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Climatology No. 21/2005

CLIMATOLOGICAL FEATURES OF DROUGHT INCIDENCES IN INDIA

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INTRODUCTION

Among the different natural hazards, drought is one of the most disastrous as it inflicts untold numerous miseries on the human societies. Drought occurs in nearly all climatic zones of the world at one time or the other, but this creeping phenomenon mostly affects tropics and adjoining regions. Its beginning is subtle and difficult to be precisely identified because of lack of sharp distinction from non-drought dry spells. As a disaster, it is experienced only after it has occurred. The termination of drought is, on the contrary, easily recognizable, associated as it is, with the occurrence of precipitation.

For the countries in which the rainfall is seasonal in nature, agriculture often becomes tuned with the rainy season. Any deficiency of significant amount thus directly affects the agriculture, ruining the economy., (Mooley and Parthasarathy, 1984). Not only agriculture, drought also exerts profound influence on other disciplines like hydrology, tourism, transport, water supply, hydroelectric power generation, etc. The vast Indian landmass extends from near equator to extra- tropics and has not remained unaffected by incidence of drought. This phenomenon has become more frequent after 1965. There is hardly any decade when drought has not occurred in India at least in two years (Table-1). Naturally, the study of monsoon features and consequent drought has attracted the attention of Indian Meteorologists from a long time, (Rao et al 1970, Bhalme and Mooley 1980, Mooley and Parthasarathy 1983 etc.). Its various facets, particularly reconstruction of drought history, drought frequency and its probabilities and possible method for its forecasting has been examined by Banerjee et al.(1978); Chowdhury et al.(1981); Chowdhury and Sarwade (1981); Thapliyal (1984); Dugam et al.(1993), etc. Most of these studies were undertaken on meteorological sub-divisionwise basis though a few attempts were also made taking the country as a whole as one unit, (Chowdhury at al.1989).

The present study utilizes a long series of data to compare and contrast drought incidence over India from the point of view of area affected by drought and the rainfall deficiency. Drought definition in vogue in some of the countries has also been given. Probability of drought and effect of El Nino on drought in India has been examined in depth.

2. DATA UTILISED

Many of the earlier studies have used monsoon rainfall deficiency as a tool in drought identification. No attempt seems to have been made to build-up a comprehensive, coherent drought climatology of India from areal extent and rainfall deficiency angles. The present report undertakes to prepare climatology of drought in India using 130 years of un-interrupted data series (1875-2004). This has been accomplished from data of 36 meteorological sub-divisions in which the country has been recently divided. Another angle from which the study has been made is by taking area of the whole country as a single unit.

Besides, the basic drought event has been classified into moderate and severe categories. There are certain regions of the country, which most frequently experience this hazard. As such, the report identifies chronically drought prone areas and distinguishes it from areas having non-recurrent, drought phenomenon. Probability of drought and two or more consecutive droughts (both in meteorological sub-divisions and the country) have also been determined and discussed.

Drought in India during monsoon occurs not only due to lack of favourable synoptic situations over and near Indian landmass, but in recent years, it has been suggested that extra-regional climatic events like southern oscillations and marine event like El Nino in the Pacific also influence occurrence of monsoon rainfall (Mooley and Paolino 1989; Mooley 1997; Shewale and Rase 2000), etc.). An attempt has also been made to determine possible linkage between monsoon rainfall of India and the El Nino event as also in different meteorological sub-divisions.

3 (A) DROUGHT AND DESERTIFICATION

Among the events, which influence earth's environment and ecosystem, drought is perhaps the one that is often linked with desertification. Desertification is vastly different from drought and the latter could be one of the several causes, which lead to the formation of the former. In other words, desertification is not synonymous with drought. Successive occurrences of drought for a number of years over marginal lands often leads to loss of top soil, soil fertility and hence to desertification. Marginal lands are highly vulnerable to drought and hence desertification. Desertification or permanent aridity of lands otherwise useful, is often restricted to low rainfall regions and is a permanent feature of climate. It is now recognized that more than climate, the changes wrought by reckless human land use pattern actually contribute to desertification.

3 (B) DROUGHT AND FAMINE

There is a wrong perception generally, to blame drought as a cause of famine. The truth is famine is the result of extreme food shortage in an area (which may or may not have had deficient rainfall) when due to lack of efficient transport infrastructure, it is not possible to timely rush food grains from food-surplus area to those facing the shortage. Drought need not precipitate a famine situation and historical records have shown that famines have occurred in the absence of drought. Droughts by themselves have seldom led to famines (Sen 1981; Watts 1983; Torry 1984). The best example that can be cited in this regard is that of 1943, when Bengal faced famine, though the monsoon rainfall in that year was 103.7% of its long term normal.

4. DROUGHT CONCEPTS AND DEFINITION

Undoubtedly, the drought is a phenomenon of lack of rainfall, but this concept of drought is highly controversial. What should be the threshold value of rainfall which sets-in drought in the region, is difficult to quantify. Different disciplines have different threshold to define drought, but this varies from region to region. Even in agriculture where drought impact is most visible, one cannot quantify the threshold. This is because different crops need different amount of rainfall for their growth and maturity. Even for the same crop, different varieties have different water need. Moreover, this need differs from one phase to another phase of the same crop.

