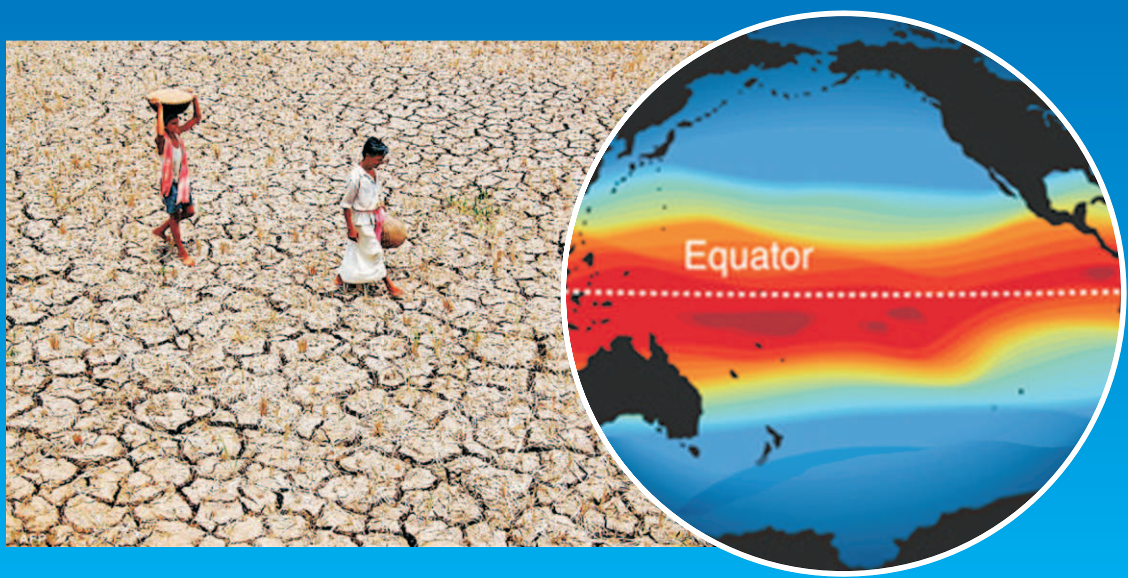
Technical Bulletin: 01/2014-15

El Niño episodes and agricultural productivity in Gujarat



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FORWARD

The inter-annual variability of Indian monsoon rainfall has profound influence on agriculture and national economy. Occurrences of droughts and floods associated with the inter-annual variability of Indian monsoon affects the agriculture, water resources and financial sectors. This inter-annual variability of Indian monsoon is also largely affected under the influence of occurrences of El Nino episodes. This phenomenon affects wind patterns and trigger floods and droughts in different parts of the world. El Nino is an unusual warming of ocean surface along coast of Ecuador over northern Peru. It is well established that El Nino affect monsoon circulation and thereby rainfall over India.

A strong El Nino can cause drought -like conditions. About 60 per cent of net sown area of the country is rain-fed. With every one per cent deficit in rains, the country's gross domestic produce falls by 0.35 per cent. Under the El Nino monsoon situation operational contingent crop planning on a regional basis should be adopted to minimize crop losses to certain extent. This may include seed availability, alternate crops, crop insurance, rain water harvesting and suggesting various efficient management practices.

Gujarat receives rainfall mainly through SW monsoon which is likely to be affected by El Nino event, and thereby effect on crop production. The relationship between El Nino and its effects on Gujarat rainfall and agricultural production, however, was not been established. Hence, such work have been undertaken by the Dept. of Agril. meteorology , AAU, Anand.

The efforts of the team of National Initiative on Climate Resilient Agriculture (NICRA)AICRP on Agrometeorology and Centre for Weather Forecasting and Climate Change AAU, Anand to brought out this Bulletin on "El Nino episodes, rainfall pattern and crop production inter linkages in recent past of Gujarat state" is really not worthy. I congratulate them and wish that this publication will be useful to state scientists/farmers/planners of the Gujarat state.

I appreciate the efforts put in by NICRA AICRP and Centre for Weather Forecasting and Climate Change team in compilation of data and bringing out this valuable bulletin.

Date: 06/06/2014
Place: Anand

(K.B. Kathiria)
Vice-Chancellor
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CONTENTS

1. INTRODUCTION

Agriculture continues to be the primary occupation in the Gujarat state where two thirds of the population is engaged in agriculture and earn their livelihood from this occupation. More than 52% of total workforce of the state is engaged in agriculture directly. Moreover, agriculture provides indirect employment to large portion of population in agro-based sectors. Thus, prosperity and well being of people in Gujarat are closely linked with agriculture and allied activities. The state has distinguished agriculture seasons that can be broadly divided into *kharif*, *rabi* and *summer* seasons. Out of 125.82 lakh hectares of gross cropped area, 70 % area is cultivated during *kharif*,25 % area during *rabi* and 25% area during *summer* seasons. Most of the *kharif* crops depend on rainfall, but good crop harvests are associated with one or two life saving irrigations due to the erratic nature of rain. *Rabi* and *summer* crops are mostly grown under limited irrigation except in "Bhal" and other low laying areas.

1.1 El Niño, La Nina and ENSO

The term El Niño (Spanish for "the Christ Child") was originally used by fishermen along the coasts of Ecuador and Peru to refer to a warm ocean current that typically appears around Christmas time and lasts for several months. Fish are less abundant during these warm intervals, so fishermen often take a break to repair their equipment and spend time with their families. In some years, however, the water is especially warm and the break in the fishing season persists into May or even June. Over the years, the term "El Niño" has come to be reserved for these exceptionally strong warm intervals that not only disrupt the normal lives of the fishermen, but also bring heavy rains.

El Niño normally occurs around Christmas and usually lasts for a few weeks to a few months. Sometimes an extremely warm event can develop that lasts for much longer time periods. In the 1990s, strong El Niños developed in 1991 and lasted until 1995, and from fall 1997 to spring 1998.

The formation of an El Niño is linked with the cycling of a Pacific Ocean circulation pattern known as the southern oscillation. In a normal year, a surface low pressure develops in the region of northern Australia and Indonesia and a high pressure system over the coast of Peru (Fig 1). As a result, the trade winds over the Pacific Ocean move strongly from east to west. The easterly flow of the trade winds carries warm surface waters westward, bringing convective storms to Indonesia and coastal Australia. Along the coast of Peru, cold bottom water wells up to the surface to replace the warm water that is pulled to the west.When the warming or cooling occurs for only seven to nine months, it is classified as El Niño/La Nina "conditions"; when it occurs for more than that period, it is classified as El Niño/La Nina "episodes". The El Niño events known as per the recorded history are presented in Table 1.

Table 1: History of El Niño events

Previous El Niño Years			
1902–1903	1905–1906	1911–1912	1914–1915
1918–1919	1923–1924	1925–1926	1930–1931
1932–1933	1939–1940	1941–1942	1951–1952
1953–1954	1957–1958	1965–1966	1969–1970
1972–1973	1976–1977	1982–1983	1986–1987
1991–1992	1994–1995	1997–1998	2002–2003
2006–2007	2009–2010		

*Years in red colour were major events; **The 1997–1998 event was the strongest ever recorded

