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Droughts and aridity over districts of Gujarat

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ABSTRACT

The large scale droughts over Gujarat State (India) have been identified by considering rainfall for the period 1901-1999. Their association with Pacific temperature anomalies and all India droughts have been examined. A trend analysis for the area affected by drought over Gujarat state as a whole and subdivisions of Gujarat has been made. The Agricultural drought conditions over the state have also been assessed. The decadal variability and probabilities of district wise occurrence of droughts have been discussed. The study reveals 43 large scale droughts and significant increasing trend in the area affected by drought over Gujarat. The correlation between Pacific temperature anomalies and area affected by drought over Gujarat is found to be significant. The probability of large scale drought occurrence over Gujarat in all India drought years is 82%.

Key Words : Large scale droughts, Trend, El Nino, Probability, Aridity

The rainfall variability of seasonal and annual rainfall over India has been studied by many scientists. Pramanik and Jagannathan (1953) have noticed the tendency of deficit rainfall in semi arid/arid regions of India. Mooley and Parthasarathy (1984) have studied rainfall series of India as a whole during 1871 to 1920 and depicted epochal behavior of rainfall. Study of Sarker and Thapliyal (1988) and Srivastava *et al.* (1998) indicated no trend in all India summer monsoon rainfall. Trend studies in rainfall over India by Srivastava *et al* (1998) on smaller spatial scale, did not show any trend in rainfall for Gujarat state as a whole during South West (SW) monsoon season except for a decreasing trend in rainfall in the district of Kuchchh. Study on decadal variability of monsoon by De and Vaidya (1996) has shown that on an average 7 sub-divisions come under deficit or scanty rainfall category. Rao (1958) studied trends in rainfall in Rajasthan. Chowdhury and Abhyankar (1979) found no significant decrease in rainfall over Gujarat state. Singh *et al.* (1991) studied variability of rainfall over Kuchchh region in detail.

Bhalme and Mooley (1980), Gregory and Parthasarathy (1986), Mooley *et al.* (1984), Chowdhury *et al.* (1989), Parthasarathy *et al* (1987) studied large scale droughts over India. Sen and Sinha Ray (1997) have found decreasing trend in the area affected by drought over India. Rainfall or drought over India in relation to El Nino have been studied by De (1997), Mooley (1997), Kane (1998), Saseendran *et al.* (1996). Gore and Thapliyal (2000) studied dry spells over Maharashtra. Gore and Sinha Ray (2001) have worked on spatial coherence of occurrence of droughts over Maharashtra. In the present study an attempt has been made to identify large scale droughts and the trend if any, over Gujarat, their linkage with El Nino and all India droughts. Droughts over smaller spatial scale like district have also been studied and

agricultural drought conditions over the state have been assessed.

MATERIALS AND METHODS

The state of Gujarat comes under arid and semi arid region with rainfall mostly less than 40cm in Saurashtra and Kuchchh and 40 to 100cm in Gujarat region. The basic data used comprises of daily rainfall data for Gujarat for the period 1901-1999 collected from National Data Center, Office of Additional Director General of Meteorology (Research), Pune. The data required for computation of aridity indices is weekly rainfall, potential evapotranspiration (Penman's PE, Rao *et al.* 1971) and field capacity of soil were extracted from the soil map of India published by the National Atlas organization of India. The SST anomalies over Pacific (source, NOAA/NWS/NCEP, USA) were used for the period 1950-1999 for seeing association between El-Nino and droughts over Gujarat..

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 SW monsoon season for the period 1901-1999, the years with deficit rainfall more than 25% for different districts in Gujarat, 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 of moderate and severe droughts have been computed for various districts for the period 1901-1999. If in an 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.

The correlation coefficients between Pacific temperature anomalies in Nino 1+2 (0-10S, 90W-80W), Nino3 (5N-5S, 150W-90W) and Nino4 (5N-5S, 160E-150W) regions in different months and seasons and area affected by drought over Gujarat during 1950 to 1999 have been worked out. The years were identified when the mean temperature anomalies over Pacific Nino3 region for last 8 months of the year were >1°C and examined with large scale drought years over Gujarat.