In a more general way, we may however, define drought as a lack of rainfall so large and so long continued to adversely affect all established human activities of the region (Warrick, 1965). Different countries have, however, defined drought as per their rainfall pattern. The British Rainfall Organisation in UK defines “absolute drought” when at least 15 consecutive days none of which receive at least 0.25 mm of rainfall and “partial drought” when at least 29 days during which mean rainfall does not exceed 0.25 mm per day.

In U.S.A., according to Conrad (1944), a period of 20 consecutive days or more without 6.4 mm or more of precipitation in 24 hours during the season March to September, is considered as a drought situation. In Australia, according to Gibbs and Maher (1967), the rainfall is the best single index of drought and use of rainfall deciles demonstrate temporal and spatial distribution. Areas where rainfall is in the first decile range, roughly coincide with drought-affected zone.

The India Meteorological Department (IMD) defines drought in any area when the rainfall deficiency in that area is ≥26% of its long term normal. It is further classified into moderate and severe drought depending upon whether the deficiency is between 26 to 50% and more than 50% respectively. For the country as a whole, the area-weighted rainfall having normal of 88 cm, also called Indian summer monsoon rainfall (ISMR), is considered. When the rainfall deficiency exceeds 10% and when the area under drought exceeds 20% of the total area of the plains in the country (which is 32,87,782 km^2), such a situation is considered as drought for the country as a whole. The present study uses these two criteria for preparation of this Report.

5. *RESULTS AND DISCUSSION*

Before considering drought for the country as a whole, it may be worthwhile to study how the drought climatology varies from region to region.

Frequency of drought in different sub-divisions along with their probabilities for the 36 sub-divisions, is given in Table-2. In the 130 years of which data is analysed, highest frequency (i.e. 33) is observed in the arid west viz. West Rajasthan and Saurashtra & Kutch with 31 cases. The adjoining Gujarat Region which mostly belongs to semi-arid also experiences high incidence of drought i.e., 27. Surprisingly, Jammu & Kashmir meteorological sub-division which mostly receives rains from extra-tropical systems (like western disturbance) in post-monsoon and winter season also faces numerous incidences (i.e.28 cases) of drought. Other areas recording significantly large incidences of drought are Haryana, Delhi & Chandigarh, Punjab, Himachal Pradesh and east Rajasthan in northwest India and Rayalaseema in southern Peninsula. The lowest number of droughts have been observed, for obvious reasons, in per-humid and humid areas in the northeast (viz. Arunachal Pradesh, Assam & Meghalaya, Orissa, Gangetic west Bengal and Jharkhand. Per humid areas of coastal Karnataka also experience significantly less frequency of droughts, though similar climatic zone of Konkan and Kerala do experience drought on comparatively more occasions.

Probability of drought occurrences is also given in Table-2. They follow the same pattern as the drought frequency mentioned above. The probabilities are also depicted in Fig.-1 and are self-explanatory.

Based on the probability of drought an attempt has been made in this report to identify chronically drought prone and other areas.

5.2 Chronically drought affected areas

Areas having probability of drought exceeding 20% has been defined as chronically drought prone. In other words, such regions can expect at least one drought in 5 or 4 years. The report could identify chronically drought prone areas as west Rajasthan and entire Gujarat State (Fig.1). These arid regions of the country deserve special attention for drought proofing like evolving crop varieties resistant to water shortages for a prolonged period, better water management (building check-bunds), effective land management (contour bunding, etc.).

5.3 Frequently drought prone areas

Areas having drought probability between 10% to 20% have been assigned this category. These areas are east Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, east Rajasthan, west Madhya Pradesh, Marathwada, Vidarbha, Telangana, coastal Andhra Pradesh and Rayalaseema and can expect drought once in 6 to 10 years. These areas generally belong to sub-humid climate zone (both dry & moist).

5.4 Least drought affected areas

Areas having drought probability less than 10% belong to this category and comprise rest of the country. Apparently, these pose no problem from rainfall point of view as they mostly belong to per-humid and humid regions climatic zones.

5.5 Categorisation of drought

As mentioned above, droughts have been categorised as : moderate drought with rainfall deficiency between 26 to 50% and severe drought with deficiency exceeding 50%.

Instances when drought in these two categories have been experienced by different sub-divisions are given in Table-2. It is clear from the table that whenever drought has occurred, it is mostly on moderate scale. Surprisingly, as can be seen from the Table-2, except the humid and per-humid regions of the northeast India and Madhya Pradesh, Karnataka, Tamil Nadu, Kerala and Konkan & Goa, other sub-divisions generally have often experienced severe drought. This seems to be more common in Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Gujarat, Maharashtra (except Konkan) and Rayalaseema. In fact, whenever drought occurs, chances of it being of severe nature are quite high in Saurashtra & Kutch (with 48% probability), Gujarat Region (41% probability), west Rajasthan (with 36% probability), east Rajashan (23% probability), Haryana and Punjab (18% each) and Himachal Pradesh (14% probability). In rest of the sub-divisions, the chances of a drought to be severe in intensity appear quite remote.

