__Original Research Article__

IMPACT OF ENSO ON INDIAN MONSOON AND FOOD PRODUCTION

ABSTRACT

El Nino is a big ocean-atmosphere climate interaction It happens when Sea Temperatures (SST) warm up in central and eastern parts of the Equatorial Pacific. Whereas La Nina is the opposite event of it, when ocean SST cools down in those same areas. Together, El Nino and La Nina are known as the El Nino Southern Oscillation Index (O). Usually, El Nino brings warm and dry weather to southern & eastern inland regions of India, Australia, Indonesia, Philippines, Malaysia, and the central Pacific islands. The variations of Indian summer monsoon Rainfall (ISMR) are linked to changes in sea surface temperatures over the equatorial Pacific & Indian Oceans. ENSO events really affect summer rainfall in India and major droughts have faced during El Nino events. When El Nino kicks in, it often leads to weak monsoons & higher temperatures in India. This raises the chances of droughts, which could upset crop production & water supply in India. The lack of rain because of El Nino causes crop production to drop, especially short-duration Kharif crops. This situation can lead to higher inflation rates & slower GDP growth, since agriculture is such a huge part of India’s economy. Therefore, this paper provide information about how El Nino affects climate throughout various regions of India, especially regarding monsoons and growing food.

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

INTRODUCTION

Agriculture and its related industries serve as the main source of food and crucial for employment. Weather stands out as a major factor influencing production. Farmers lack control over weather's variability, both within and between seasons. Predicting these changes with accuracy is particularly challenging. Currently, India produces around 280 million tonnes of cereals to support a population of 1.37 billion people. By 2030, this number is expected to rise to 1.5 billion, and by 2050, to 1.7 billion. Therefore, it’s vital that India increases its food production to keep up with this growing demand. However, adverse weather events pose significant challenges to the Indian monsoon and overall food production (Anon. 2020). Sustainable food production becomes essential amid climate change concerns stemming from various phenomena[13,14,15,16}. One prominent example is ENSO—El Nino Southern Oscillation affecting the Indian monsoon and impacting food production, fisheries, and even human health. ENSO is a widespread climate phenomenon linked to regional climate changes across the world. The walker circulation describes pressure differences caused by a high-pressure system over the eastern Pacific Ocean and a low-pressure system near Indonesia. ENSO includes three phases: the warm phase (El Nino), the cool phase (La Nina), and a neutral phase. The word El Nino means "the Christ Child" in Spanish. Fishermen along Ecuador and Peru originally called it after a warm ocean current that shows up around Christmas and can last several months (Rao et al., 2011). The establishment of El Niño relates closely to the cycling of Pacific Ocean circulation patterns known as the Southern Oscillation (Fig. 1a). In regular years, low pressure forms in northern Australia and Indonesia while high pressure sits off Peru's coast. Consequently, trade winds blow strongly from east to west across the Pacific Ocean. These winds push warm surface waters westward, sparking stormy conditions in Indonesia & coastal Australia while cold bottom water replaces them along Peru's coast. Conversely, during an El Niño year, air pressures drop dramatically across the central Pacific and South America's coastlines. This replaces the normal low-pressure system with a weak high pressure in the western Pacific (the Southern Oscillation). This change diminishes trade winds, allowing warm waters to accumulate along Peru and Ecuador's coasts. Such warmth causes the thermocline the layer dividing warm surface water from cooler deep water to descend in eastern Pacific waters, preventing cold water from rising off Peru's coast. Notably, during an El Nino event, drought affects western Pacific regions like India while equatorial South America sees increased rainfall along with storms in central Pacific areas. Weather tends to normalize after an El Nino event, however, in certain years, strong trade winds can lead to an unusual build-up of cold water in central and eastern Pacific seas, this event is termed La Nina (Fig. 1b). La Nina translates to “little girl” in Spanish and indicates a cold climatic phenomenon. In years characterized by La Nina conditions, winter temperatures are generally warmer than average in southern regions but cooler than normal up north. It leads to droughts in Peru and Ecuador while triggering heavy rains in Australia alongside warmer temperatures prevalent in parts of the Western Pacific and Indian Ocean as well as beneficial monsoon rains for India. La Nina has multiple classifications based on how long cooling lasts: if it occurs for seven to nine months it's termed La Nina conditions, if it continues for over nine months it's classified as La Nina episodes.

