Original Research Article

IMPACT OF ENSO ON INDIAN MONSOON AND FOOD PRODUCTION

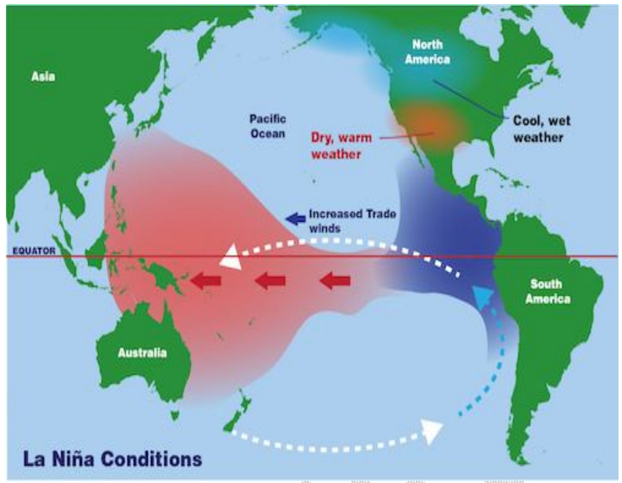
ABSTRACT

El Niño refers to a large-scale ocean-atmosphere climate interaction associated with the episodic warming in Sea Surface Temperatures (SST) across the central and east-central Equatorial Pacific. La Niña is an opposite event of El Niño which is termed as the episodic cooling of ocean SST in the central and east-central equatorial pacific. El Niño and La Niña combine together is generally known as El Niño Sothern Oscillation Index (ENSO). El Niño events are mostly associated with warm and dry conditions in southern and eastern inland areas of India, Australia, Indonesia, Philippines, Malaysia and central Pacific islands. The inter-annual variability of Indian Summer Monsoon Rainfall (ISMR) has been linked to variations of sea surface temperatures over the equatorial Pacific and Indian Oceans. ENSO events have a profound impact on summer monsoonal rainfall across India and most of the major droughts have occurred during El Niño events. El Niño conditions mostly coincide with a period of weak monsoon and rising temperatures in India and thus the probability of drought occurrence surges during El Niño events that could be disturbing for Indian crop production and water supply. The deficit of rainfall due to El Niño leads to decline in the production of crops especially short duration *Kharif* crops. Hence, it will results in high inflation rates and lower GDP due to high contribution of agriculture sector in Indian economy. This paper describes the impact of El Niño on climate in different parts of India with special reference to Indian monsoon and crop production.

Keywords: El-Nino, La-Nina, ENSO, SST, ISMR, Agricultural production.

INTRODUCTION

Agriculture and associated industries are the primary source of food and the major employment sector. Among several factors that govern agricultural production, weather appears to be the most critical factor as the farmers have no control over its inter and intra seasonal variability's and are difficult to predict with greater reliability and confidence. India currently producing about 280 million tonnes of cereals to meet the needs of population of 1.37 billion and India's population is likely to reach 1.5 billion by 2030 and 1.7 billion by 2050, hence India has to produce more and more food to feed its ever-increasing population but weather calamities hindering the Indian Manson thereby food production (Anon. 2020). Sustainable food production is critical for meeting growing global food needs in a context of climate change due to various phenomena like ENSO which has detrimental effect on Indian monsoon, food production, fisheries and also on human health. The ENSO (El Niño Southern Oscillation Index) is a pervasive climate phenomenon which has been found to be associated with regional climatic variations throughout the world. 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 hence it is called as “the Christ Child” or “boy child” (Rao *et al.*, 2011). The formation of an El Niño is linked with the cycling of a Pacific Ocean circulation pattern known as the southern oscillation (Fig. 1a). 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. 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. The easterly flow of the trade winds carries warm surface waters westward, bringing convective storms to Indonesia and coastal Australia. In an El Niño year, air pressure drops over large areas of the central Pacific and along the coast of South America. The normal low pressure system is replaced by a weak high pressure in the western Pacific (the southern oscillation). This change in pressure pattern causes the trade winds to be reduced. This reduction allows the equatorial counter current (which flows west to east) to accumulate warm ocean water along the coastlines of Peru and Ecuador. This accumulation of warm water causes the Thermocline to drop in the eastern part of Pacific Ocean which cuts off the upwelling of cold deep ocean water along the coast of Peru. Climatically, the development of an El Niño brings drought to the western Pacific that includes India, rains to the equatorial coast of South America and convective storms and hurricanes to the central Pacific. After El Niño event weather conditions usually return back to normal. However, in some years the trade winds can become extremely strong and an abnormal accumulation of cold water can occur in the central and eastern Pacific. This event is called as La Niña (Fig. 1b).