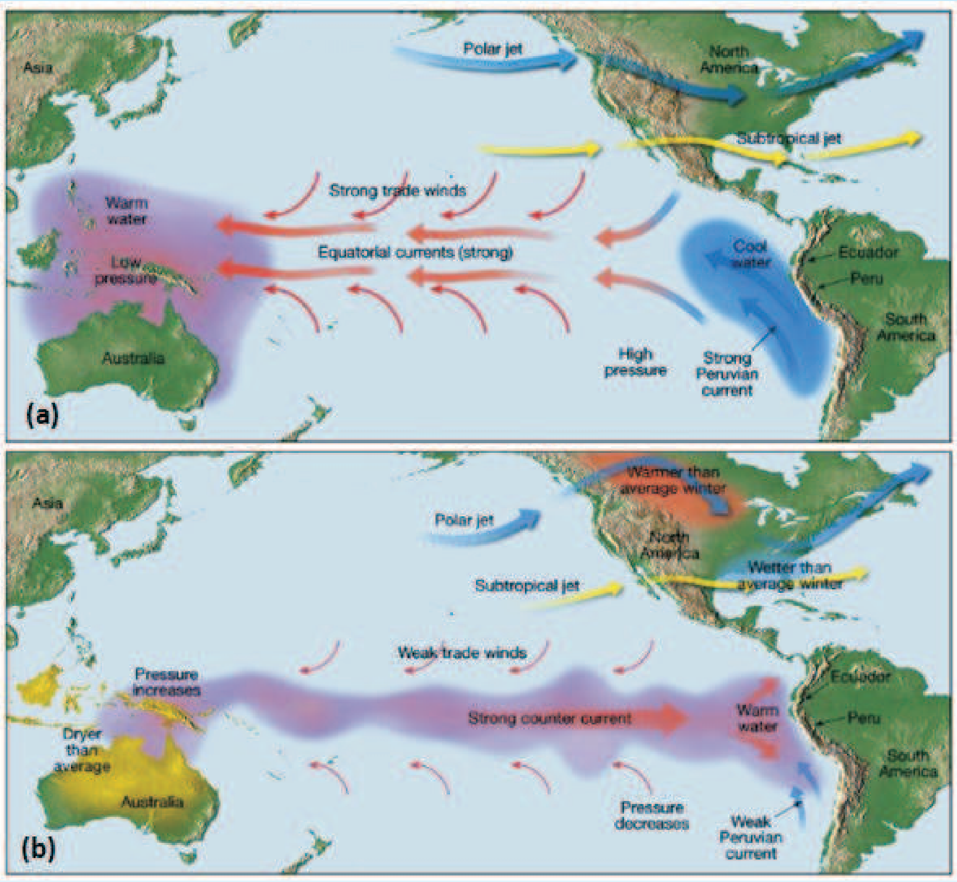

Fig 1: Wind circulation pattern over Pacific ocean during a) normal years andb) El Niño years

1.2 El Niño episodes and south west monsoon rainfall

India receives about 1180 mm of rainfall annually. The rainfall over India has a large spatial as well as temporal variability. Normal monsoon rainfall of more than 150 cm is observed over most parts of north east India, Konkan & Goa. Normal monsoon rainfall is more than 4000 mm over major parts of Meghalaya. For the country as whole, mean monthly rainfall during July (286 mm) is highest and contributes about 24.2% of annual rainfall. The mean rainfall during August is slightly lower and contributes about 21.2% of annual rainfall. June and September rainfall are almost similar and contribute 13.8% and 14.2% of annual rainfall, respectively. The mean south-west monsoon (June, July, August & September) rainfall (877 mm) contributes74.2% of annual rainfall. Contribution of premonsoon (March, April & May) rainfall and post-monsoon (October, November & December) rainfall in annual rainfall is mostly the same (11%). Coefficient of variation is higher during the months of November, December, January and February.

Gujarat receives about 919 mm rainfall annually, of which 95% (874 mm) comes through southwest monsoon season. Among the different agroclimatic regions of the state, there is a large variation in rainfall amounts. For instance, north-west zone receives 250 to 500 mm rainfall, while south Gujarat receives greater than 1500 mm. Parts of Valsad district receives rainfall in the range of 1400-1800 mm whereas, entire Kutch district and Dwarika of Jamnagar district and Dhari of Amreli district receives in the range of 200-400 mm.

The departure of rainfall during southwest monsoon season in different meteorological sub-divisions during non El Niño and different categories of El Niño years are depicted in Fig 2. It could be noticed that during weak El Niño years, the rainfall over Gujarat region was found to be more than normal. In moderate El Niño years, the rainfall was deficit over Gujarat and scanty over the adjoining parts of Rajasthan. In strong El Niño years, western parts of Gujarat received rainfall in excess whereas, the rest of Gujarat experienced deficit rainfall conditions. Thus it can be inferred that there is no one to one relation between the severity of the El Niño episode and rainfall distribution over Gujarat.

1.3 El Niño episodes and Indian food grain production

In a recent study,El Niño episodes were found to improve the global mean soybean yield by 2.1 to 5.4 per cent but, appears to change the yields of maize, rice, and wheat by -4.3 to +0.8% (Lizumi, 2014).In an earlier study, Selvaraju (2003) observed that during the warm El Niño southern oscillation (ENSO) phase, the total Indian food grain production frequently decreased (12 out of 13 years) by 1 to 15 per cent during 1950-1999 period. The relationship between the SST-based NINO3 ENSO index and kharif season (June–September) food grain production anomalies was greater than for rabi season (October–February) food grain production. The ENSO impact on rice production was greatest among the individual crops. The average drop in rice (kharif season crop) production during a warm ENSO-phase year was 3.4 million tonnes (7%). In a cold ENSO-phase year the average production increase was 1.3 million tonnes (3%). Wheat (*rabi* season crop) production was also influenced by ENSO, as it depends on the carry over soil water storage from *kharif* season. Sorghum and chickpea production were found to be not significantly influenced by ENSO extremes.

The above review suggests that, during El Niño years there is a large spatial variability in the rainfall distribution in the country as well as productivity of different crops. In the light of India Meteorological Department's forecast of a 60 % probable El Niño episode during the current year (2014) along with a below normal monsoon projection, we felt that it is opt to analyse rainfall pattern and agricultural productivity in Gujarat state in relation to the El Niño episodes.