Weekly aridity indices (AI) were computed for stations in Gujarat during SW monsoon season using Thronthwaite aridity index and water balance technique for the period from 1980-1990.

$$AI = (PE-AE)/PE \times 100.$$

where, PE is potential evapotranspiration. AE is actual evapotranspiration and PE-AE is deficit. The anomaly of AI was computed by taking difference of actual and normal aridity index values. The aridity anomaly values were classified as below.

Aridity anomaly	Agricultural drought intensity
26 to 50	Moderate
>50	Severe

Table 1: Normal rainfall and variability at district level over Gujarat state.

	Name of district	No. of stations	Seasonal normal rainfall (cm)	C.V. (%)
Gujarat Region				
1	Ahmedabad	11	60	30-40
2	Amreli	01	53	40-50
3.	Banaskanta	11	54	40-50
4.	Baroda	14	95	30-40
5.	Broach	15	83	30-40
6.	Balsar	10	171	20-30
7.	Dangs	02	183	20-30
8.	Kaira	18	78	30-40
9.	Mehsana	12	60	40-50
10.	Panch-Mahals	11	92	30-40
11.	Sabarkantha	13	77	30-40
12.	Surat	12	121	30-40
Saurashtra & Kuchchh				
13.	Bhavnagar	09	55	30-40
14.	Jamnagar	09	45	40-50
15.	Junagarh	08	66	40-50
16.	Kuchchh	11	34	50-60
17.	Rajkot	07	56	30-40
18.	Surendranagar	05	48	40-50

RESULTS AND DISCUSSION

Variability of rainfall

The Table1 gives the SW monsoon seasonal normal rainfall and coefficient of variation (CV) for Gujarat. The normal varies from 53 to 183cm in the Gujarat region. The districts Bulsar and Dangs in southern parts show 170 to 180cm seasonal rainfall. In Saurashtra and Kuchchh rainfall varies from 30 to 66cm. The Kuchchh region has minimum seasonal rainfall of 34cm, while Junagarh district has 66cm. The C.V varies from 20 to 50% in Gujarat region and 30 to 60% in Saurashtra and Kuchchh.

Variability of district wise drought incidence

Table 2 shows decadal frequencies of district wise droughts (when rainfall deficit is >25%) over Gujarat. Lower frequencies for

Table 2: Decadal frequencies of districtwise droughts over Gujarat.

Name of Subdivision/ 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 1999	Average decadal frequency.
Gujarat Region											
1. Ahmedabad	2	4	3	3	1	4	3	2	4	1	3
2. Amreli	3	3	3	5	3	3	1	3	3	2	3
3. Banaskanta	3	3	4	4	3	4	4	4	4	2	3
4. Baroda	1	3	3	2	1	3	2	2	4	3	2
5. Broach	3	4	2	1	1	1	1	2	4	1	2
6. Bulsar	3	4	3	1	1	2	0	2	1	0	2
7. Dangs	4	4	2	0	0	3	2	2	1	0	2
8. Kaira	2	4	1	3	2	3	2	2	3	4	3
9. Mehsana	0	0	1	4	3	3	4	2	4	1	2
10. Panchmahals	2	4	2	2	1	2	3	3	4	3	3
11. Sabarkantha	2	3	2	4	1	3	4	2	4	3	3
12. Surat	3	4	1	1	1	3	1	2	3	2	2
Saurashtra& Kuchchh											
13. Bhavnagar	3	4	3	0	1	2	2	3	4	4	3
14. Jamnagar	4	3	5	6	4	3	2	3	4	5	4
15. Junagarh	3	4	5	4	3	3	2	2	4	3	3
16. Kuchchh	3	3	4	4	2	4	5	3	5	6	4
17. Rajkot	2	3	2	3	3	2	4	3	5	4	3
18. Surendranagar	2	4	4	4	2	3	3	2	4	2	3

most of the districts in Gujarat Region are noticed in the decade 1941-1950. The decades 1911-1920 and 1981-1990 show increased frequencies of drought (3 to 4) for most of the districts in Gujarat region. The districts Bulsar and Dangs in southern Gujarat region have good rainfall and no drought or only 1-2 occasions of drought in most of the decades.

In Saurashtra and Kuchchh on most of the occasions the decadal frequencies of

Table 3 : Decadal variability of large scale droughts over Gujarat state.