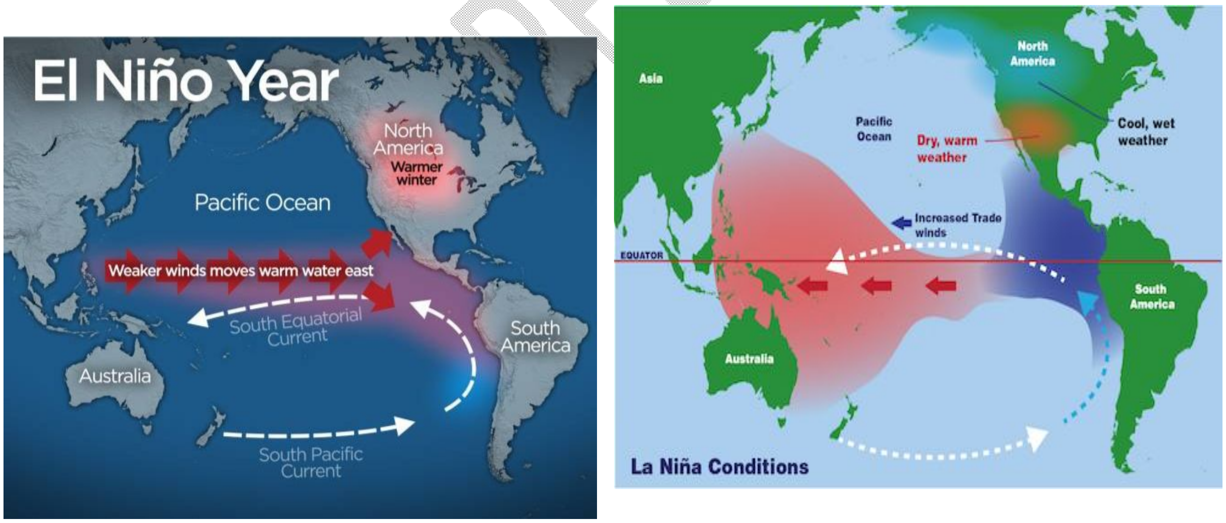

Fig. 1: a) El Niño b) La Niña

The National Oceanic and Atmospheric Administration (NOAA) now classifies ENSO occurrences using the Oceanic Niño Index (ONI), which has become the standard criterion (Fig. 2) for recognizing El Niño (warm) and La Nina (cool) episodes in the tropical Pacific. El Niño is classified into three categories based on the rise in Pacific Ocean temperature: weak, moderate, and strong. Weak El Niño is defined as an increase in temperature of the Pacific Ocean of 0.5 to 0.9 °C. El Niño mild occurs when the Pacific Ocean's temperature rises by 1.0 to 1.4 °C. Strong El Niño occurs when the Pacific Ocean's temperature rises by more than 1.5 °C (Cherian et al., 2021).