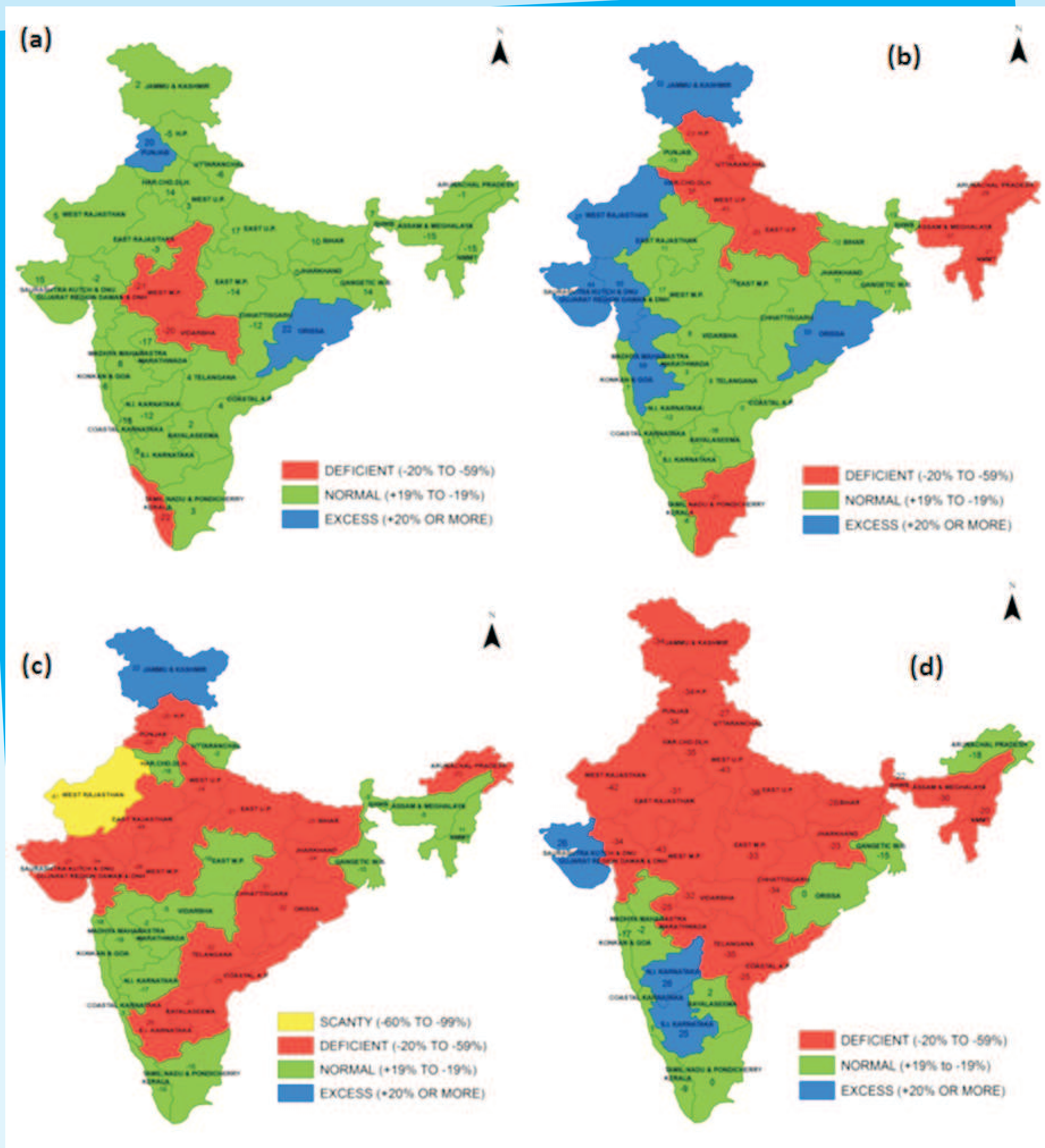

Fig 2: Departure of sub-divisional southwest monsoon season rainfall during a) non-El Niño year; b) weak El Niño year (2006); c) moderate El Niño year (2002) and d) strong El Niño year (2009)

2. METHODOLOGY

2.1 Rainfall data

Daily rainfall data recorded at 26 agromet observatories of SAUs, geographically distributed over the Gujarat state for the period 1978-2011 were used in the present analysis. The geographical location of these observatories is depicted in Fig 3. The length of weather data time series was in range of 10 to 33 years for different stations. The daily rainfall data were converted into first monthly and then into different seasons *viz.,* summer (March to May), southwest (June to September), *rabi* (October to December) and winter (January to February).

We have classified the El Niño years into weak (0.5 to 0.9), moderate(1.0 to 1.4) and strong (above 1.5), based on the threshold values that persisted for at least 3 months and placed the rainfall data in the group accordingly (Table 2). The years of the rainfall record thus categorized as normal years (non El Niño years), weak El Niño years, moderate El Niño years and strong El Niño years. During year 1978 to 2011, there were 2 weak El Niño years, 4 moderate El Niño years and 4 strong El Niño years. The mean rainfall for different El Niño years for each district was deduced by averaging the corresponding rainfall data.

Table 2: Classification of El Niño years based on the SST anomaly

Intensity	**Years**
Weak	1951,1963,1968,1969,1976,1977,2004,2006
Moderate	1986,1987,1994,2002
Strong	1957,1965,1972,1982,1991,1997,2009

2.2 Crop yield data

The time series data on the area, production and productivity of different crops at district scale of Gujarat state are sourced from Director of Agriculture, Ahmedabad. The particulars of data used are presented in Table 3.

Table 3: Time series of crop data used in the present analysis

Crop	**Period**
Paddy, sugarcane, maize, cotton, bajra and groundnut	1960-61 to 2010-11
Wheat	1960-61 to 2009-10
Castor and bajra	1960-61 to 2005-06
Mustard	1960-61 to 2004-05

Time series yield data may feature strong trends that mask seasonal fluctuations likely to be associated with year on year variations in climate. Researchers have isolated these seasonal fluctuations by fitting and removing trends with polynomial and other parametric functions. For example, Parthasarathy*et al.* (1992) employed an exponential function to filter the All India Foodgrain Production Statistics. Bapuji Rao *et al.*(2014) used a fourth degree polynomial to remove the technology trend in country level paddy yields. We also used a fourth to sixth degree polynomial in the present investigation to remove the technology trend in various crops.

Fig 3: Geographical location of meteorological stations selected for rainfall data

3 . RESULTS

3.1 Rainfall distribution

The changes in rainfall pattern at different locations and time scales under the influence of the intensity of El Niño are presented in Tables 4 to 7. During El Niño years, both the annual and seasonal rainfall received at the state level in the past was more than the rainfall received during non-El Niño years (Table 4). However, a large spatial variability is noticed in both the rainfall amounts (Fig. 4). During monsoon season rainfall over Godhra and Bhuj during El Niño years was about 25% deficit compared to non-El Niño years. In other districts the deficit ranged from -2 to -14, with Rajkot recorded highest deficit. Compared to monsoon season rainfall, the spatial variability in annual rainfall was found to be high and widespread. The magnitude of deficit was about 30% at Bhuj followed by Godhra (25%). The number of stations that showed deficit rainfall was more for annual figures (14) compared to seasonal rainfall (10). This implies that, rainfall during El Niño years may exhibit large spatial variability compared to the non-El Niño years.

