22.				1971	1969		1974	1974		
23.				1972	1971		1982	1982		
24.				1979	1974		1985	1985		
25.				1982	1980		1986	1986		
26.				1991	1981		1987	1987		
27.					1982			1991		
28.					1985			1993		
29.					1986			1995		
30.					1987					
31.					1991					

It has been noticed that out of the 124 years, the probability of occurrence of drought is maximum, *i.e.*, 25 percent in west Rajasthan followed by Saurashtra and Kutch, Jammu and Kashmir and Gujarat region with 23, 21 and 21 percent probabilities respectively (Table 2). It has also been noticed that some sub-divisions have probabilities of occurrence of drought in two consecutive years. Few sub-divisions have some chances of occurrence of droughts in more than two consecutive years also. Maximum probability of occurrence of two consecutive years of drought is noticed in Jammu & Kashmir and west Rajasthan *i.e.*, once in 16 years followed by Punjab, where probability of occurrence of consecutive years of drought is once in 25 years. While in the sub-divisions like Arunachal Pradesh, Assam & Meghalaya, Gangetic West Bengal, Orissa, Bihar plateau, Bihar plains and plains of west Uttar Pradesh, Konkan and Goa, Tamil Nadu & Pondicherry, coastal Karnataka and south interior Karnataka, the probabality of occurrence of two consecutive years is nil. Probability of occurrence of droughts in more than two consecutive years is nil except in Himachal Pradesh and Jammu &

TABLE 4

El Nino and drought years during 1875 to 1998

El Nino Years			Drought years in India		
1877	1880	1884	1877	1891	1899
1887	1891	1896	1901	1904	1905
1899	1902	1905	1907	1911	1913
1911	1914	1918	1915	1918	1920
1923	1925	1929	1925	1939	1941
1930	1932	1939	1951	1965	1966
1941	1951	1953	1968	1972	1974
1957	1965	1969	1979	1982	1985
1972	1976	1982	1987		
1987	1997				

Underlined years are El Nino years

Kashmir, Saurashtra & Kutch and Gujarat region. In Himachal Pradesh and Jammu & Kashmir the chances of occurrence of droughts for three or more consecutive years is once in 50 years. Whereas, the occurrence of the

TABLE 5

Drought years for different sub-divisions of India during 1875-1999

1.	Andaman & Nicobar Islands	1886 1892 1893 1899 1900 1907 1915 1919 1924 1925 1927 1979 1984 1990 1993 1999
2.	Arunachal Pradesh	1937 1942 1961 1971 1992 1994
3.	Assam & Meghalaya	1884 1896
4.	Nagaland, Manipur, Mizoram & Tripura	1884 1887 1888 1889 1895 1896 1899 1907 1972 1980 1981 1986
5.	Sub Himalayan West Bengal	1890 1891 1896 1904 1908 1972 1994
6.	Gangetic West Bengal	1895 1966
7.	Orissa	1878 1901 1924 1974 1987
8.	Bihar plateau	1903 1966 1979 1982 1992
9.	Bihar plains	1877 1891 1901 1908 1932 1951 1959 1966 1972 1982 1992
10.	East Uttar Pradesh	*1877 1883 1896 1907 1913 1918 1928 1932 1959 1965 1966 1979 1987
11.	Plains of west Uttar Pradesh	*1877 1883 1905 1907 1913 1918 1928 1941 1979 1987
12.	Hills of west Uttar Pradesh	*1877 1883 1905 1907 1913 1918 1941 1951 1965 1972 1976 1980 1982 1987 1991 1992 1997
13.	Haryana,Chandigarh & Delhi	*1877 1883 1898 *1899 1905 1907 1913 1915 *1918 1920 1928 1929 1938 1939 1941 1951 1965 1968 1979 1986 *1987
14.	Punjab	*1899 1904 1905 *1911 1915 1918 1920 1921 1928 1929 1938 1939 1951 1964 1965 1969 1972 1974 *1979 *1987
15.	Himachal Pradesh	1877 1883 1899 1902 1905 *1907 1911 *1918 1928 1965 1968 1972 1979 1981 1982 1983 1984 1986 *1987 1989
16.	Jammu & Kashmir	1878 *1879 *1883 *1884 *1885 1886 1887 *1889 *1891 1895 1896 1898 1900 1902 1911 1918 1920 1937 1949 1951 1965 1971 1972 1979 1982 1992
17.	West Rajasthan	*1877 1883 1885 1887 1891 *1899 *1901 1902 *1904 *1905 *1911 1913 *1915 *1918 1920 1925 1938 *1939 1951 1963 1968 *1969 1971 1974 1980 1981 1982 1985 1986 *1987 1991
18.	East Rajasthan	*1877 1898 1899 1901 *1905 1907 1911 1913 *1915 *1918 1925 1928 1939 1941 1951 1965 1966 1972 *1987 1991
19.	West Madhya Pradesh	1877 1899 1905 1907 1918 1920 1940 1951 1965 1966 1979 1987
20.	East Madhya Pradesh	1878 1899 1941 1962 1965 1966 1974 1998
21.	Gujarat region	*1877 1885 1888 1892 *1899 1901 *1904 *1911 *1915 *1918 1920 1923 1925 1936 1939 *1948 1951 1957 1960 1965 1972 *1974 1982 *1985 *1986 *1987
22.	Saurashtra & Kutch	1875 *1877 1889 1890 1894 *1899 *1901 *1904 1905 *1911 *1915 *1918 *1923 1925 1931 *1939 *1948 1951 1968 1969 *1972 *1974 1982 *1985 1986 *1987 1991 1993 1995 *1999
23.	Konkan & Goa	1877 1899 1905 1918 1920 1941 1968 1972 1986
24.	Madhya Maharashtra	1877 *1899 1904 1905 1911 *1918 1972 1985 1987
25.	Marathwada	1877 1885 1899 1905 1907 1912 1918 *1920 1925 1929 1939 1941 1972 1974 1984 1985 1993 1997
26.	Vidarbha	1877 *1899 1902 1904 1918 1920 1950 1952 1965 1971 1972 1974 1982 1985 1987
27.	Coastal Andhra Pradesh	1877 1888 1899 1904 1920 1952 1968 1972 1973 1979 1984 1987
28.	Telangana	1876 1877 1881 1888 1899 1918 1920 1939 1941 1952 1968 1971 1972 1977 1985 1997
29.	Rayalaseema	1876 1884 1891 1896 1899 1901 *1904 1907 1911 1913 1918 1920 *1922 1923 1934 1941 1948 1952 1971 1972 1985 1993
30.	Tamil Nadu & Pondicherry	1884 1891 1899 1904 1918 1934 1952 1969 1980 1982 1999
31.	Coastal Karnataka	1881 1899 1918 1972
32.	North interior Karnataka	1876 1891 1899 1905 1937
33.	South interior Karnataka	1875 1881 1884 1905 1918 1976 1985
34.	Kerala	1881 1899 1918 1944 1951 1952 1965 1966 1976
35.	Lakshadweep	1901 1918 1927 1928 1934 1941 1948 1952 1956 1957 1969 1980