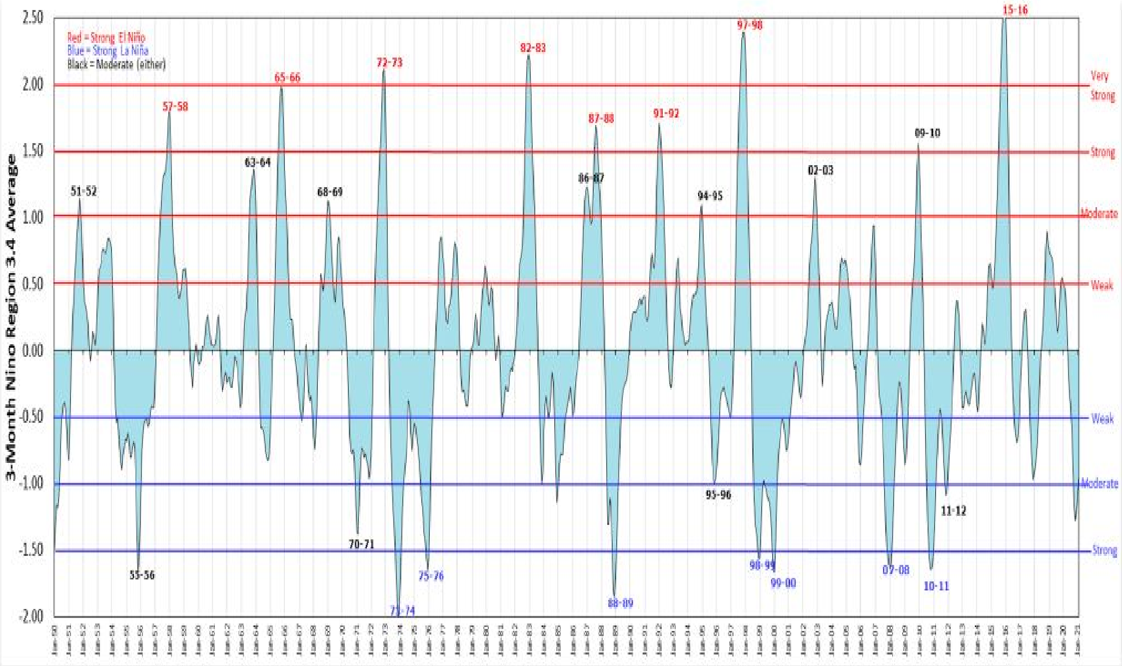

Fig. 2: OceanSic Niño Index (ONI)

There are 26 El Nino episodes and 23 La Nina 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

El Nino-related anomalies in the Indian monsoon caused droughts, which had catastrophic consequences for business, agriculture, and hydropower production. Mooley and Parthasarathy (1983) examined the amount of rainfall in El Nino years compared to normal years between 1871 and 1976. According to the findings, there was an 8.8% annual variation in rainfall from typical years over all years.

Indian Institute of Tropical Meteorology, Pune, India, did a study on droughts over India during El Niño years. In this case, a year was deemed droughty if the standardized Indian summer monsoon rainfall (ISMR) was less than one. A standard deviation is equal to 10% of the average ISMR. They discovered that there was a negative deviation of rainfall from the average during every El Niño year, indicating a lack of rainfall during the El Niño years, which frequently resulted in drought conditions over the Indian subcontinent. El Niño driving drought years had an average standardized ISMR of -2. Not every El Niño year, nevertheless, resulted in a drought in India. For example, there was no drought during the intense El Niño years of 1997–1998. On the other hand, the combination of inherent epochal variability of rainfall and external forces such as El Niño in 2002 caused one of the worst droughts, despite a moderate El Niño. Based on 126-year historical data (1880-2005), almost 90% of evolving El Niño years resulted in below-average rainfall, and 65% of evolving El Niño years brought about droughts. Additionally, same data suggested that there would be floods or excessive rainfall across India during La Niña. According to Kripalani and Kulkarni (1996), six out of ten La Niña years resulted in flooding, or rainfall in a year when the standardized Indian Summer Monsoon Rainfall (ISMR) was higher than one.