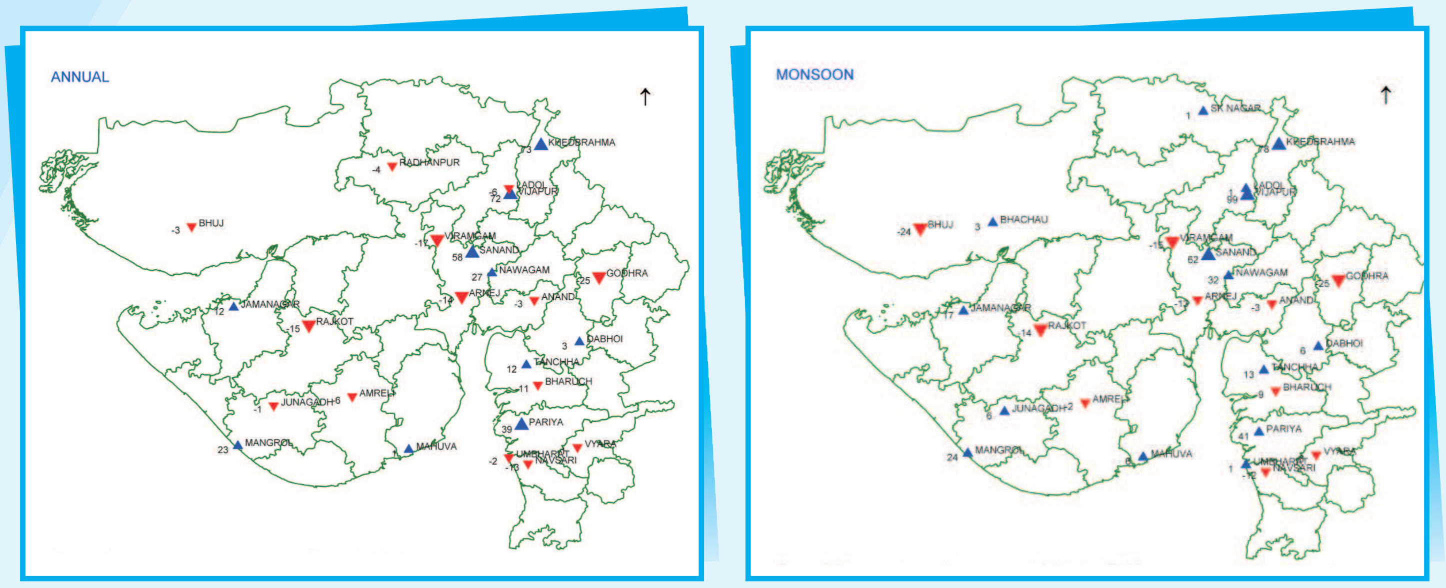

Fig 4: Spatial variability in a) annual and b) monsoon season rainfall anomalies

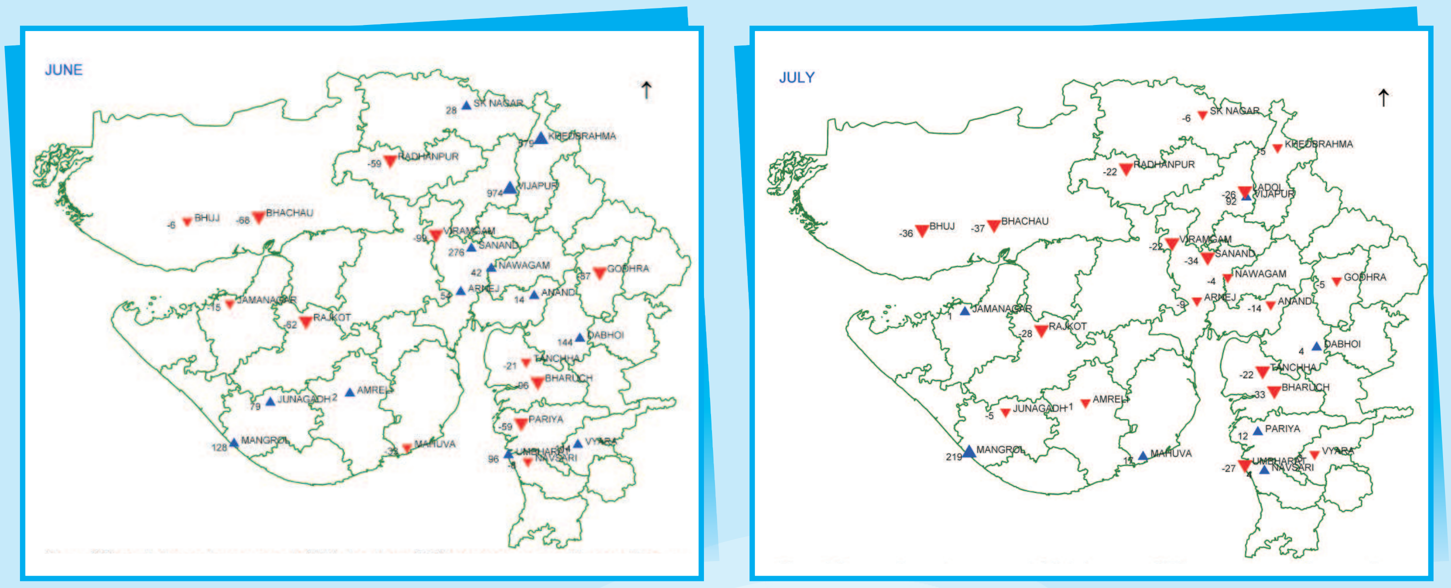

Fig 5: Spatial variability in a) June and b) July rainfall anomalies during strong El Niño years

Table 4: A comparison of seasonal and annual rainfall (mm) at different locations of Gujarat during El Niño years to non–El Niño years

Name of the Station	Monsoon season (June-September)			Annual (January-December)		
	El Niño years	Non–El Niño years	% change	El Niño years	Non–El Niño years	% change
Amreli	608.3	622.9	–2	638	677.2	–6
Arnej	610.8	705.4	–13	633.5	735.9	–14
Anand	810.2	838.1	–3	851.7	882.5	–3
Bhachau	484	471.8	3	496.6	497.7	0
Bharuch	729	797.2	–9	741.2	832.6	–11
Dabhoi	704.5	666.9	6	713.8	689.7	3
Godhra	696.2	933.6	–25	730	968.5	–25
Jamnagar	723.5	619.5	17	725.3	646.2	12
Khedbrahma	1066.4	598.9	78	1075.2	620.3	73
Ladol	574.4	568.1	1	578.1	613.5	–6
Mahuva	506.2	478.6	6	516.8	511.7	1
Mangrol	950.2	768.7	24	969	786.2	23
Navsari	1272.2	1441.9	–12	1304.2	1498.7	–13
Nawagam	890	675.1	32	908.2	717.7	27
Pariya	2205.5	1562.4	41	2232.3	1611.1	39
Radhanpur	481.5	479.8	0	486.5	507.3	–4
Junagadh	809.6	762.3	6	823.6	829.2	–1
Sanand	862	533.2	62	883	557.9	58
SKnagar	574.1	568.8	1	610	609.9	0
Tanchha	851.7	753.3	13	879.1	783.3	12

Umbhrat	1152.9	1144.5	1	1161.2	1180.5	−2
Vijapur	1036.7	521.5	99	1048.3	610.5	72
Viramgam	546.5	640.7	−15	553.1	663.8	−17
Vyara	1116.7	1212.1	−8	1128.9	1256.3	−10
Bhuj	253.2	334	−24	270.4	386.9	−30
Rajkot	454.1	530.4	−14	480.4	563.5	−15

The success of agriculture under Indian conditions largely depends not only on the quantum of seasonal rainfall, but on its temporal distribution. Thus, there is a need to assess the impact of El Niño episodes on rainfall at monthly time scales. When the El Niño episodes are segregated into weak, moderate and severe, their respective influence on the rainfall pattern at different locations could be studied in depth. During the weak El Niño years, southwest monsoon rainfall for the entire state was about 25% more than that of normal years (Table 5). During the months of June, July and August, the departures were positive, but in the month of September, these were turned negative at most of the locations.Even during the month of June, the rainfall at four locations (Dabhoi, Godhra, Jamnagar, Nawagam) was deficit by more than 50% (Fig 5). During July, the number of stations showing greater than 50% deficit came down to three (i.e.Vyara, Viramgam and Godhra). These were further reduced to two (Vyara and Mahuva) in case of August rainfall. A peculiar rainfall pattern was noticed at Vyara. At this location, the rainfall decreased drastically beyond June month in the weak El Niño years.

Table 5: A comparison of monthly rainfall (mm) at different locations of Gujarat during weak El Niño years against non−El Niño years

Name of the station	June			July			August			September		
	Weak El Niño year	Non-El Niño year	Anomaly (%)	Weak El Niño year	Non-El Niño year	Anomaly (%)	Weak El Niño year	Non-El Niño year	Anomaly (%)	Weak El Niño year	Non-El Niño year	Anomaly (%)
Amreli	199.6	107.2	86	357.7	193	85	111.9	162.2	31−	82.7	160.5	−48
Arnej	62.9	106.4	−41	329.7	233.9	41	299.2	222.3	35	86.1	142.8	−40
Anand	185.8	114.3	63	370.6	302.2	23	366.1	253.9	44	87.7	167.6	−48
Bhachau	–	170.1	–	–	199.6	–	–	32.2	–	–	70	–
Bharuch	130.6	148.5	−12	776.2	306.4	153	270.6	153.3	77	100.4	188.9	−47
Dabhoi	24	55.1	−56	433.9	242.8	79	316.2	194.8	62	83.1	174.2	−52
Godhra	39.1	78.5	−50	154.5	354.9	−56	487	320	52	68.1	180.3	−62
Jamnagar	13.5	90.5	−85	392.8	281.3	40	283	152.4	86	92.5	95.3	−3
Khedbrahma	158.2	63.5	149	292.8	309	−5	841.8	114	638	293.8	112.4	161
Ladol	71	60	18	330	306.3	8	537	161	234	87	40.8	113
Mahuva	305	102.2	198	304	162	88	44	110.2	−60	20	104.2	−81
Mangrol	216	163.5	32	424	290.3	46	111	219.6	−49	86	95.2	−10
Navsari	408	246.9	65	1012	553.5	83	314.4	405.6	−22	151.8	235.9	−36
Nawagam	58.6	125.9	−53	429.3	240.7	78	549.9	176.2	212	57	132.3	−57
Pariya	–	425.4	–	–	615.8	–	–	297.3	–	–	223.9	–
Radhanpur	66.4	51.7	28	121.4	226.8	−46	416.5	151.9	174	0	49.3	−100
Junagadh	132.4	129.4	2	569	294.9	93	299.2	189.4	58	238.2	148.5	60

Sanand	–	54.2	–	–	244.7	–	–	176.3	–	–	58.1	–
SKnagar	90	42.7	111	131.2	228.7	-43	485.2	187.4	159	57.2	110.1	-48
Tanchha	190.2	151.2	26	495	301.7	64	373.2	152.2	145	124	148.2	-16
Umbhrat	328.7	271.8	21	633.1	446.9	42	130.3	238.4	-45	115.9	187.3	-38
Vijapur	–	53.7	–	–	233.3	–	–	108.4	–	–	126.1	–
Viramgam	72.7	96.3	-25	134.5	287.5	-53	283.8	147.6	92	145.3	109.4	33
Vyara	177.8	168.7	5	40	517	-92	35.9	317	-89	75.2	209.4	-64
Bhuj	49	49.1	0	97	115.2	-16	153.9	112.3	37	45.8	57.4	-20
Rajkot	107.4	99.1	8	328.6	203	62	241.8	120.3	101	119.9	108	11

