Review Article

Impact of El-Nino and La-Nina episodes on rainfall variability and crop yield

ABSTRACT

El Nino and La Nina events have an impact on the Indian monsoon in terms of less rainfall than average and more rainfall in La Nina years. El-Nino years are more likely to see rainfall variability during the monsoon and depressions over the Bay of Bengal (July and August). ENSO is broadly defined as a disruption in ocean surface temperatures and atmospheric circulation over the Pacific Ocean leading to wide spread changes in precipitation regimes around the world. El Nino years' effects on crop production in India as a result of lower rainfall during the south-west monsoon. In the kharif season (June to September), crops suffer from moisture and have lower yields in El-Nino years, but the opposite in La-Nina years. The El Nino is associate with the possibility of drought like situation at many occasions and La Nina is the reverse of El-Nino.

Key words: Rainfall, El-Nino, La-Nina, Production, Monsoon

INTRODUCTION

The term El Nino refers to the large-scale ocean-atmosphere climate phenomenon linked to a periodic warming in sea-surface temperatures across the central and east-central equatorial Pacific (between approximately the date line and 120° W). El Nino represents the warm phase of the El Nino/Southern Oscillation (ENSO) cycle, and is sometimes referred to as a Pacific warm episode. El Nino originally referred to an annual warming of sea-surface temperatures along the west coast of tropical South America. The El Nino Southern Oscillation (ENSO) episodes affect weather, climate, marine and terrestrial ecosystems worldwide. The climatologists have tried to figure out the coupling of the Indian Monsoon with the Southern Oscillation in order to predict the monsoon rainfall over South Asia. ENSO is broadly defined as a disruption in ocean surface temperatures and atmospheric circulation over the Pacific Ocean leading to wide spread changes in precipitation regimes around the world. It has been noted that there is an increased frequency of warm episodes of ENSO, which affect the precipitation regime in the tropics and sub-tropics (Houghton *et al* 2001). The relationship between warm phase of ENSO and below average summer monsoon precipitation over the Indian subcontinent has been investigated in several previous research studies (Sikka and Gadgil 1980; Rasmusson and Carpenter 1982; Shukla and Paolino 1983; Ropelwski and Halpert 1989; Thapliyal *et al* 1998). However, India's immediate neighbour, Myanmar (formerly known as Burma) which is an agriculturally important country, occupying a vast landmass in the tropical belt of Southeast Asia has received comparatively scant form of Pacific decadal oscillation (PDO) in modulating the impact of ENSO. More specifically, it has been indicated that the warm phase of PDO amplifies the effect of warm phase of ENSO on precipitation patterns.

El Nino and La Nina episodes: Li (1990) studied that very cold winters across eastern China frequently came one year before El Nino episodes. The flow from the anomalous East Asian anticyclone may loop onto the original SSTA, increasing cold air advection across the Kuroshio Current region and further reducing the SSTs (as in cold WNP situations). This possibility hasn't been investigated here, although it is theoretically possible. Similar to how a cyclonic anomaly may cause warm air to advect towards East Asian coastal seas, warming the SSTs (in warm WNP situations).

In Nials *et al.* (1979) investigation of the emergence and fall of early irrigation systems in the Moche Valley on the north coast of Peru, they found an E1 Nino catastrophe of enormous proportions. They referred to this historic catastrophe as the "Chimu flood." A century before the year 1100 A.D., they discovered evidence indicating this flood of extraordinarily huge proportions happened early in the Chimu dynasty. A very cautious assessment, in their opinion, would show that flood waters at least 2-4 times the size of the extraordinary floods in 1925 happened then. They added that there seems to be evidence of a different significant flood that happened around 500 B.C. in the Moche Valley. Their worry about the escalating coastal population growth,

Mooley and Paolino (1989) found that the response of Indian monsoon was associated with the changes in sea surface temperature over the eastern south equatorial Pacific. Mooley (1997) suggested that El-Nino also influenced the occurrence of rainfall over India. Walker and Bliss (1932) had also found that drought in India tended to occur with S.O.

Kirtman and Shukla (2000) found that a strong (weak) monsoon reduces (enhances) the amplitude of an ongoing warm event or enhances (reduces) the amplitude of an ongoing cold event. They also found that a variable monsoon serves as a trigger for ENSO. Thus, to enhance our understanding of ENSO variability and predictability, it is necessary to clarify the impacts of monsoon variability on the circulation in the Pacific and the associated SST anomalies.