5.6 Drought Climatology of India as one Unit

5.6. (a) Identification from area affected :

As has been mentioned above, in any year, area of the meteorological sub-division receiving rainfall with deficiency of 26% or more has been assumed to be drought affected. Adding all such areas in a particular year would give total drought affected area of the country in that year. For each year from 1875 to 2004, these areas were determined to give a series of drought-affected areas for all the 130 years. The country as one single Unit is assumed to be drought affected, if such area exceeds 20% of the total area of the country (i.e. 6,57,556 km^2). Drought years thus identified are presented in Table 3-4. As can be seen from these tables, in 1918 the country seems to be affected as never before when 70% of India experienced drought. The second large scale drought was in 1899 with 68% of the area affected, followed by 1877 (with 59%), 1987 (with 48%) and 1905(37%). In all, 27 years of drought as per the above criteria were observed, yielding a probability as 20%. This agrees well with the drought probabilities computed by Chowdhury et al (1989) and Ray and Shewale (2001). It was obsereved that 13 year's periods each from 1878 to 1890, 1926 to 1938 and 1952 to 1964, the country was free from drought menace. A twelve year period from 1988 to 1999 was also generally free from drought of areal extent exceeding 20%.

5.6 (b) Drought mapping from rainfall departure point of view

Area weighted rainfall (ISMR) deficiency from normal in any year during the monsoon can also be a tool in identifying if the country has faced drought. The present report examined departure of ISMR to identify years of drought. As has been mentioned, a deficiency of more than 10% of the ISMR from the normal of 88 cm has been considered as the threshold for this purpose. Incidences of drought observed in this process are also given in the Table-3. In the 130 years under study, only 20 cases of drought were observed which gave a probability of drought for India as 15%. This figure seems to be lower than what has been obtained by the other method.

The ranking of droughts by both these methods is given in Table-4. Difference in some of the worse droughts identified by either methods can be seen. Thus as per this definition, the worst drought the country faced was in 1877 with ISMR deficiency of 33%, followed by 1899 with 29% deficiency, 1918 with 25% deficiency, 1972 with nearly 24% deficiency and 2002 with nearly 19% deficiency. It can also be observed that in some years like 1891, 1907, 1913, 1915, 1925, 1939, 1985 and 2000 drought identified by the criteria of area affected did not reflect in the criteria of rainfall deficiency. As against this, during the 130 years there were only two years i.e., 1986 and 2004 when the ISMR was deficient by 12.7 and 13.0% but it affected only about 19% area of the country in both the years and therefore they were not considered as a drought years for the country as a whole.

5.7 Consecutive droughts

For country as a whole consecutive droughts, by its vary nature, should be a rare event. This is because macro-scale synoptic situations which lead to large scale monsoon failures are generally not likely to repeat in consecutive years in toto. As such, in 130 years of data analysed, we could identify only two cases of consecutive droughts over India as one unit i.e. 1904-1905 and 1965-1966. This was noticed by both the methods adopted in the study.

However, when the analysis is extended to the meteorological sub-divisions, obviously, a different picture emerged. For a good number of sub-divisions, we not only found two consecutive droughts but sometimes even more occasions of consecutive droughts. Sub-divisions which experience such situations are shown in Table-5. Not surprisingly, the humid areas of Arunachal Pradesh and Assam and Meghalaya, Gangetic West Bengal, Bihar, Jharkhand and coastal Karnataka seem to be free from persistent drought in consecutive years. Even sub-divisions like west Uttar Pradesh and Tamil Nadu had no cases when drought repeated itself in successive years. However, Sub-Himalayan West Bengal and Nagaland, Manipur, Mizoram and Tripura (NMMT) though belonging to per-humid climate have been observed to experience drought on 2 or more consecutive years. In fact, in NMMT the drought has occurred in three consecutive years once viz. 1887-1889. Cases when areas where drought has occurred once in 2 consecutive years are east Uttar Pradesh, Uttaranchal, Madhya Pradesh (including Chattisgarh),Marathwada, Vidarbha, Coastal Andhra Pradesh and South Interior Karnataka. In parts of northwest India like Haryana, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Gujarat and Kerala in southern India, recurrent drought appears more common as is evident from the table. Over Punjab, Jammu & Kashmir, West Rajasthan and Saurashtra & Kutch such occasions even exceed 5 in number. They attain a frequency of 8 over west Rajasthan. Over western Himalayas viz. Himachal Pradesh and Jammu & Kashmir, in 4 consecutive years droughts have occurred. In fact over Jammu & Kashmir there was one incidence during 1983 to 1987 the drought has occurred on 5 consecutive years.

Cases of persistent drought recurring 3 or more years, it is felt, need to be examined from micro-level synoptic point of view, to determine their cause (Bhalme and Mooley, 1980).

5.8 Secular variations

Systematic long-term secular tendency in rainfall has been studied by a large number of research workers. Most of these investigations have been on data from individual stations (Pramanik, 1953) or meteorological sub-divisions. Hardly any attempt seems to have been made in ISMR or area affected by drought in India.