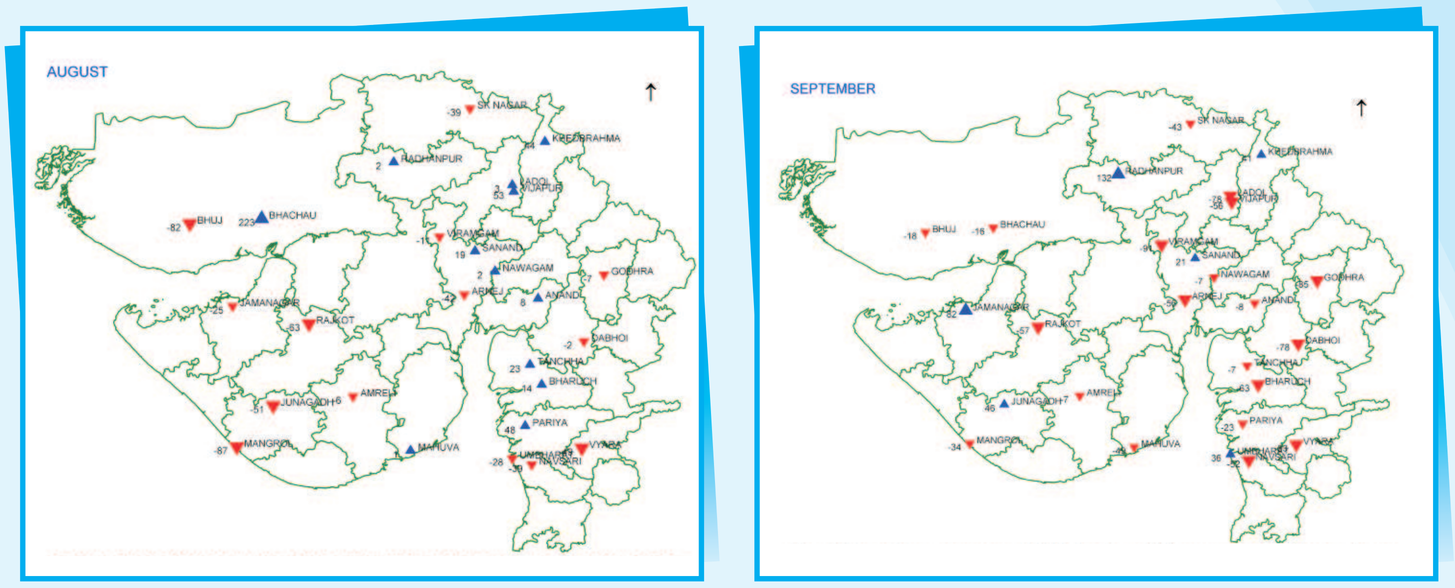

Fig 6: Spatial variability in a) August and b) September rainfall anomalies during strong El Niño years

Table 6: A comparison of monthly rainfall (mm) at different locations of Gujarat during moderate El Niño years against non–El Niño years

Name of the station	June			July			August			September		
	Moderate El Nino year	Non-El Niño year	Anomaly (%)	Moderate El Nino year	Non-El Niño year	Anomaly (%)	Moderate El Nino year	Non-El Niño year	Anomaly (%)	Moderate El Nino year	Non-El Niño year	Anomaly (%)
Amreli	291.9	107.2	172	171.6	193	-11	139.6	162.2	-14	56.7	160.5	-65
Arnej	66.6	106.4	-37	131.2	233.9	-44	138.6	222.3	-38	169.8	142.8	19
Anand	106.9	114.3	-6	166.3	302.2	-45	220.9	253.9	-13	105.3	167.6	-37
Bhachau	26.6	170.1	-84	330.5	199.6	66	171.8	32.2	434	240	70	243
Bharuch	251.5	148.5	69	195.7	306.4	-36	239.5	153.3	56	175.4	188.9	-7
Dabhoi	189.7	55.1	244	141.8	242.8	-42	186.9	194.8	-4	164.1	174.2	-6
Godhra	240	78.5	206	82.5	354.9	-77	207	320	-35	139.5	180.3	-23
Jamnagar	74.6	90.5	-18	390.9	281.3	39	181.6	152.4	19	122.8	95.3	29
Khedbrahma	169.9	63.5	168	167.1	309	-46	331.5	114	191	216	112.4	92
Ladol	129	60	115	5	306.3	-98	107.7	161	-33	11.5	40.8	-72
Mahuva	129.8	102.2	27	164.2	162	1	199	110.2	81	40.4	104.2	-61
Mangrol	147.1	163.5	-10	150.5	290.3	-48	96.5	219.6	-56	173	95.2	82
Navsari	272.9	246.9	11	531.4	553.5	-4	286.7	405.6	-29	96.6	235.9	-59
Nawagam	126.8	125.9	1	436	240.7	81	222.6	176.2	26	374.2	132.3	183
Pariya	722.3	425.4	70	651.4	615.8	6	720.3	297.3	142	132.4	223.9	-41
Radhanpur	92.3	51.7	79	80.5	226.8	-65	120.3	151.9	-21	80.3	49.3	63
Junagadh	149.4	129.4	15	321.1	294.9	9	109.4	189.4	-42	82.4	148.5	-45
Sanand	25.8	54.2	-52	426.4	244.7	74	336.4	176.3	91	413.2	58.1	611
SKnagar	66.2	42.7	55	125.6	228.7	-45	227.6	187.4	21	98.1	110.1	-11
Tanchha	312.5	151.2	107	151.9	301.7	-50	257	152.2	69	138.8	148.2	-6
Umbhrat	469.7	271.8	73	77.2	446.9	-83	359.6	238.4	51	60.6	187.3	-68
Vijapur	86.8	53.7	62	180.8	233.3	-23	277.3	108.4	156	281.8	126.1	123
Viramgam	–	96.3	–	–	287.5	–	–	147.6	–	–	109.4	–
Vyara	809.2	168.7	380	702.2	517	36	443.4	317	40	103.3	209.4	-51
Bhuj	27	49.1	-45	117.5	115.2	2	29.2	112.3	-74	56.5	57.4	-2
Rajkot	207.5	99.1	109	4.8	203	-98	91	120.3	-24	6.1	108	-94

Table 7: A comparison of monthly rainfall (mm) at different locations of Gujarat during strong El Niño years against non–El Niño years

Name of the station	June			July			August			September		
	Strong El Niño Year	Non-El Niño year	Anomaly (%)	Strong El Niño Year	Non-El Niño year	Anomaly (%)	Strong El Niño Year	Non-El Niño year	Anomaly (%)	Strong El Niño Year	Non-El Niño year	Anomaly (%)
Amreli	109.7	107.2	2	191.2	193	-1	65	162.2	-60	47.4	160.5	-70
Arnej	164.3	106.4	54	213.1	233.9	-9	128.7	222.3	-42	63.2	142.8	-56
Anand	129.9	114.3	14	259.5	302.2	-14	275.3	253.9	8	34.3	167.6	-80
Bhachau	53.8	170.1	-68	125.3	199.6	-37	104	32.2	223	58.5	70	-16
Bharuch	5.9	148.5	-96	206.5	306.4	-33	174.1	153.3	14	70.7	188.9	-63
Dabhoi	134.5	55.1	144	252.9	242.8	4	191.3	194.8	-2	38.8	174.2	-78
Godhra	10	78.5	-87	336.6	354.9	-5	296.5	320	-7	27.2	180.3	-85