ENSO is now recognised as the single most important mode of the earth's year-to-year climatic variability. During the last decade, evidence has been accrued for the link between the Indian monsoon rainfall and ENSO, first suggested by Sir Gilbert Walker over 70 years ago (Krishna Kumar et al (1995). Ropelewski and Halpert (1987) investigated the "typical" global and large scale regional precipitation patterns that are associated with the ENSO.

Knaff and Landsea (1997) employed Climatology and Persistence (CLIPER) forecasting scheme for prediction of ENSO. This statistical approach is entirely based on optimal combination of persistence, month to month trend of initial condition and climatology involving 14 possible predictors including SOI, Niño 1+2, Niño 3, Niño 4 and Niño 3.4 SST indices for equatorial and central Pacific at lead times ranging from zero seasons (0-2 months) through seven seasons (21-23 months).

Barrett (1998) while discussing the value of imperfect ENSO forecast emphasized that forecasts have value only if they alter decision makers' subjective probability distributions over stochastic variables that influence choice. In this context, he found El Nino as heavily overhyped because forecast skill with respect to ENSO phase is not the same as the ability to forecast ENSO's impacts on variables of direct interest to decision makers.

Impact of ENSO and Rainfall Variability

Webster and Yang (1992) have reviewed the Monsoon and ENSO coupling's historical context. Season to season changes affect how the Indian Ocean responds to the El Nino Southern Oscillation (ENSO). Monsoon depressions over the Bay of Bengal in July and August are more likely to occur during El Nino years. According to Singh et al. (2000), El Nino and La Nina conditions frequently suppress the summer monsoon and winter precipitation, respectively (Rasul 2012). It was evident that rainfall, hydrology, and rice productivity in the Cauvery river basin are all associated with El Nino occurrences. According to the investigation, El Nino years had higher interannual rainfall variability (809.3mm to 2366 mm) than La Nina and normal years.

La Nina, which is the opposite of an El Nino event, is brought on by a change in the Pacific Ocean's Sea Surface Temperature (SST). The La Nina cycle is a result of intricate interactions between oceanic and atmospheric systems. The trade winds during a La Nina cycle force warm water towards the west, where it builds up in the western Pacific. The atmospheric conditions are managed by the Walker circulation. As the north-south Hadley circulation diminishes, the subtropical high-pressure system decreases as well, implying a feeble vortex transport from the tropics to the subtropics. Meehl (1994) reported on the dynamically interlined climatic system variability across several geographical regions. According to Ranade *et al.* (2010), the La Nina phenomena offers crucial information for operations involving heavy rainfall across the Indian subcontinent. When compared to La Nina years, the rainfall circumstances during El Nino years are significantly more detrimental to nearly all hydro-ecosystems worldwide.

The study of the relationships between the monsoons and the ENSO phenomena has definitely been the most fascinating on the interannual scale in the tropics (Glantz *et al*. 1991; Webster and Yang 1992).

Progress has been made in recent decades in foretelling how the ENSO phenomenon in the Pacific Ocean would develop (Goddard *et al*. 2001). 5 months in advance, forecast centres provide passably accurate estimates of the seasonal evolution of tropical sea surface temperatures (SST) (see, for instance, Goddard *et al*. 2001). As a result, seasonal rainfall can be predicted using the link between rainfall and ENSO. Such statistical forecasts based on surface temperature teleconnections offer a different basis for seasonal climate prediction that complements and frequently outperforms those based on global climate models (Barnston *et al* 2005). According to Soman and Slingo (1997), SST-based indices for ENSO are better to SOI because they are explicitly predicted, have less high-frequency noise, and more accurately depict the ENSO influence over the Asian monsoon region.

According to Sikka (1980), El Nino and monsoon failures over India are linked year to year, with the monsoon failing in the majority of El Nino cases. Based on more accurate El Nino indices, Rasmusson and Carpenter's (1983) thorough investigation revealed that the correlation between El Nino and monsoon failures is even larger than what Sikka's study suggested. In Krishna Kumar *et al*. (1995), an overview of the research on the r61e of ENSO in monsoon variability is provided. In conclusion, the majority of occurrences during the ENSO warm (cold) extremes cause below-normal (above-normal) rainfall. So, in addition to the internal epochal variability, external forces like El Nino and La Nina can cause drought and flood conditions.