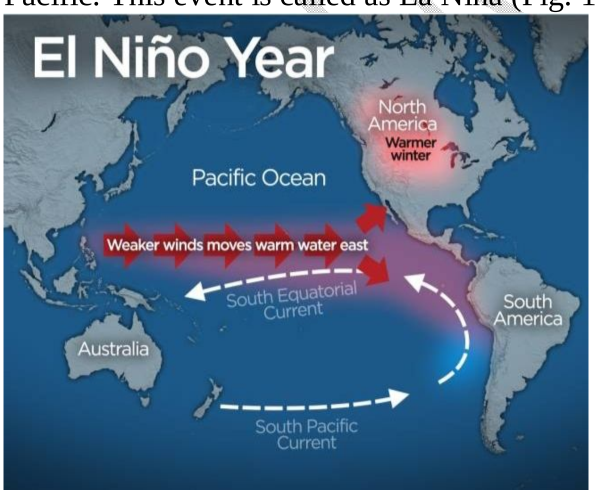


Fig. 1: a) El Niño b) La Niña

The Oceanic Niño Index (ONI) has become the accepted criteria (Fig. 2) that the National Oceanic and Atmospheric Administration (NOAA) uses for identifying El Niño (warm) and La Niña (cool) events in the tropical Pacific and they categorized the ENSO events Based on increase in temperature of the Pacific Ocean El Niño is divided into weak, moderate and strong El Niño those are defined as when temperature of Pacific Ocean is raised by 0.5 to 0.9 °c then it is called weak El Niño. When temperature of Pacific Ocean is raised by 1.0 to 1.4 °c then it is called moderate El Niño. When temperature of Pacific Ocean is raised by >1.5 °c then it is called strong El Niño (Cherian *et al.,* 2021).

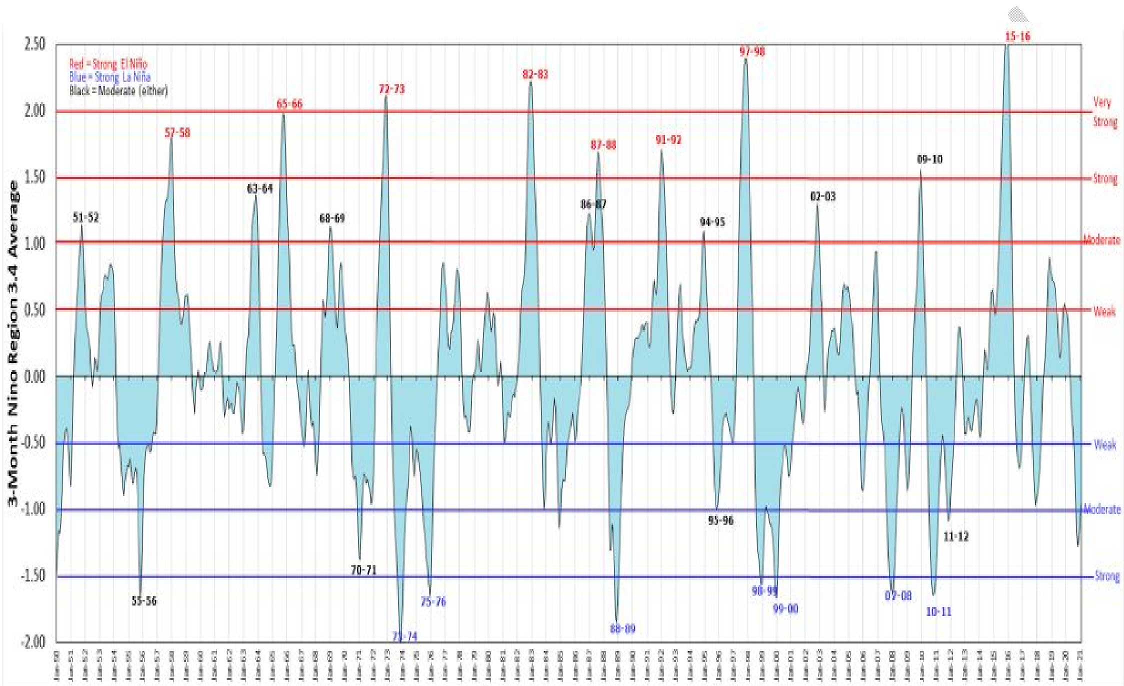


Fig. 2: OceanSic Niño Index (ONI)