Secular changes taking place in rainfall occurrences, particularly in drought affected areas have been examined in this report. This has been accomplished by subjecting the data of year wise drought affected areas of the country and also ISMR to 11 year moving average. The results are depicted in Fig 2 (a & b). Area affected by drought seems to have shown a steady increase between 1894 to 1908 and between 1964 to 1975. A progressive decline from 1908 to 1964 and from 1985 to 1998 are also seen. Drought area has, more or less, remained constant from 1976 to 1986. Surprisingly, in recent years there again seems to be a tendency for drought affected area to increase from 1998 onwards.

The above results are generally supported by the analysis for ISMR. Thus, the ISMR also reveal a distinct decrease from 1894 to 1908 and approximately from 1960 to 1973. Rainfall has more or less remained unchanged between 1917 to 1960 and between 1974 to 1998. Changes found in the drought affected areas in the recent years, are confirmed in the ISMR viz. when area affected by drought has increased, the ISMR has decreased and vice-versa.

5.9. Effect of El Nino

The effect of El Nino in modulating and modifying weather in different parts of the world is a well-established fact (Kane, 1999). Many of these studies have tried to establish linkages between drought and El Nino (Ropelewski and Halpart 1987, Rase 1996; Shukla et al. 1983; Shewale and Rase 2000), etc. The wide-spread drought the world experienced in 1972, 1982,1987, etc. have been attributed to the presence of El Nino. Effect of this phenomenon on rainfall over different sub-divisions has been studied by Ray and Shewale (2001). In this section, an attempt has been made to find out the effect of El Nino on area affected by drought and also on ISMR.

When the area affected by drought exceeds 20% of the area of the country (which we have taken as a condition for drought for the country as a whole), we observed 27 cases of drought, among these 15 occurred when there was El Nino phenomenon simultaneously occurring in the Pacific. This gives a probability of areal drought due to El Nino as slightly more than 50% (Table-6). There were, again, 16 cases when El Nino was present but no drought was seen according to the criteria of area. Moreover, there was 12 years of drought occurrence without El Nino. In other words, the study shows presence or absence of El Nino does not necessarily have an over-riding influence on occurrence or absence of drought in India.

Table-6 also contains drought years identified by the criteria of more than 10% deficiency of ISMR. There were 20 years with deficiency of more than 10% in ISMR or drought from rainfall deficiency point of view. Within these 20 years, 13 years were associated with El Nino giving a probability of drought as 65% of drought and El Nino occurring simultaneously. The remaining 7 year's drought or nearly 35% cases shown in this table were not associated with El Nino. This analysis also shows that effect of El Nino on drought occurrences in India is marginal. In fact, there are a good number of drought incidences without El Nino being present.

The El Nino being a global phenomenon, it is often believed, it affects extensive areas, far removed from the centre of action. This has been proved incorrect by Pisciottano et al.(1994) and Abigail et al. (2002) who found it to affect smaller areas as well. Rase (1996), similarly found some association between it and rainfall over central India. Effect of

El Nino on smaller areas like meteorological sub-divisions in India, when examined, the following results were observed.

In 130 years data analysed, Haryana, Chandigarh and Delhi, Punjab and east Rajasthan each experienced drought on 22 occasions out of which 10 were associated with El Nino events, i.e. over 45% cases. In Himachal Pradesh there were 21 such occasions of which only 10 (or 48%) were associated with El Nino. Gujarat Region and Jammu & Kashmir had drought on 27 years and 26 years respectively, of which 13 and 11 years were El Nino events i.e. in 48% cases droughts were associated with El Nino events. The largest number of drought (or 33 instances) occurred in west Rajasthan of which 14 years (i.e. 42%) were simultaneously with El Nino event. Saurashtra & Kutch experienced second largest number i.e. 30 of drought cases; among them 14 years (or 47%) were associated with El Nino events. The other chronically drought affected area i.e. Rayalaseema had drought on 23 occasions of which only 8 were associated with El Nino events i.e. on 35% cases droughts there were associated with El Nino events. In short, this association between drought and El Nino over different meteorological sub-divisions in India also does not seem to be strong as was also the case when country as one unit was considered.

CONCLUSIONS

i) The arid sub-divisions of west Rajasthan and Saurashtra & Kutch are the most drought prone areas of the country.

ii) Most areas of per-humid and humid northeast India, face the drought menace but infrequently.

iii) Occurrence of drought in consecutive monsoon seasons are common in northwest Indian sub-divisions, particularly west Rajasthan, Saurashtra & Kutch and Jammu & Kashmir and Rayalaseema in the Peninsular India.

iv) Both methods used in the Report to identify drought for the country as a whole, indicate a probability of drought incidence as nearly 20%.

v) Drought seems to have become frequent since 1965; the past 5 years witnessed 3 years of drought over India.

vi) Clear evidence in drought affected areas in the country to increase in recent years, is seen; correspondingly there exist a decrease in ISMR.

vii) Influence of El Nino episodes on monsoon rainfall over India is not over-riding; only nearly 50% of drought incidence is seen associated with simultaneous occurrence of El Nino.