1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991 1999
1901*	1911*	1923*	1931	1942	1951*	1962*	1972*	1982*	1991*
1904*	1915*	1924	1936*	1948*	1952	1963	1973	1985*	1993
1905*	1918*	1925*	1938		1955	1965	1974*	1986*	1995*
	1920	1927	1939*		1957*	1966*		1987*	1997
		1929	1940*		1960*	1968*		1990	1999*
						1969			
Worst Droughts									
3	3	2	3	1	3	3	2	4	3

drought are 3 to 5. On a few occasions they have increased up to 6. Jamnagar and Junagadh districts during 1921 to 1940 and Kuchchh and Rajkot districts during 1981 to 1990 recorded higher drought frequencies.

Large scale drought years over Gujarat

There are 43 large scale droughts identified over Gujarat during 1901-1999 and out of them 27 drought years are worst droughts (marked with star) when the area affected by drought exceeded 50% of the area of the state (Table 3)

Table 3 shows that the least number of the worst droughts are in decade 1941-1950. The highest of four worst droughts are in decade 1981-1990 and 2-3 years of worst droughts on an average are noticed in each decade.

The 18 large scale drought years over Gujarat are common with all India drought years (underlined). As such, the probability of large scale drought over Gujarat could be assigned to be 82% whenever there is drought over the country. Moreover, 90% of these droughts are severe in nature.

Large scale droughts over Gujarat and Pacific temperature anomalies

The correlation coefficients between Pacific temperature anomalies in different months and seasons and area affected by drought over Gujarat (Table 4) during 1950-1999 are significant at 95% level of confidence in the monsoon (June-September) and post monsoon (October to December) seasons in Nino 3 and Nino4 regions of the Pacific.

The correlations are significant at 95% level of confidence in Nino1+2 region in post monsoon season, and at 99% level in Nino3 region for months July and August.

Table 4 : Correlation of Pacific temperature anomalies vs drought area over Gujarat (1950-1999).

Month/Season	Nino 1 +2	Nino 3	Nino 4
January	0.07	0.11	-0.16
February	-0.03	-0.10	-0.08
March	-0.00	-0.00	-0.05
April	-0.11	0.13	0.06
May	0.08	0.17	0.15
June	0.16	0.19	0.29
July	0.20	0.41 **	0.21
August	0.27	0.42 **	0.36 *
September	0.28	0.30 *	0.36 *
October	0.32 *	0.32 *	0.32 *
November	0.31 *	0.35 *	0.32 *
December	0.24	0.34 *	0.31 *
Winter	0.03	-0.07	-0.13
Pre-Monsoon	-0.01	0.12	0.05
Monsoon	0.23	0.35 *	0.33 *
Post-Monsoon	0.30 *	0.34 *	0.33 *

*Significant at 95% confidence level
** Significant at >95% confidence level

The years identified when mean SST anomalies over Pacific Nino3 region >1°C for last 8 months of the year are 1951,1957, 1965, 1969, 1972, 1982, 1987, 1991 and 1997. All these years were found to be large scale drought years over Gujarat.

The El Nino years identified by Mooley(1997) since 1900 are 1902, 1905*, 1911*, 1914, 1918*, 1923*, 1925*, 1930, 1932, 1939*, 1941, 1951*, 1953, 1957*, 1965*, 1969*, 1972*, 1976, 1982*, 1987*, 1991*. The recent El Nino year was 1997*. The 15 large scale drought years marked with star are common with El Nino years, showing probability of large scale drought over Gujarat in El Nino year as 68%. Most of these droughts are devastating.

Trend for the area affected by drought

Mann Kendall Rank statistics test has

Table 5 :Probability of occurrence of moderate and severe drought for Gujarat during 1901-1999.