There are 26 El Niño episodes and 23 La Niña episodes from 1950 to 2021 according to Golden Gate Weather Services 2021 (Table 1).

Table 1. Historical El Niño and La Niña events and their severity (1950-2021) (Golden Gate Weather Services 2021)

El Niño – 26				La Niña - 23		
Weak - 11	**Moderate - 7**	**Strong - 5**	**Very Strong – 3**	**Weak - 11**	**Moderate - 5**	**Strong - 7**
1952-53	1951-52	1957-58	1982-83	1954-55	1955-56	1973-74
1953-54	1963-64	1965-66	1997-98	1964-65	1970-71	1975-76
1958-59	1968-69	1972-73	2015-16	1971-72	1995-96	1988-89
1969-70	1986-87	1987-88		1974-75	2011-12	1998-99
1976-77	1994-95	1991-92		1983-84	2020-21	1999-00

1977-78	2002-03			1984-85		2007-08
1979-80	2009-10			2000-01		2010-11
2004-05				2005-06		
2006-07				2008-09		
2014-15				2016-17		
2018-19				2017-18		

Impact of El Niño on Indian monsoon

Abnormalities in Indian monsoon due to El Niño, manifested as droughts and it have disastrous effects on agriculture, industry and generation of hydrological power. Mooley and Parthasarathy (1983) studied intensities of rainfall during El Niño years and that of normal years from 1871 to 1976. The results revealed that there was departure of rainfall from normal years up to the extent of 8.8 per cent including all the years.

A study on droughts over India during El Niño years was conducted at Indian Institute of Tropical Meteorology, Pune, India. Here they considered drought year as one for which standardized ISMR (Indian summer monsoon rainfall) was less than one, one standard deviation is equivalent to 10 per cent of the normal ISMR. They found out that during all the El Niño years, there was a negative departure of rainfall from the normal indicating deficiency in rainfall received during the El Niño years, which often led to drought conditions over the Indian sub-continent. The average standardized ISMR for drought years caused by El Niño forcing was -2. However, not all El Niño years led to a drought in India. For instance, 1997 to 98 was a strong El Niño year but there was no drought. On the other hand, a moderate El Niño in 2002 resulted in one of the worst droughts due to coincidence of internal epochal variability of rainfall and external forcing like El Niño. According to historical data of 126 years (1880-2005), about 90 per cent of all evolving El Niño years have led to below normal rainfall and 65 per cent of evolving El Niño years has brought droughts and also revealed that there will be flood or excess rainfall over India during La Niña episodes. Out of ten La Niña years six La Niña years caused flood *i.e.*, rainfall in a year when standardized ISMR (Indian Summer Monsoon Rainfall) was greater than one (Kripalani and Kulkarni, 1996).

Selvaraju (2003) worked out average SMR (Summer Monsoon Rainfall) in various states of India during warm and cold ENSO years for the period from 1950 to 1999 and revealed that the SMR varied with ENSO phases in major food grain producing sub-divisions of India. During warm ENSO-phase years, the SMR declined by 14 per cent on average and during cold ENSO-phase years the rainfall increased by 9 per cent. This deviation in rainfall pattern during warm ENSO years reduces food grain production, as SMR is a critical input for both *Kharif* and *Rabi* season crops under intensive crop production systems. Also examined the impact of ENSO (1950 to 1999) and concluded that during the warm ENSO phase there was reduction in summer monsoon in (5 to 24%) and during cold phase of ENSO there was increase in summer monsoon (2 to 11%) all the rainfall subdivisions of India. The ENSO impact on rice crop production was greater compare to other crops.