Underlined years are El Nino years

Years with asterisk (*) are severe drought years

same in Gujarat region and Saurashtra & Kutch is once in 100 years.

Probability of occurrence of moderate drought in various sub-divisions of India is shown in Fig. 1 (a). It is noticed that maximum probability of occurrence of moderate drought is over Jammu & Kashmir, west Rajasthan and Rayalaseema, whereas, the maximum probability of occurrence of severe droughts is over Saurashtra & Kutch, where there is a chance of occurrence of severe drought once in 9 years [Fig. 1 (b)].

The years of occurrence of drought in sub-divisions where probability of occurrence of drought is more than 15% is given in Table 3. It may be noted that during last 124 years drought occurred in 31 years, in west Rajasthan and in 29 years over Saurashtra & Kutch *i.e.*, about once in 4 years. Occurrence of drought over Gujarat region and Jammu & Kashmir is also very high.

During the period from 1875 to 1998 there were 29 ENSO years and there were 25 drought years in India (Table 4). Out of these 25 drought years there was El Nino in 14 years as underlined in column two of Table 4. Remaining 11 drought years were not connected with El Nino events. Similarly among the El Nino years indicated in Table 4 there were only 14 years affected by drought situation over the country as a whole *i.e.*, 15 El Nino years were not associated with drought.

Drought years of different sub-divisions of India are indicated in Table 5. The years with El Nino event are underlined. Occasions of drought during 124 years in sub-divisions with more than 15% probability of drought occurrence and its association with El-Nino for those sub-divisions are described below :

Haryana, Chandigarh and Delhi had drought on 21 occasions of which 10 were associated with El Nino events, *i.e.*, on 48% cases droughts were associated with El Nino events. Punjab had drought on 20 occasions of which 11 were El Nino years, *i.e.*, on 55% cases droughts were associated with El Nino events. Himachal Pradesh also had drought on 20 occasions of which 10 were associated with El Nino events, *i.e.*, on 50% cases droughts were associated with El Nino events. Jammu & Kashmir had drought on 26 years of which 11 were El Nino years, *i.e.*, on 42% cases droughts were associated with El Nino events. West Rajasthan had maximum occurrence of drought on 31 years of which 13 were El Nino years, *i.e.*, on 42% cases droughts were associated with El Nino events. East Rajasthan had drought on 20 years of which 12 were El Nino events, *i.e.*, on 58% cases droughts were associated with El Nino events. Gujarat region had drought on 26 years of which 13 were El Nino

events, *i.e.*, on 50% cases droughts were associated with El Nino events, Saurashtra & Kutch had second largest number of drought years, *i.e.*, there were 29 drought years during the period of which 13 were associated with El Nino events, *i.e.*, on 45% cases drought were associated with El Nino events. Marathwada had drought on 18 occasions of which 10 were El Nino events, *i.e.*, on 55% cases droughts were associated with El Nino events. Rayalaseema had drought on 22 occasions of which 9 were associated with El Nino events, *i.e.*, on 41% cases droughts were associated with El Nino events.

4.   Conclusions

(*i*)   Probability of occurrence of drought was found to be maximum in Saurashtra & Kutch, followed by Jammu & Kashmir and Gujarat region.

(*ii*)   Maximum probability of occurrence of two consecutive years of drought was in Jammu & Kashmir and west Rajasthan.

(*iii*) During last 124 years there were 29 ENSO events out of which only 14 years were associated with drought over India.

(*iv*)   During last 124 years there were 25 years with drought over India out of which 11 were non El Nino years.

(*v*)   El Nino affects summer monsoon rainfall in various sub-divisions of India differently.

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