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TABLE – 1

Decadal frequencies of drought years for the country as a whole

Criteria for Drought Monitoring	1875-1884	1885-1894	1895-1904	1905-1914	1915-1924	1925-1934	1935-1944	1945-1954	1955-1964	1965-1974	1975-1984	1985-1994	1995-2004	**Total**
Area Covered	1	1	3	4	3	1	2	1	0	5	2	2	2	27
Rainfall Deficiency	1	0	3	2	2	0	1	1	0	5	2	1	2	20

TABLE - 2

Sub-divisionwise frequencies of Moderate and Severe drought during 1875-2004 and probabilities of drought years

S.No.	*Name of Sub-division*	*Moderate*	*Severe*	*Total*	*Drought probabilities (Total) %*
1.	Andaman & Nicobar Islands	17	0	17	13
2.	Arunachal Pradsh	6	1	7	5
3.	Assam & Meghalaya	2	0	2	1
4.	Nagaland, Manipur, Mizoram & Tripura	12	0	12	9
5.	Sub-Himalayan West Bengal	7	0	7	5
6.	Gangetic West Bengal	2	0	2	1
7.	Orissa	5	0	5	4
8.	Bihar	11	0	11	8
9.	Jharkhand	5	0	5	4
10.	East Uttar Pradesh	12	1	13	10
11.	West Uttar Pradesh	10	1	11	8
12.	Uttaranchal	15	2	17	13
13.	Haryana, Delhi & Chandigarh	18	4	22	17
14.	Punjab	18	4	22	17
15.	Himachal Pradesh	18	3	21	16
16.	Jammu & Kashmir	20	6	26	20
17.	West Rajasthan	21	12	33	25
18.	East Rajasthan	17	5	22	17
19.	West Madhya Pradesh	13	0	13	10
20.	East Madhya Pradesh (including Chhattisgarh)	10	0	10	8
21.	Gujarat Region	16	11	27	21
22.	Saurashtra & Kutch	16	15	31	24
23.	Konkan & Goa	9	0	9	7
24.	Madhya Maharashtra	7	2	9	7
25.	Marathwada	17	1	18	14
26.	Vidarbha	15	1	16	12
27.	Coastal Andhra Pradesh	13	0	13	10
28.	Telangana	17	0	17	13
29.	Rayalaseema	20	2	22	17
30.	Tamil Nadu & Pondicherry	12	0	12	9
31.	Coastal Karnataka	5	0	5	5
32.	North Interior Karnataka	10	0	10	8
33.	South Interior Karnataka	9	0	9	7
34.	Kerala	10	0	10	8
35.	Lakshdweep	10	3	13	10

TABLE - 3
DROUGHT AREA (%)

Year	All India %departure of rainfall	% Drought area	Year	All India %departure of rainfall	% Drought area	Year	All India %departure of rainfall	% Drought area
1875	11.3	6.9	1921	3.7	2.0	1967	0.1	0
1876	-5.3	9.0	1922	3.5	7.0	*1968	-10.3	21.5
*1877	-33.3	59.5	1923	-2.5	9.0	1969	0.2	16.5
1878	12.9	12.8	1924	4.1	5.0	1970	12.2	0
1879	7.2	0.2	**1925	-3.3	21.0	1971	4.0	16.6
1880	-3.8	0	1926	6.9	0	*1972	-23.9	39.0
1881	2.8	9.0	1927	2.0	0	1973	7.5	3.0
1882	5.2	0	1928	-8.6	18.3	*1974	-12.0	33.0
1883	-4.8	18.5	1929	-6.5	5.5	1975	15.2	0
1884	8.4	14.5	1930	-5.4	0	1976	2.5	4.0
1885	-0.2	12.1	1931	2.9	3.8	1977	4.1	4.0
1886	2.6	0.2	1932	-3.7	8.2	1978	9.2	0
1887	3.6	3.5	1933	15.1	0	*1979	-18.9	34.5
1888	-2.1	10.0	1934	4.7	6.6	1980	3.9	11.0
1889	8.0	4.0	1935	-2.9	0	1981	-0.2	7.9
1890	8.8	4.5	1936	6.1	3.0	*1982	-14.5	28.9
**1891	-6.3	22.2	1937	-2.3	3.0	1983	13.0	1.2
1892	15.7	3.0	1938	5.0	10.0	1984	-4.4	8.5
1893	12.1	0	**1939	-8.7	27.9	**1985	-7.1	42.3
1894	17.0	4.0	1940	-2.6	0	1986	-12.7	19.4
1895	-2.5	2.5	*1941	-13.3	35.0	*1987	-19.4	47.7
1896	-2.5	11.0	1942	13.8	0	1988	19.3	0
1897	4.8	0	1943	3.7	0	1989	0.9	1.2
1898	3.9	7.0	1944	4.8	1.2	1990	6.3	0.3
*1899	-29.4	68.4	1945	3.7	0	1991	-9.3	16.1
1900	6.5	0.2	1946	6.7	0	1992	-6.6	8.0
*1901	-13.1	29.0	1947	5.2	0	1993	-0.7	8.3
1902	-9.1	11.5	1948	1.8	9.0	1994	12.5	2.8
1903	2.6	3.0	1949	0.5	0.2	1995	-1.9	3.8
*1904	-11.8	34.5	1950	3.7	3.0	1996	3.4	0
*1905	-17.4	37.2	*1951	-18.7	34.0	1997	2.0	4.5
1906	4.0	0	1952	-8.2	18.0	1998	5.0	7.3
**1907	-10.0	29.0	1953	9.8	0	1999	-4.0	8.4
1908	7.4	4.0	1954	3.1	0	**2000	-8.0	27.2
1909	7.1	0	1955	10.1	0	2001	-9.0	0.8
1910	8.1	0	1956	13.6	0	*2002	-19.0	29.0
*1911	-14.7	28.0	1957	-2.4	3.0	2003	2.0	7.1
1912	-4.5	2.0	1958	9.8	0	2004	-13.0	18.5
**1913	-10.0	24.0	1959	14.3	8.2			
1914	10.3	0	1960	0.6	3.0			
**1915	-9.4	22.0	1961	21.8	0			
1916	13.2	0	1962	-3.0	7.3			
1917	22.9	0	1963	-2.1	6.7			
*1918	-24.9	69.5	1964	9.8	1.7			
1919	5.9	0	*1965	-18.2	37.5			
*1920	-16.7	37.0	*1966	-13.2	34.7			