Effect of ENSO is different for different region and however, not all El Niño years led to a drought in India, For instance, 1997- 98 was a strong El Niño year but there was no drought.

On the other hand, a moderate El Niño in 2002 resulted in one of the worst droughts (Golden Gate Weather Services, 2018). A study was conducted on the per cent change in district wise average annual rainfall (mm) during El Niño years compared to normal rainfall (mm) years in Andhra Pradesh (1971-2009) and revealed that the average annual rainfall during El Niño years was less than normal and reduction is about more than 10 per cent in both Rayalaseema and Telangana regions. It was only four per cent in coastal Andhra Pradesh. The departure was less than 10 per cent in all the districts of Coastal Andhra Pradesh. Hence, from this they concluded that there is slight to notable decrease in rainfall during El Niño years compared to normal years (Rao *et al.,* 2011).

Prasad *et al.* (2014) worked out per cent change in average Southwest Monsoon rainfall (mm) from June-September during El Niño years compared to non El Niño years in selected districts of Himachal Pradesh (1971-2009) and reported that the average rainfall during El Niño years was less than the non El Niño years. The departure of rainfall was more than 40 per cent in Kullu and Kangra fallowed by 20 per cent in Bilaspur**,** Sirmaur, Shimla and Mandi. Therefore, it is obvious that compared to non El Niño years' rainfall, the rainfall during El Niño years is likely to be less during Southwest Monsoon season.

ENSO has decreased the average Summer Monsoon Rainfall (SMR) of India by 14%. To understand this Patel *et al.* (2014) worked out seasonal and annual rainfall (mm) at different locations of Gujarat during El Niño years to non-El Niño years (1978-2011) and revealed that during El Niño years both the annual and seasonal rainfall received at the state level was deficient compared to normal years. The monsoon season rainfall over Bhuj and Godhra during El Niño years was about 30 per cent and 25 per cent respectively. In other districts the deficit ranged from 2 to 17. This implies that, rainfall during El Niño years may exhibit large spatial variability compared to the non-El Niño years.

District-wise percent change in annual rainfall during all El Niño years was and it was observed that during all El Niño years, there is negative departure of annual rainfall in the range of 1 per cent to 10 per cent in different districts of Chattisgarh. In strong El Niño years, there was negative deviation in rainfall of about 3 per cent (Jashpur) to 21 per cent (Dantewada) was observed. Therefore, it is clear that during El Niño years, significant reduction in rainfall during the major crop growing season will be experienced (Manikandan *et al*., 2016).

The per cent change in district wise average annual rainfall during the El-Nino years as compared to normal years in selected districts of Eastern Plain Zone of Uttar Pradesh was studied and revealed that the average annual rainfall during El-Nino years is less than normal years. Maximum departure of rainfall was recorded in Ballia district (5.7%) followed by Jaunpur district (5.1%). The lowest departure of 0.4 per cent was found in Varanasi district followed by Barabanki district (1.1%) of Eastern Plain Zone of U.P. Hence, El-Nino unambiguously serves as a signal of deficit rainfall for the Eastern Plain Zone of U.P. during the Southwest Monsoon season (Kushwaha *et al.,* 2020).

The weekly rainfall data for 36 years (1981-2016) recorded at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani were analyzed for mean seasonal, weekly rainfall and also weekly rainfall probabilities. The results revealed that the average Southwest Monsoon and annual rainfall received during El Niño years (683 and 826.5, respectively) was found to be less compared to normal years (721.6 and 830.3, respectively) (Dakhore *et al.,* 2020).

The average S-W monsoon rainfall during weak, moderate and strong El Niño years was less than the normal rainfall in all the districts of Karnataka. Across the regions, during weak El Niño years the more pronounced negative effect was noticed in the South Interior Karnataka (16.43%) followed by North Interior Karnataka (13.47%), Coastal Karnataka (10.13%) and Malnad Region (4.58%). During moderate and during strong El Niño years more pronounced negative effect was noticed in the Malnad region (11.51% and 13.72%, respectively) followed by South Interior Karnataka (8.99% and 13.52%, respectively), Coastal Karnataka (7.25% and 11.93%, respectively), North Interior Karnataka (4.46% and 10.24%, respectively) (Cherian *et al.*, 2021). Karnataka state as a whole the S-W monsoon and yearly rainfall were less than normal with an anomaly range of -6.69 to -10.66% and -6.66 to -10.29% under moderate to weak El Niño years, respectively. However, N-E monsoon rainfall was above normal during moderate El Niño years with a percent anomaly of 12.76, but it was less than normal during strong and weak El Niño years (-10.02 and -7.42%, respectively) (Fig. 3).