Selvaraju (2003) analyzed the average Summer Monsoon Rainfall (SMR) across various Indian states during warm and cold ENSO years from 1950 to 1999. The study found that SMR fluctuated according to ENSO phases in key food grain-producing regions of India. Specifically, during warm ENSO years, there was an average decrease of 14 percent in SMR, while cold ENSO years saw an average increase of 9 percent. This variability in rainfall, particularly during warm ENSO phases, negatively impacts food grain production since SMR is crucial for both Kharif and Rabi crops in intensive agricultural systems. Additionally, the study highlighted that during warm ENSO phases, summer monsoon rainfall decreased by 5 to 24 percent, whereas during cold ENSO phases, it increased by 2 to 11 percent across all rainfall subdivisions in India. The impact of ENSO on rice production was notably more significant compared to other crops.

The influence of El Niño-Southern Oscillation (ENSO) on Indian rainfall exhibits considerable regional variability. While not every El Nino event results in drought conditions, significant differences can be observed. For example, despite the strong El Niño of 1997-98, no drought was recorded in India. Conversely, the moderate El Nino of 2002 triggered one of the most severe droughts (Golden Gate Weather Services, 2018).

In Andhra Pradesh, a study spanning 1971 to 2009 assessed the percentage change in district-wise average annual rainfall during El Nino years compared to normal years. Findings indicated a reduction of over 10 percent in average annual rainfall during El Nino years in the Rayalaseema and Telangana regions, while the decline was approximately 4 percent in coastal Andhra Pradesh (Rao et al., 2011). This suggests a notable decrease in rainfall during El Niño years, though the impact varies regionally.

Prasad et al. (2014) analyzed the percentage change in average southwest monsoon rainfall (June-September) in Himachal Pradesh from 1971 to 2009. They reported a decrease in rainfall during El Nino years compared to non-El Nino years, with reductions exceeding 40 percent in Kullu and Kangra, and around 20 percent in Bilaspur, Sirmaur, Shimla, and Mandi. This indicates a significant reduction in Southwest Monsoon rainfall during El Niño years.

Patel *et al.* (2014) investigated seasonal and annual rainfall patterns in Gujarat for the period 1978-2011. Their analysis revealed that both seasonal and annual rainfall were generally deficient during El Niño years compared to non-El Niño years. Specifically, rainfall during the monsoon season in Bhuj and Godhra dropped by approximately 30 percent and 25 percent, respectively, with deficits ranging from 2 to 17 percent in other districts. This highlights considerable spatial variability in rainfall deficits during El Niño years.

Manikandan *et al.* (2016) examined the district-wise percentage change in annual rainfall during El Nino years in Chhattisgarh. They found a negative departure in rainfall ranging from 1 percent to 10 percent across various districts, with stronger El Nino years showing more pronounced reductions, such as a 21 percent deficit in Dantewada. This underscores a significant reduction in rainfall during major crop-growing seasons in El Niño years.

In Uttar Pradesh's Eastern Plain Zone, a study on district-wise average annual rainfall during El Niño years compared to normal years indicated that average annual rainfall was lower during El Niño years. The most significant departures were recorded in Ballia (5.7%) and Jaunpur (5.1%), while the smallest departure was in Varanasi (0.4%) and Barabanki (1.1%) (Kushwaha *et al.*, 2020). This consistently points to El Nino as a reliable indicator of reduced rainfall during the Southwest Monsoon season in this region.

Data from Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, covering 1981-2016, revealed that the average Southwest Monsoon and annual rainfall during El Nino years were lower than during normal years, with recorded averages of 683 mm and 826.5 mm, respectively, compared to 721.6 mm and 830.3 mm during normal years (Dakhore et al., 2020).

In Karnataka, Cherian et al. (2021) reported that the Southwest Monsoon rainfall during weak, moderate, and strong El Niño years was consistently below normal across all districts. The most significant reductions were observed in South Interior Karnataka (16.43% during weak El Nino), followed by North Interior Karnataka (13.47%), Coastal Karnataka (10.13%), and the Malnad Region (4.58%). During moderate and strong El Nino years, the Malnad region experienced the greatest negative impacts (11.51% and 13.72%, respectively), with other regions also showing reduced rainfall. Overall, Karnataka experienced a range of anomalies from -6.69% to -10.66%

under moderate to weak El Niño conditions, although the Northeast Monsoon showed above-normal rainfall during moderate El Nino years, with a 12.76% anomaly, but less than normal during strong and weak El Nino years (-10.02% and -7.42%, respectively).