* Drought years (identified by both method).
** Drought years with all India rainfall deficiency ≤ 10%.

TABLE – 4

Drought years with percentage area of the country affected by drought, rank as per the area, % departure of ISMR and rank as per the% departure

S. No.	Year	Areas affected in percentage of total area of the country by			*Rank* as per drought area	% Departure of ISMR	*Rank* As per % departure of ISMR
		Moderate drought	Severe drought	Total			
1.	1877	30.6	28.9	59.5	3	-33.3	1
2.	*1891	22.4	0.3	22.7	24	-6.3	26
3.	1899	44.1	24.3	68.4	2	-29.4	2
4.	1901	19.3	10.7	30.0	16	-13.1	16
5.	1904	17.5	16.9	34.4	14	-11.8	18
6.	1905	25.2	12.0	37.2	9	-17.4	10
7.	*1907	27.9	1.2	29.1	18	-10.0	20
8.	1911	13.0	15.4	28.4	21	-14.7	12
9.	*1913	24.5	0.0	24.5	22	-10.0	21
10.	*1915	18.8	3.4	22.2	25	-9.4	22
11.	1918	44.3	25.7	70.0	1	-24.9	3
12.	1920	35.7	2.3	38.0	8	-16.7	11
13.	*1925	21.1	0.0	21.1	27	-3.3	27
14.	*1939	17.8	10.7	28.5	20	-8.7	23
15.	1941	35.5	0.0.	35.5	10	-13.3	14
16.	1851	35.1	0.0	35.1	12	-18.7	7
17.	1965	38.3	0.0	38.3	7	-18.2	9
18.	1966	35.4	0.0.	35.4	11	-13.2	15
19.	1968	21.9	0.0	21.9	26	-11.3	19
20.	1972	36.6	3.8	40.0	6	-23.9	4
21.	1974	27.1	6.9.	34.0	15	-12.0	17
22.	1979	33.0	1.8	34.8	13	-18.4	8
23.	1982	29.1	0.0	29.1	17	-14.5	13
24.	*1985	25.6	16.7	42.3	5	-7.1	25
25.	1987	29.8	17.9	47.7	4	-19.4	5
26.	*2000	27.2	-	27.2	23	-19.0	6
27.	2002	19.0	10.0	29.0	19	-8.0	24