Jamnagar	76.8	90.5	-15	283.8	281.3	1	114	152.4	-25	173.5	95.3	82
Khedbrahma	431	63.5	579	155.8	309	-50	164.4	114	44	159	112.4	41
Ladol	-	60	-	227	306.3	-26	209	161	30	9	40.8	-78
Mahuva	68.6	102.2	-33	189.9	162	17	111.8	110.2	1	53.1	104.2	-49
Mangrol	372.5	163.5	128	927	290.3	219	27.5	219.6	-87	63	95.2	-34
Navsari	48.5	246.9	-80	773.9	553.5	40	245.6	405.6	-39	112.5	235.9	-52
Nawagam	178.4	125.9	42	144	240.7	-40	212.2	176.2	20	39.1	132.3	-70
Pariya	176	425.4	-59	1352.6	615.8	120	441	297.3	48	173	223.9	-23
Radhanpur	21	51.7	-59	176.8	226.8	-22	155.2	151.9	2	114.3	49.3	132
Junagadh	231.7	129.4	79	281.5	294.9	-5	92	189.4	-51	217.3	148.5	46
Sanand	203.5	54.2	275	161.3	244.7	-34	209.2	176.3	19	174.8	58.1	201
SKnagar	131.4	42.7	208	214.5	228.7	-6	114.2	187.4	-39	63.1	110.1	-43
Tanchha	119.3	151.2	-21	234.1	301.7	-22	186.6	152.2	23	138.1	148.2	-7
Umbhrat	533	271.8	96	324.7	446.9	-27	171.9	238.4	-28	254.1	187.3	36
Vijapur	576.5	53.7	974	448.9	233.3	92	166.2	108.4	53	55.3	126.1	-56
Viramgam	1.4	96.3	-99	224	287.5	-22	131.8	147.6	-11	9.8	109.4	-91
Vyara	360.4	168.7	114	363.4	517	-30	162.2	317	-49	77.3	209.4	-63
Bhuj	19.4	49.1	-60	73.5	115.2	-36	20.2	112.3	-82	47.3	57.4	-18
Rajkot	37.4	99.1	-62	146	203	-28	44	120.3	-63	46	108	-57

In moderate El Niño years also, the mean seasonal rainfall of all these stations was above than that of non-El Niño years and the magnitude of difference was about 10%. Except for the month of July, the rainfall during all other monsoonal months was above the non-El Niño years. As the case with weak El Niño years, the spatial variability during moderate El Niño years was also found exists (Table 6). Rainfall during the month of July was found deficit at majority of locations with the magnitude of deficit ranging from -4 to -98. At stations like, Ladol, Rajkot, Umbhrat, Godhra and Radhanpur the activity of monsoon was very much subdued during July.

In strong El Niño years, the mean seasonal rainfall of all the stations was slightly (1%) lower than that of non-El Niño years. Though the June and July rainfall during strong El Niño years was more than normal, the rainfall during the 2nd half (August and September) were in deficit (Table 7). The magnitude of deficit was more during September. The number of districts that experienced deficit rainfall and magnitude of deficits were more in the month of September. This implies that during strong El Niño years, there is a chance of early withdrawal of monsoon from parts of Gujarat which may induce terminal moisture stress in *kharif* crops.

In sum, large spatial variability is noticed both in annual and seasonal rainfall during El Niño years in comparison to non-El Niño years. During weak and strong El Niño years, the rainfall towards the end of the monsoon season was deficit at most of the locations. However, in moderate El Niño years, the July rainfall was deficit indicating a break in monsoon activity.

3.2 Crop productivity *vis-a-vis* El Niño episodes in Gujarat

Considering the dependence of Indian food grain production on the performance of southwest monsoon, it is natural to expect the influence of the El Niño episodes on productivity of different crops of Gujarat state. The following discussion focus on this aspect and the presentation is made crop-wise.

3.2.1 Paddy

Paddy occupies about 7 to 8% of the gross cropped area of the state and accounts for around 14 % of the total food grain production. It is grown on an average over 7.25 lakh hectares comprising nearly 55 to 60 % of low land (transplanted) and 40 to 45 % of upland (drilled). The average yield of paddy is 1955 kg/ha. The change in paddy yields during different El Niño intense years in major paddy growing districts when compared to non–El Niño years is presented in Table 8. It could be noticed that the productivity is highly influenced by El Niño episodes in all the major paddy growing districts.The impact was more pronounced in Vadodara district and the reason could be attributed to more area in this district being under upland cultivation.

Table 8: Anomalies (%) in paddy yields during El Niño years compared to non El Niño years in major paddy growing districts

Name of the district	El Niño category			
	Weak	Moderate	Strong	Combined
Ahmedabad	5.9	-5.2	-9.0	-2.0
Vadodara	-64.4	-1.2	-5.3	-59.4
Bharuch	-26.5	40.0	-31.9	-12.7
Kheda	3.6	-15.2	-34.6	-14.3
Surat	-5.0	15.0	-26.9	-7.9
Panchmahals	-4.2	13.6	-26.4	-7.8

3.2.2 Groundnut

Gujarat produces 3.6 million tonnes of groundnut on average which is 25% of the country's production. It is grown over 1.9 million hectares on average with a productivity of 1860 kg/ha.Groundnut productivity as influenced by intensity of El Niño in different districts is presented in Table 9. Except for Bhavnagar district, all other major groundnut growing districts showed negative impact of El Niño episodes on groundnut productivity. In majority of the districts, productivity declined during strong El Niño years. Groundnut productivity in Bhavnagar district was observed to be independent of El Niño episodes, whereas it appears to be more sensitive in districts like Jamnagar and Junagadh.

Table9: Anomalies (%) ingroundnut yields during El Niño years compared to non El Niño years in major groundnut growing districts

Name of the district	El Niño category			
	Weak	Moderate	Strong	Combined
Bhavanagar	-0.6	33.0	5.8	32.4
Jamnagar	-0.2	-44.2	-19.3	-17.3
Junagadh	-22.8	56.8	-41.0	-10.5
Kutch	13.0	-19.2	-10.4	-2.8
Rajkot	6.9	-23.2	-16.3	-8.3
Surendranagar	-0.05	17.6	-16.0	-1.5

3.2.3 Maize

Maize is grown in 0.6 million hectares with an average production of 1730 kg/ha in Gujarat state. Maize cultivation is mostly confined to Vadodara, Panchmahal, Kheda and Sabarkantha districts. Maize occupies 6.4 % area of total foodgrain crops of the state. Maize productivity in different districts during different El Niño years is presented in Table 10. Maize yields in Panchmahal district were found to be more sensitive compared to other districts. Maize productivity during strong El Niño years appears to be more influenced compared to weak and moderate years. The magnitude of decline in maize yields in Vadodara district was relatively marginal.

Table10: Anomalies (%) in maize yields during El Niño years compared to non El Niño years in major maize growing districts

Name of the district	El Niño category			
	Weak	Moderate	Strong	Combined
Vadodara	24.2	-0.7	-7.1	7.3
Kheda	-47.7	12.9	-50.1	-34.3
Panchmahal	-94.3	-14.8	-69.8	-67.0
Sabarkantha	20.1	-29.0	-6.4	-0.8

3.2.4 Cotton

Gujarat contributes nearly 31 % of total cotton production in the country. Cotton is grown over nearly 26 lakh ha area with an average yield of 637 kg/ha. During recent years, cotton is grown under irrigated conditions. Cotton yields in different categories of El Niño years are presented in Table 11.Compared to food crops, the yields of cotton appear to be less sensitive to El Niño events. This could be due to the ability of the crop to tolerate drought conditions. Among the different categories of El Niño, the strong events exerted more negative impact on cotton yields in different districts. Cotton productivity in Ahmedabad, Bharuch and Rajkot were influenced to a greater extent compared to other districts during strong El Niño years.