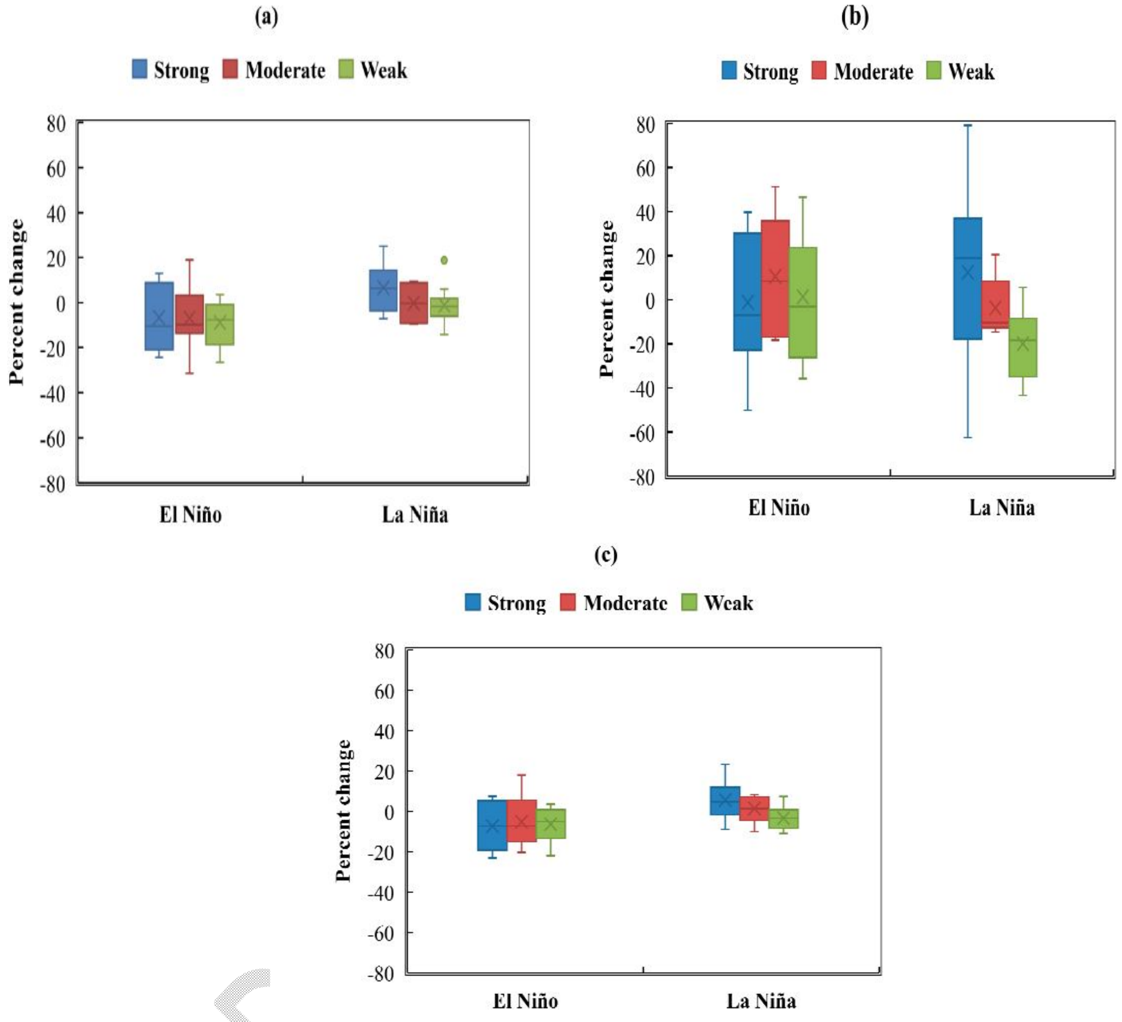

Fig. 3. Box plots depicting the percent change in (a) S-W monsoon, (b) N-E monsoon, and (c) annual rainfall during El Niño and La Niña years compared to normal years in Karnataka (1951–2014).