Sr. No	District	Probability (%) of occurrence of drought	
		Moderate	Severe
1.	Ahmedabad	17	10
2.	Amreli	22	8
3.	Banaskantha	20	15
4.	Baroda	17	7
5.	Broach	13	8
6.	Bulsar	14	3
7.	Dangs	17	2
8.	Kaira	14	11
9.	Mehsana	22	8
10.	Panchmahals	21	6
11.	Sabarkantha	17	11
12.	Surat	16	5
13.	Bhavnagar	16	11
14.	Jamnagar	20	19
15.	Junagarh	17	17
16.	Kuchchh	15	25
17.	Rajkot	22	9
18.	Surendranagar	17	13

been applied to the area affected by drought over Gujarat state for studying the trend over the period 1901-1999. The 11 years running means of area affected by drought in Gujarat state for the period 1901-1999 indicate a significant increasing trend at 95% level of confidence (Fig.1). The trends for the area affected by drought examined separately (Fig 2 and 3) for the sub-divisions showed significant increasing trend at 95% level of confidence for Gujarat region and Saurashtra and Kuchchh.

Probabilities of moderate and severe droughts

The probability of occurrence of moderate drought in the districts of sub-divisions Gujarat Region and Saurashtra and Kuchchh (Table 5) vary from 13 to 22% and 15 to 22% respectively, those for severe drought vary from 2 to 15% and 9 to 25% respectively.

Agricultural drought during southwest monsoon season

The Table 6 gives the number of weeks in which less than 50% or more than 50% of the area of the sub-divisions of Gujarat experienced moderate to severe agricultural drought conditions during the years 1980 to 1990. It shows that on an average about 10-13 weeks in SW monsoon season Gujarat had experienced moderate to severe agricultural drought conditions considering both the cases when less than and more than 50% of the area of the sub-divisions of Gujarat was affected by drought conditions.

The years 1986 and 1987 especially showed the highest number of 10 and 11 weeks under agricultural drought conditions for Gujarat region and 12 and 14 weeks for Saurashtra and Kuchchh respectively when more than 50% of the area of both sub-divisions was affected by either moderate or severe agricultural drought conditions.

CONCLUSIONS

There are 43 large scale meteorological droughts identified over Gujarat during 1901-1999 and out of them 27 years are worst drought years when more than 50% of the area of the state was affected by drought.

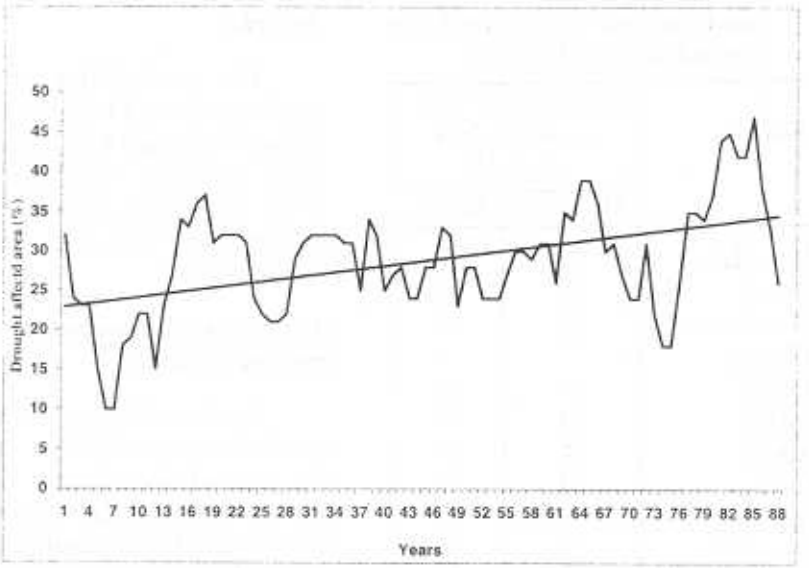

Fig. 1 : 11 years moving average of drought affected area (%) over Gujarat state.