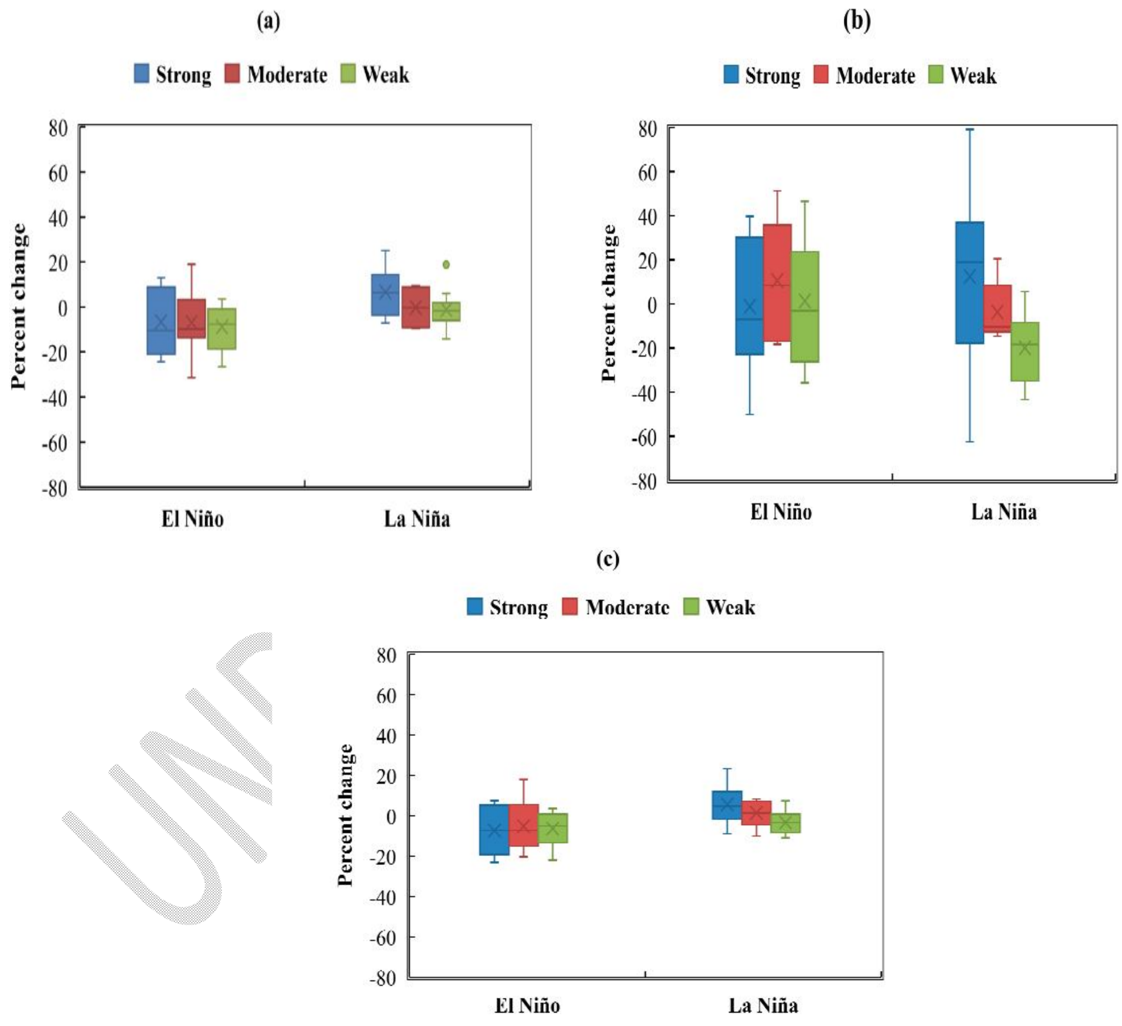


Fig. 3. Box plots depicting the percent change in (a) S-W monsoon, (b) N-E monsoon, and (c) annual rainfall during El Niño and La Niña years compared to normal years in Karnataka (1951–2014).