Effect of ENSO on food production

A study conducted by Rao *et al.* (2011) at the Central Research Institute for Dryland Agriculture, Hyderabad, found that El Niño years resulted in a substantial decline in agricultural productivity. Specifically, the average production during these years dropped by 42.7 percent, and productivity decreased by 36.4 percent. This significant reduction is attributed to the adverse effects of El Niño on the Southwest Monsoon, which is critical for rainfed crops.

Prasad et al. (2014) analyzed the impact of El Nino on maize cultivation in Himachal Pradesh from 1981 to 2009. Their findings revealed that maize production in the state decreased by 11.9 percent during El Nino years, with productivity reductions of 19.7 percent in Kullu, 17.2 percent in Lahul and Spiti, and 15.2 percent in Solan. Among these, Kullu experienced the most severe impacts, with production and productivity reductions of 23.7 percent and 19.7 percent, respectively. The area under maize decreased marginally by 0.8 percent during El Nino years. Additionally, their study on rice revealed that yield reductions were highest in Chamba (13.2 percent) and Hamirpur (12.8 percent), with decreases in production and productivity of 5.4 percent and 4.5 percent, respectively. Overall, El Niño years led to notable declines in both production and productivity across most districts in Himachal Pradesh.

Agricultural practices in the region are segmented into kharif, rabi, and summer seasons, with 70 percent of the gross cropped area dedicated to kharif crops, which are heavily reliant on monsoon rainfall. Patel et al. (2014) investigated the effects of El Nino on paddy and groundnut yields in Gujarat from 1978 to 2011. They found significant negative impacts on productivity in major paddy-growing districts, with Vadodara experiencing the most pronounced decline (64.4 percent). Similarly, groundnut productivity also suffered across all major growing districts during El Nino years, with the most severe effects observed in Junagadh district.

The broader implications of El Nino on food grain production in India have been substantial. Pandey et al. (2019) reported that during warm ENSO phases, rice production fell by an average of 3.4 million tonnes (7 percent), while cold ENSO phases saw a rise in production by 1.3 million tonnes (3 percent).

A study in Parbhani district focused on key kharif crops cotton, sorghum, soybean, black gram, green gram, pigeon pea, and rice found that average productivity declined by over 20 percent during El Nino years, with the exception of rice, which had a minimal area of cultivation. The productivity of short-duration crops like green gram, black gram, soybean, and sorghum was particularly affected, showing reductions ranging from 21.1 to 52.8 percent during weak El Niño years. This decline is attributed to exposure to dry spells at critical growth stages. In contrast, during strong and moderate El Niño years, the crops were less affected by soil moisture deficits, resulting in better yields compared to weak El Niño years (Dakhore et al., 2020).

CONCLUSION

Crop production in India is intricately linked to the Southwest Monsoon, with inter-annual variability in rainfall contributing to widespread droughts and floods. These climatic extremes significantly impact food grain production and, consequently, the national economy. Evidence suggests that El Nino years frequently correlate with either drought conditions or below-normal rainfall, indicating a detrimental effect of El Niño events on monsoon precipitation.

The sensitivity of different crops to El Nino and La Nina events varies across regions, highlighting the necessity for more comprehensive research to elucidate these mechanisms. Effective ENSO forecasting is vital for mitigating the risks associated with extreme weather conditions, such as excessive rainfall or drought. Improved forecasting can help avert severe yield losses, thereby safeguarding the livelihoods of farmers and stabilizing the agricultural economy in India.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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