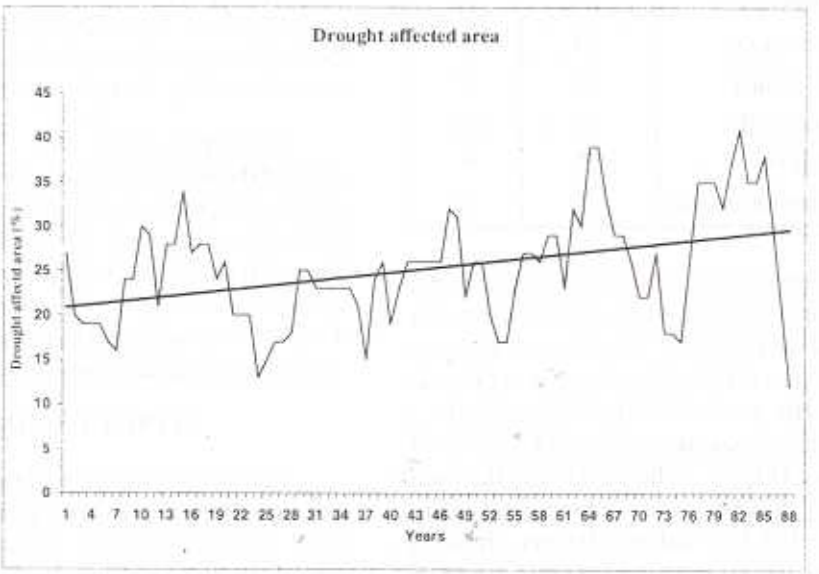

Fig. 2 : 11 years moving average of drought affected area (%) over Gujarat region.

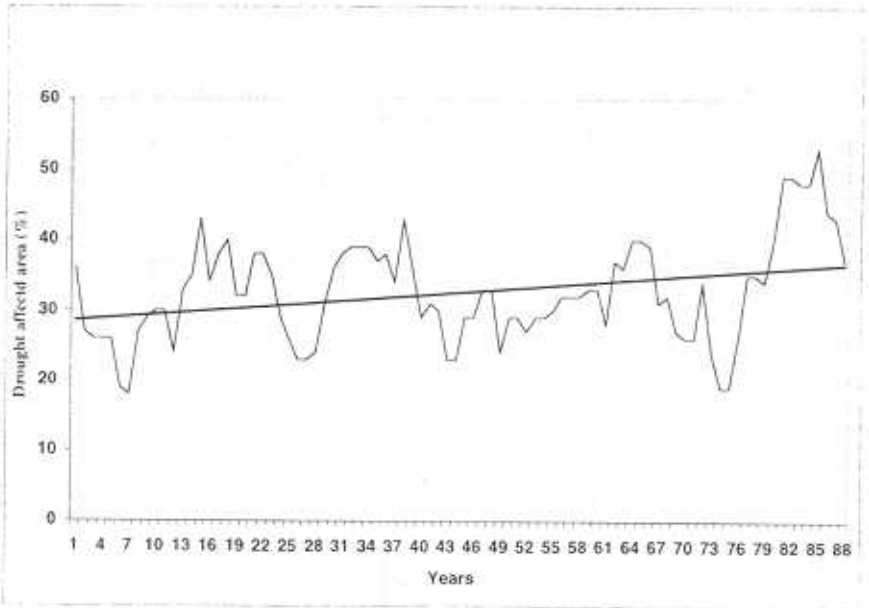

Fig. 3 : 11 years moving average of drought affected area (%) over Saurashtra and Kuchchh.

In 82% of the nationwide drought years, Gujarat State simultaneously experienced large scale droughts.

There is a significant correlation between Pacific temperature anomalies and area affected by drought over Gujarat.

A significant increasing trend of the area affected by drought over subdivisions of Gujarat and the state as a whole was observed during 1901-1999.

The severe drought probabilities in Gujarat region and Saurashtra and Kuchchh vary from 2 to 15% and 9 to 25% respectively.

Banaskantha district of Gujarat region and Kuchchh district of Saurashtra and Kutch witness highest probability of severe drought occurrence.

Agricultural drought conditions prevail over Gujarat in 10-13 weeks during southwest monsoon season.

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Table 6 : Period of moderate or severe agricultural drought conditions during southwest monsoon season.

Year	Gujarat region		Saurashtra and Kuchchh	
	< 50% of the subdivision affected weeks	>50% of the subdivision affected weeks	< 50% of the subdivision affected weeks	>50% of the subdivision affected weeks
1980	4	2	4	5
1982	4	2	8	9
1983	6	2	7	4
1984	6	1	9	2
1985	5	5	8	7
1986	5	10	4	12
1987	5	11	3	14
1988	4	1	7	4
1989	9	5	9	5
1990	5	6	5	7

* 1981 data not available

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