Effect of ENSO on food production

A study conducted at Central Research Institute for Dryland Agriculture, Hyderabad by Rao *et al.* (2011) concluded that the average production during El Niño years decreased by 42.7 per cent and the productivity by 36.4 per cent. Therefore, it was obvious that El Niño was exerting greater influence on productivity of rainfed crops as a result of decreasing tendency of Southwest Monsoon.

Prasad *et al.* (2014) worked out the per cent change in average area sown (‘000 ha), production (‘000 tones) and productivity (kg/ha) of maize during El Niño years compared to non El Niño years in Himachal Pradesh (1981-2009) and revealed that production of the maize for the state was highly affected by El Niño years (11.9%) and the reduction in productivity was about 19.7 per cent in Kullu, 17.2 per cent Lahul & Spiti and 15.2 percent in Solan. Kullu seems to be the most affected district with respect to production (23.7%) and productivity (19.7%), and the average area under maize decreased only marginally (0.8 %) in the state during El Niño years. He also worked out the per cent change in average area sown (‘000 ha), production (‘000 tonnes) and productivity (kg/ha) of rice during El Nino years compared to non El Niño years in Himachal Pradesh (1981-2009) and revealed that the highest reduction in yield was noticed in Chamba that is 13.2 per cent and 12.8 per cent in Hamirpur districts. Average area under rice is decreased by less than 1 per cent but production and productivity is decreased by 5.4 per cent and 4.5 per cent, respectively. Hence, it is concluded that the production and productivity was decreased in most of the selected districts of Himachal Pradesh during El Nino years compared to non El Nino years.

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 and this rainfall will be affected by climatic extremes like El Niño which leads to reduced rainfall thereby affecting food production. Patel *et al.* (2014) worked out the anomalies (%) in paddy and groundnut yields during El Niño years compared to non El Niño years in crop growing districts of Gujarat (1978-2011) and revealed that the productivity was highly influenced by El Niño episodes in the entire major paddy growing districts. The impact was more pronounced in Vadodara district (64.4) and the reason could be attributed to more area in this district being under upland cultivation. In case of groundnut, all 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. It appears to be more sensitive in Junagadh district.

The total food grains production in the country was severely affected by “ENSO extremes”. El Niño phases brought down the global rice production. In India, the average drop in rice (*kharif*) production during a warm ENSO-phase was 3.4 million tonnes (7%), on the other hand the average increase IN production was 1.3 million tonnes (3%) during cold ENSO-phase (Pandey *et al.*, 2019).

The study was undertaken in the major crops grown in Parbhani. The Major crops were cotton, sorghum, soybean, black gram, green gram, pigeon pea and rice during *Kharif* season. In these above mentioned crops, detailed analysis was carried out to find the changes in productivity of some major crops in Parbhani districts due to El Nino episode. The average productivity of all the crops during *Kharif* season decreased by more than 20 per cent except rice because area of rice crop was very less. The weak El Niño years was more negatively affected on productivity of all *kharif* crops ranging from 21.1 to 52.8 per cent, it might be due to the short duration crops like green gram, black gram, soybean, sorghum and rice was exposed for dry spells occurred in July and September months at critical growth stages of these crops. During weak El Nino years the short duration crop was highly imparted due to soil moisture deficit at critical growth stages, while Strong and moderate El Nino years the crops was not exposed to soil moisture deficit hence yield was better compare to weak El nino years (Dakhore *et al.*, 2020).

CONCLUSION

Crop production in India is directly linked to the rains received during southwest monsoon in which inter-annual rainfall variability leads to large scale droughts and floods resulting in major impact on food grain production and also on the economy of the country. It has been found that most of the El Nino years have either led to droughts or below normal rainfall and therefore it is clear that El Nino events adversely affect the monsoon rain. Furthermore, sensitivity of crops to El Niño and La Nina episodes is not uniform for all the regions and more rigorous study needs to be conducted to understand its mechanism in better way. Forecasting of ENSO helps to escape from the dangers of drastic yield loss that occur due to excess rainfall or drought, which majorly influence the economy of the farmers in India.

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