The monsoon rainfall is the major source of water in South East Asian regions. The success and failure of monsoon adversely affect the livelihoods of many people who depend upon it for agricultural activities. The monsoon is a thermally driven circulation system; it should intensify during global warming and produce more rains over India. On the contrary the decline in monsoon rainfall over India, particularly over Indo-Gangetic plains and central India has been experienced during ENSO years. (Sen Roy *et al* 2003), it was found that regression coefficients showing the relationship between July–August precipitation in

India and ENSO were negative for northeast India, which is contiguous with Myanmar. In the case of Myanmar, under similar ENSO conditions, the relationship is negative as with northeast India. Similar results maybe noted with warm PDO and El Nino years. This appears to indicate that the descending leg of the Walker circulation cell perhaps affects Myanmar and the adjacent areas of India similarly during these conditions.

Impact assessment of ENSO of crop production

Changes in South west monsoon rainfall behaviour raise concern about the food security. Numerous studies have demonstrated that the kharif harvest was lower when total June –September rainfall was lower (Webster *et al* 1998, Kumar 2004). The El Nino is associate with the possibility of drought like situation at many occasions and La Nina is the reverse of that and thus a drought during the 2009 was on of the most severe in decade with rice harvesting declining by 14 per cent (Commission for Agriculture and Cost Prices 2010).

Bhuvaneswari *et al* (2013) concluded that an El Nino episode is correlated with rainfall hydrology and rice productivity in the Cauvery basin. The validation of SWAT model indicated the capability of SWAT to accurately predict stream flow and rice productivity. They further investigated that the quantum of rainfall was more during the El Nino years with high interannual rainfall varialbility (809.3mm -2366mm).

An analysis of wheat productivity found global yields for the world's most widely grown grain were on average 1.4 percent lower than normal in El Nino years, according to the study published in the journal Nature Communications. Based on the area harvested worldwide in 2000, about 22 percent of wheat suffered "significant" negative impacts from El Nino, including in south and east Australia, Mexico, parts of China and the northwest U.S., the study indicated. About 6 percent of wheat benefited significantly, including in parts of Russia, Argentina and northern China, the researchers found. Global wheat yields were 4 percent lower than normal in La Nina years, the researchers found (www.bloomberg.com/news/article/2014-15).

Jones (2000) in a study Comparative Assessment of Agricultural Uses of ENSO-Based Climate Forecasts in Argentina, Costa Rica and Mexico analysed the data from government statistics and showed that El Nino has a significant impact on yield at the national level. In 15 of 20 El Nino events (75%) maize yield was equal to or as much as 36% higher than the mean historical value, while in 17 of 23 La Niña events (74%) it was as much as 56% lower than the mean. In soybeans, an even greater impact from La Niña was observed, with yield reductions in 71% of events. In El Nino and neutral years, yield residuals were positive in 58% and 62% of cases, respectively. Sunflowers presented less association between yield and ENSO phases, with only one trend: a 59% probability of achieving higher yield during La Niña years. Wheat showed the least response of all, with only 57% of La Niña years showing lower yields. Neither sunflowers nor wheat showed consistent trends during El Nino years. An analysis at the county level showed broad reproduction of these national trends, but indicated several areas where ENSO effects on crop production consistently differed from the norm.

Rao *et al* (2011) conducted a study and observe that the total food grain production in the state of Andhra Pradesh during El Nino years fluctuated only between 9 million tons to 12 million tons up to the year 2002, although it ranged from about 9.5 to 15.0 million tons during the normal years. Therefore, there is an obvious signal that the total food grain production decreases by at least 0.5 million tons to 3 million tons during the years with El Nino , despite of the increasing trend in the total food grain production in the state up to the year 2002. It was only during the recent two El Nino years 2004 and 2006, the total food grain production was above average in spite of these two years being weak El Nino years. But the total food production during the years 2004 and 2006 declined compared to the corresponding preceding year, thereby confirming the fact that achieving increased growth rate in food grain production may be a difficult task during El Nino years.

CONCLUSION

Events such as El Nino and La Nina affect the Indian monsoon by causing rainfall to be higher during La Nina years and lower than average during El Nino years. In El-Nino year's crops suffer moisture stress in kharif season result decreases the yield and completely reverse in La-Nina years in which received higher rainfall and higher production also.

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