Table 11: Anomalies (%) in cotton yields during El Niño years compared to non El Niño years in major cotton growing districts

Name of the district	El Niño category			
	Weak	Moderate	Strong	Combined
Ahmedabad	-0.01	2.80	-20.89	-6.71
Vadodara	-0.36	4.31	-21.11	-6.58
Bharuch	-0.04	3.67	-20.73	-6.47
Panchmahal	6.26	-16.17	-15.67	-6.75
Rajkot	0.05	3.30	-20.62	-6.47
Surendranagar	4.22	10.28	-10.77	0.35
Banaskantha	11.91	-17.19	-11.59	-3.23

3.2.5 Sugarcane

Sugarcane is grown in Gujarat over 1.9 lakh ha area with a total production of 13.76 lakh tonnes and yield of 72.4 tonnes/ha.The crop is mostly grown under assured irrigated conditions. Surat, Valsad and Bharuch are the three major sugarcane growing districts in the state.Sugarcane productivity in different categories of El Niño years are presented in Table 12. Among the different categories, strong El Niño appears to be influencing sugarcane productivity. In the district of Bharuch, sugarcane productivity was found to be influenced more by moderate El Niño events.

Table 12: Anomalies (%) in sugarcane yields during El Niño years compared to non El Niño years in major sugarcane growing districts

Name of the district	El Niño category			
	Weak	Moderate	Strong	Combined
Valsad	0.05	-0.31	-20.48	-7.28
Surat	-0.85	5.47	-20.63	-6.34
Bharuch	12.40	-23.49	-3.43	-1.63

3.2.6 Castor

Castor occupies about 3.4 lakh ha of cropped area with a production of 6.6 lakh tonnes and an average yield of 1946 kg/ha. Gujarat produces nearly 71 % of total castor production of the country. The crop is grown mainly in semi-arid districts of the state. Castor productivity in different categories of El Niño years are presented in Table 13.

Castor productivity was largely influenced by moderate El Niño events and found to be independent of other two categories.

Table 13: Anomalies (%) in castor yields during El Niño years compared to non El Niño years in major castor growing districts

Name of the district	El Niño category			
	Weak	**Moderate**	**Strong**	**Combined**
Mehsana	4.70	-53.00	42.23	1.82
Kutch	4.89	-53.59	42.56	1.85
Banaskantha	15.17	-56.28	35.27	2.81

3.2.7 Bajra

Bajra is grown in Gujarat over 8.7 lakh ha with a production of 15 lakh M tonnes and with a productivity of 1720 kg/ha. Gujarat ranks third in area after Rajasthan and Maharashtra accounting for 14.1% of total area under its cultivation in the country.Bajra productivity in different categories of El Niño years are presented in Table 14. Though considered to be a very good drought tolerant crop, its productivity is found to be influenced by strong El Niño events. In Banaskantha district, the productivity was found more sensitive to El Niño events.

Table 14: Anomalies (%) in bajrayields during El Niño years compared to non El Niño years in major bajra growing districts

Name of the district	El Niño category			
	Weak	**Moderate**	**Strong**	**Combined**
Banaskantha	-45.9	-21.8	-65.4	-65.4
Kheda	6.5	27.3	-12.8	4.6
Jamnagar	-25.0	36.9	-47.6	-18.4
Kutch	-26.5	13.5	-44.5	-23.4

3.2.8 Wheat

Wheat occupies about 11.2 lakh ha of cropped area in the state. Gujarat produces on an average 50 lakh M tonnes with an average yield of 2916 kg/ha. It is grown mostly under irrigated conditions. However, the productivity of wheat was found to be influenced by all categories of El Niño events, more so during strong El Niño episodes. Wheat productivity in different categories of El Niño years are presented in Table 15. On an average the yields declined by about 25% in the El Niño years compared to non-El Niño years.

Table 15: Anomalies (%) in wheat yields during El Niño years compared to non El Niño years in major wheat growing districts

Name of the district	El Niño category			
	Weak	Moderate	Strong	Combined
Ahmedabad	-18.8	-9.2	-43.8	-25.3
Banaskantha	-16.1	-12.7	-42.7	-24.7
Vadodara	-17.3	-13.6	-40.9	-24.8
Bharuch	-17.2	-13.1	-41.2	-24.7
Gandhinagar	-17.7	-13.5	-42.1	-25.3
Kheda	-20.9	-9.9	-46.1	-27.2
Mehsana	-17.7	-13.0	-42.0	-25.2
Panchmahal	-17.1	-13.1	-41.8	-24.9
Sabarkantha	-17.3	-13.3	-41.9	-25.1
Bhavnagar	-15.0	-15.0	-39.0	-23.5
Junagadh	-17.6	-13.4	-41.5	-25.0
Rajkot	-17.7	-14.1	-41.3	-25.2

3.2.9 Mustard

Mustard is grown over 0.24 M lakh ha area in Gujarat with a production of 0.40 M tonnes and a yield of 1390 kg/ha. Mustard productivity in different categories of El Niño years are presented in Table 16. The productivity of mustard was largely influenced by moderate El Niño events in both the districts.

Table 16: Anomalies (%) in mustard yields during El Niño years compared to non-El Niño years in major mustard growing districts

Name of the district	El Niño category			
	Weak	Moderate	Strong	Combined
Banaskantha	3.80	-82.93	22.12	-13.21
Mehsana	-6.82	-85.97	26.59	-22.23

4. SUMMARY

Agriculture is a major enterprise in Gujarat providing employment to more than 52% of the work force. Productivity of *kharif* crops in the state mainly depends on the spatial and temporal distribution of Southwest monsoon seasonal rainfall, as this is the main rainy period during which 74% of annual rainfall is receiving. Among the different climatic zones of the state, there is a large spatial variability ranging from 200 to 1500 mm.

El Niño, which indicates a band of warm ocean water temperatures that periodically develops off the Pacific coast of South America, is found to influence the performance of south west monsoon in India during some years. Some studies indicate its influence on agricultural productivity at global and national level. In the light of IMD's forecast of a 60% probable El Niño episode during 2014, an attempt has been made to study the influence of different intensities of El Niño of the past on the rainfall pattern and productivity of different agricultural crops of Gujarat state.

During El Niño years both annual and seasonal rainfall when aggregated at state level was more than that received during non El Niño years. A large spatial variability is noticed with monsoon rainfall deficit by 25% over Godhra and Bhuj during El Niño years. In other districts, it ranged from −2 to −14. Variability was still high and widespread in annual rainfall indicating the influence of El Niño. In strong El Niño years, there is a chance of early withdrawal of monsoon from parts of Gujarat which may induce terminal moisture stress in *kharif* crops. During weak and strong El Niño years, the rainfall towards the end of the monsoon season was deficit at most of the locations studied. However, in moderate El Niño years, the July rainfall was deficit indicating a break in monsoon activity.

Influence of El Niño episodes on agricultural productivity of different crops of Gujarat state when analysed has indicated that paddy was highly influenced by El Niño episodes. The impact was more pronounced in Vadodara district probably due to more area being under upland cultivation. In majority of the districts, paddy productivity declined during strong El Niño years. Groundnut productivity appears to be more sensitive to El Niño in districts like Jamnagar and Junagadh. Maize yields in Panchmahal district were more sensitive compared to other districts. Maize productivity during strong El Niño years were more influenced compared to weak and moderate years. Among the different categories of El Niño, strong events exerted more negative impact on cotton yields especially in districts like Ahmedabad, Bharuch and Rajkot. Strong El Niño events influenced sugarcane productivity. In Bharuch, it's productivity was found to be influenced more by moderate El Niño events. Castor productivity was largely influenced by moderate El Niño events. Productivity of bajra was influenced by strong El Niño events and in Banaskantha district its productivity was found more sensitive. Wheat yields declined by about 25% in the El Niño years compared to non−El Niño years. Productivity of mustard was largely influenced by moderate El Niño events.

The present study indicates an alteration in the spatial and temporal variability of rainfall induced by El Niño and its intensity. Sensitivity of crops to El Niño episodes is not uniform across locations. This calls for further analysis of rainfall and crop data at micro level preferably block or taluka. This may probably enable all the stake holders to become prepared with contingency plans to overcome the likely El Niño impacts.