* Drought years with rainfall deficiency ≤ 10%

TABLE – 5

Drought incidence on 2 or more than two consecutive years

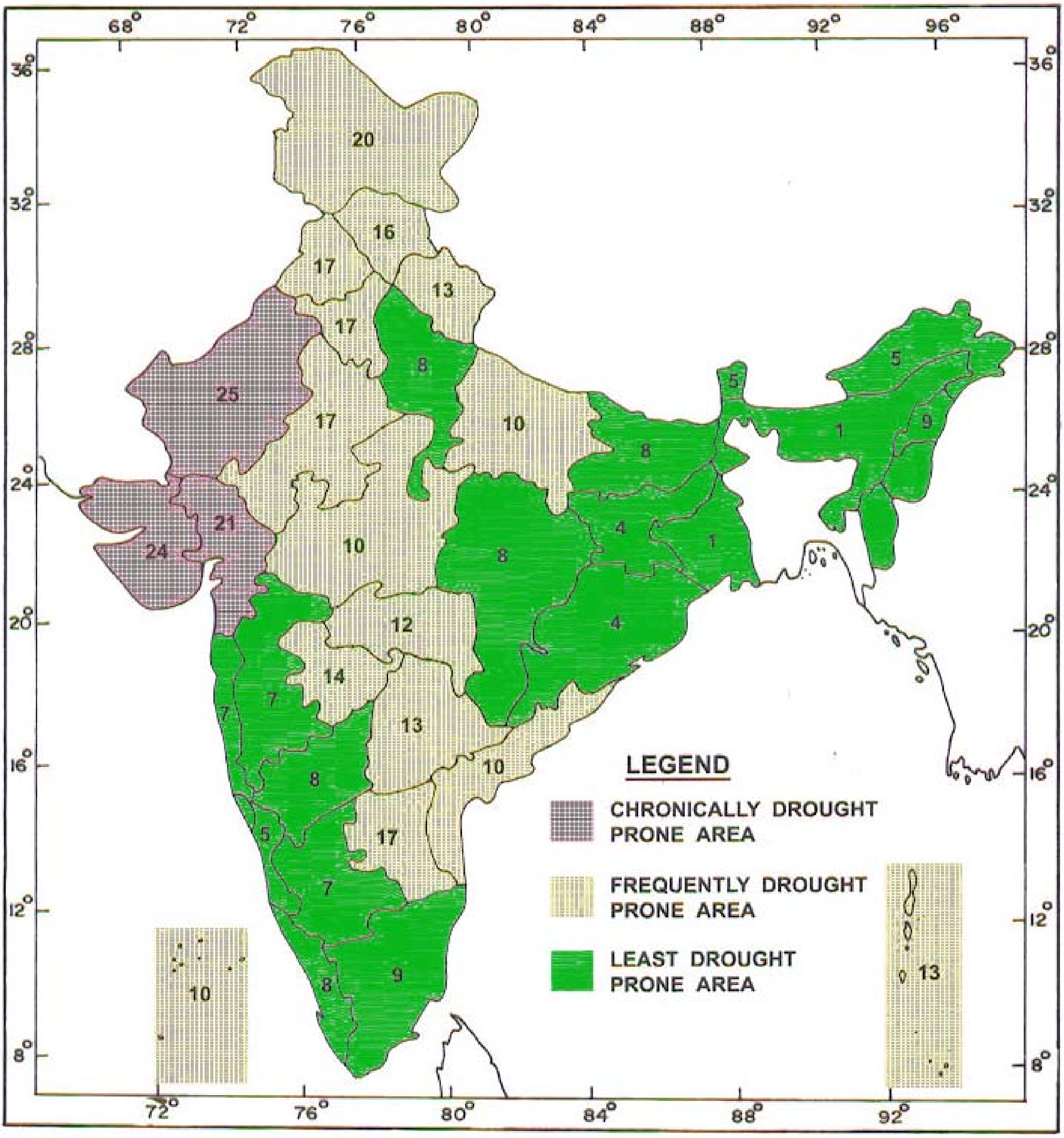
S.No.	*Sub-division*	*Two consecutive years*	*Three consecutive years*	*Four consecutive years*
1.	Andaman & Nicobar Islands	4 (1892-1893, 1899-1900, 1924-1925, 1999-2000)	0	0
2.	Nagaland, Manipur,Mizoram & Tripura	4 (1887-1888, 1888-1889, 1895-1896, 1980-1981)	1 (1887-1889)	0
3.	Sub Himalayan West Bengal	1 (1890-1891)	0	0
4.	East Uttar Pradesh	1 (1965-1966)	0	0
5.	Uttaranchal	1 (1991-1992)	0	0
6.	Haryana, Delhi & Chandigarh	4 (1898-1899, 1928-1929, 1938-1939, 1986-1987)	0	0
7.	Punjab	5 (1904-1905, 1920-1921, 1928-1929, 1938-1939, 1964-1965)	0	0
8.	Himachal Pradesh	4 (1981-1982, 1982-1983, 1983-1984, 1986-1987)	2 (1981-1983, 1982-1984)	1 (1981-1984)
9.	Jammu & Kashmir	7 (1878-1879, 1883-1984, 1884-1885, 1885-1886, 1886-1887, 1895-1896, 1971-1972)	3 (1883-1885, 1884-1886, 1885-1887)	2 (1883-1886, 1884-1887)

10.	West Rajasthan	8 (1901-1902, 1904-1905, 1938-1939, 1968-1969, 1980-1981, 1981-1982, 1985-1986, 1986-1987)	2 (1980-1982, 1985-1987)	0
11	East Rajasthan	2 (1898-1899, 1965-1966)	0	0
12.	West Madhya Pradesh	1 (1965-1966)	0	0
13.	East Madhya Pradesh (including Chattisgarh)	1 (1965-1966)	0	0
14.	Gujarat Region	2 (1985-1986, 1986-1987)	1 (1985-1987)	0
15.	Saurashtra & Kutch	6 (1889-1890, 1904-1905, 1968-1969, 1985-1986, 1986-1987, 1999-2000)	1 (1985-1987)	0
16.	Marathwada	1 (1984-1985)	0	0
17.	Vidarbha	1 (1971-1972)	0	0
18.	Coastal Andhra Pradesh	1 (1972-1973)	0	0
19.	Telangana	2 (1876-1877, 1971-1972)	0	0
20.	Rayalaseema	2 (1922-1923, 1971-1972)	0	0
21.	North Interior Karnataka	2 (1921-1922, 2002-2003)	0	0
22.	South Interior Karnataka	1 (2002-2003)	0	0
23.	Kerala	3 (1951-1952, 1965-1966, 2002-2003)	0	0
24.	Lakshadweep	2 (1927-1928, 1956-1957)	0	0

TABLE - 6

Table showing El Nino years during 1875-2004, drought years with criteria of countrywise area affected and also with deficiency in ISMR

S.No.	El Nino Years	Drought years with criteria of >20% of country's area affected		Drought years with criteria of >10% deficiency in ISMR	
		Drought year with El Nino	Drought year without El Nino	Drought year with El Nino	Drought year without El Nino
1.	1877	1877	1901	1877	1901
2.	1880	1891	1904	1899	1904
3.	1884	1899	1907	1905	1920
4.	1887	1905	1913	1911	1966
5.	1891	1911	1915	1918	1968
6.	1896	1918	1920	1941	1974
7.	1899	1925	1966	1951	1979
8.	1902	1939	1968	1965	
9.	1905	1941	1974	1972	
10.	1911	1951	1979	1982	
11.	1914	1965	1985	1987	
12.	1918	1972	2000	2002	
13.	1923	1982		2004	
14.	1925	1987			
15.	1929	2002			
16.	1930				
17.	1932				
18.	1939				
19.	1941				
20.	1951				
21.	1953				
22.	1957				
23.	1965				
24.	1969				
25.	1972				
26.	1976				
27.	1982				
28.	1987				
29.	1997				
30.	2002				
31.	2004				


LEGEND
CHRONICALLY DROUGHT PRONE AREA
FREQUENTLY DROUGHT PRONE AREA
LEAST DROUGHT PRONE AREA
68°
72°
76°
80°
84°
88°
92°
96°
36°
32°
28°
24°
20°
16°
12°
8°
20
16
17
13
17
25
8
17
10
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5
8
1
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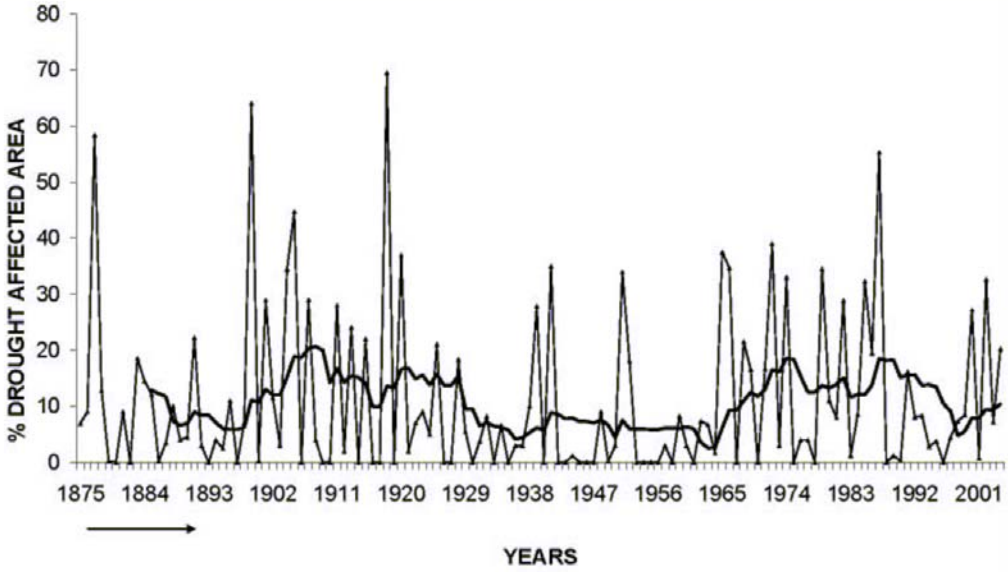

FIG. 2(a) - PERCENTAGE DROUGHT AFFECTED AREA vs YEARS

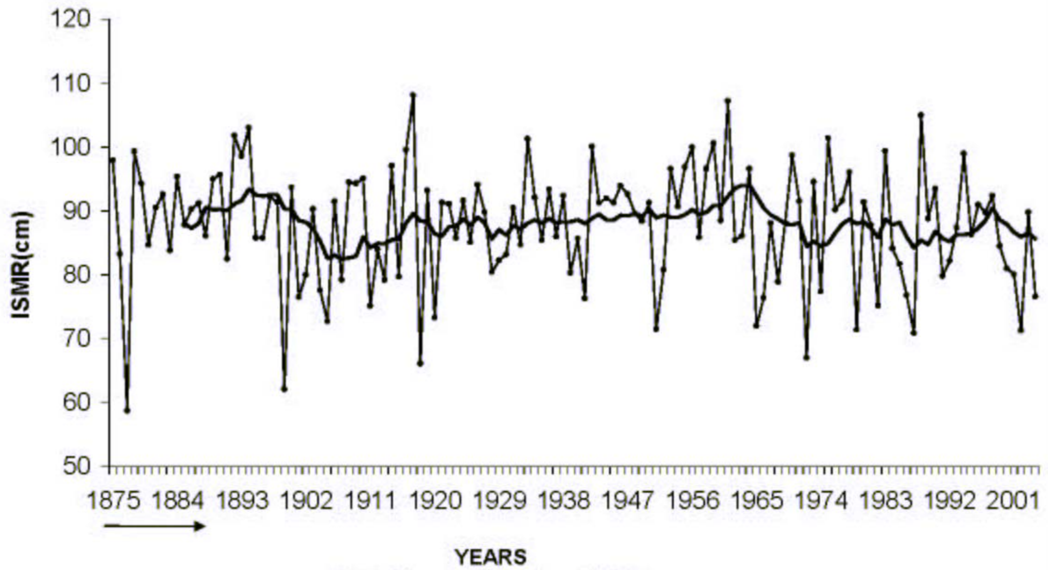

FIG.2 (b) - ISMR(cm) vs. YEARS