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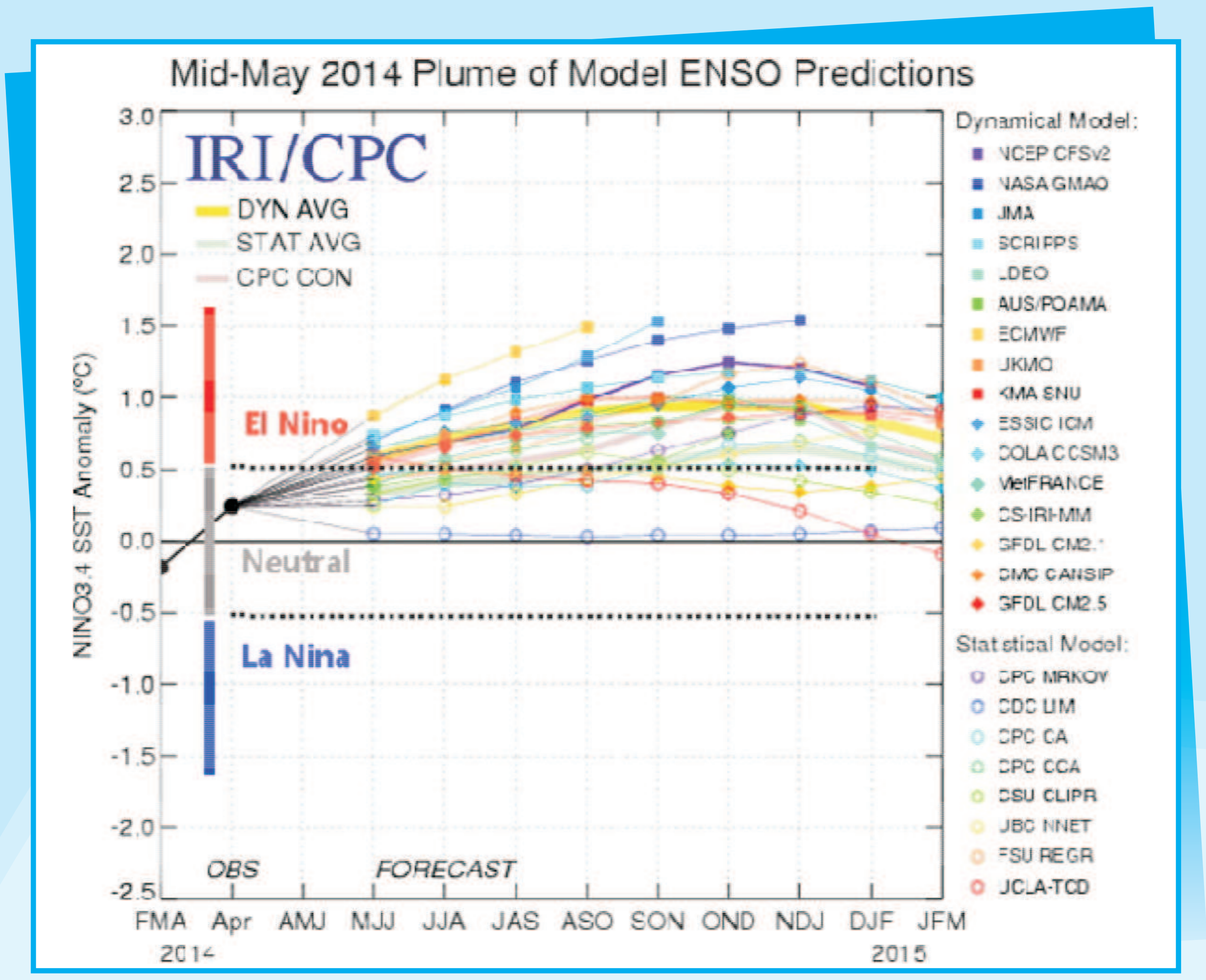


Model forecasts of El Niño strength (based on the Niño3.4 index) for the remaining 3-month seasons of 2014 and early 2015 from different global climate centres. SST anomalies above 0.5°C indicate El Niño conditions (red), below -0.5°C indicate La Niña conditions (blue). As of May 2014, most models predict the Niño3.4 index to range between +0.5°C and +1.0°C (weak to moderate El Niño) (image credit: IRI-CPC). – See more at: http://app2.nea.gov.sg/corporate-functions/newsroom/advisories/el-nino-advisory-and-outlook-for-the-southwest-monsoon-season#sthash.RFusWFwY.dpuf

How El Nino affects weather

El Nino is a warming of tropical Pacific waters that affects wind circulation patterns, recurring every three to eight years. Its effect on global climate varies from one event to the next.

NORMAL YEAR

1 Trade winds push warm surface waters westward.

2 Warmer waters heat the air, causing rain clouds to form over Asia.

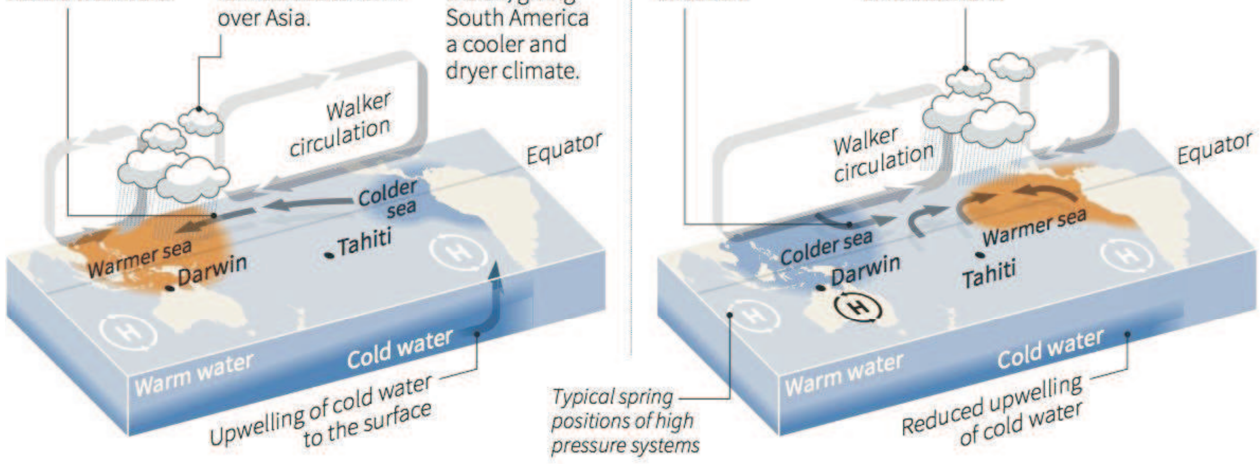
3 Colder waters rise and cool the air, giving South America a cooler and dryer climate.

EL NINO YEAR

1 Trade winds weaken or reverse direction.

2 Warm waters and rain clouds shift eastward.

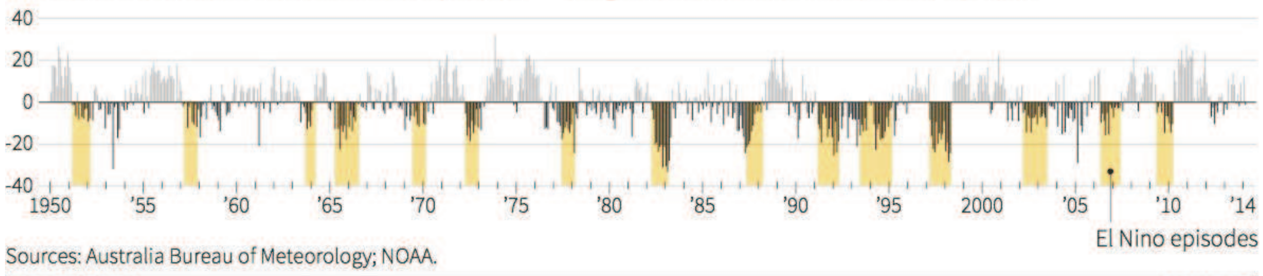
3 Asia is left unseasonably dry.



SOUTHERN OSCILLATION INDEX

The index which tracks fluctuations in air pressure between Tahiti and Darwin, gives an indication of the development and intensity of El Nino or La Nina events in the Pacific Ocean.

Positive values often indicate La Nina episodes | Negative values often indicate El Nino episodes



Sources: Australia Bureau of Meteorology; NOAA.

W. Foo, 17/03/2014

REUTERS