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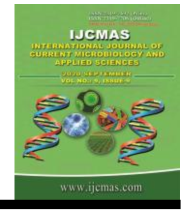

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Rainfall Variability during *El-Nino* and *La-Nina* Episodes in Punjab, India

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An analysis was carried out to study the impact of *El-Nino* and *La-Nina* on regional variability of rainfall in Punjab. Data on *El-Nino* and *La-Nina* episodes for the period of 41 years (1971-2011) were used for analysing their impact on rainfall variability. During the *El-Nino* year most of the districts found deficient rainfall ranged between 6 to 47 per cent. During *La-Nina* episodes a reverse trend in rainfall was observed. *El-Nino* showed significant association with rainfall but in case of *La-Nina* episode non-significant association was observed with rainfall. Regional rainfall was more affected by El-Nino episodes as compared to the La-Nina episodes. These episodes had no significant impact on rice productivity because of artificial source of tube well irrigation.

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 thedatelineand120°W). The inter-annual variability of seasonal precipitation over India is influenced by *El Nino*-Southern Oscillation (ENSO) phenomenon. The ENSO is negatively correlated with Indian summer monsoon (ISM). While, the Indian north-east monsoon, and the north and central India winter precipitation (NCIWP) directly correlated with ENSO.

Previous studies have shown that the strength of the ISM– ENSO tale-connection is quite dependent on the zonal position of the *El Nino* warming. Case studies belong to particular state like Andhra Pradesh and Gujarat was conducted on the implications of

El Niño episodes on crop production or productivity at district level (Rao *et al.,* 2011 and Patel *et al*., 2014).

La Nina is a climatological phenomenon akin to *El Nino*, but with opposite tendencies in the tropical Pacific Ocean and atmosphere. *La Nina* is characterized by stronger than normal trade winds and colder than normal tropical Pacific sea surface temperatures. It is also characterized by unusually high surface atmospheric pressure in the eastern tropical Pacific and low surface pressure in the western tropical Pacific in association with the Southern Oscillation. The cooling phase (*La Nina* episodes) is also termed as anti ENSO period. These signals resulted in ecological/economical disasters like heavy rains and floods in Pacific Coast of South America (Nicolls, 1991).

La Nina's effects on global weather are roughly opposite to those of *El Nino* .*La Nina* is the reverse of *El Nino* event and is triggered due to alteration of Sea Surface Temperature (SST) in Pacific Ocean. The *La Nina* cycle is a complex interaction between random atmospheric phenomenon and oceanic processes. In the *La Nina* event the trade winds push warm water to ward west and cause it to accumulate in the western Pacific.

The Walker circulation controls the atmospheric conditions and Climate variability. The Indian monsoon represents the typical seasonal signal and the anomalous monsoon heating has a large impact on local and remote circulations. The *El-Nino* has reported to have a significant impact on Indian monsoon rainfall.

It has also observed that the deficit rainfall occurs during the *El-Nino* years and excess during the *La-Nina* years. Keeping thus in view study was planned to find out the impact of *El-Nino* and *La-Nina* on rainfall in Punjab.

There have been many studies on impact of El Niño events on monsoonal rainfall at national level (Krishnamurthy and Goswami, 2000; Pai, 2003; Kane, 2005). Keshavamurthy (1982) concluded that there was no one to one relationship as El Niño years has not always produced severe droughts.

Materials and Methods

Analysis of past 41 year's teleconnections data was carried out to examine the effect of ENSO on regional rainfall variability in Punjab. The state of Punjab receives rainfall ranging from 1000 to 1100 mm in the north of the state and less than 300 mm annual rainfall extreme in south western Punjab.

The climate is generally very hot in summers and remarkably cold in winters. High temperatures of 45°C magnitude is recorded during the month of May in most parts of the sub-divisions, whereas, in winters the temperature goes down to -2 to -3°C for a few days.

Data

The mean monthly rainfall data were collected from school of climate change and agricultural meteorology, India Meteorological Department, Statistical Abstracts, Website of CRIDA. The historical crop production data was collected from the Indiastat.com and Bureau of Economics and Statistics. The data on the *El Nino* and *La Nina* episodes were collected from Climate Analysis Centre of NOAA and other agency/secondary data sources.

Data analysis

The data collected for *El-Nino, La-Nina* and rainfall were analysed using weather cock software. The data variability was quantified using the following statistical measures:

Standard deviation (SD)

Standard deviation of rainfall was calculated using the expression:

$$SD = \sqrt{\frac{\sum(X-\bar{X})^2}{n-1}}$$

Where- X is the actual value
- Mean value
SD- Sample standard deviation
n- Number of observation

Coefficient of variation (CV)

The coefficient of variation of rainfall was calculated using the formula -

$$CV = \frac{SD}{Mean} \times 100$$

Normal annual rainfall

It is average of long term (>30 years) rainfall in a region.

$$\text{Normal rainfall: } \frac{\text{Total rainfall of all years}}{\text{Number of years}}$$

Percent change in rainfall

The rainfall of El-Nino years was compared with the normal rainfall and the percent change in the rainfall was calculated as -

Percent Change = (rainfall of El-Nino years/ normal rainfall) × 100

Excess or deficient rainfall

The excess/deficit rainfall was calculated using the following expression-

Excess/ deficit rainfall (mm) = [(Actual rainfall- normal rainfall)/ normal rainfall] × 100

The positive value was considered as excess and negative value was taken as deficit rainfall. Graphical analysis was used to see the effect of rainfall variability on rice productivity during El-Nino and La-Nina years.

Results and Discussion

El Nino and *La Nina* episodes

The rainfall during the *El Nino* years was deficit during 9 occasions out of a total of 13 years at Gurdaspur and 10 times were deficit out of 15 *La Nina* years. Similarly at Ludhiana all the *El Nino* years were reported to be deficit year during the period under study where as 5 out of 10 *La Nina* years excess rainfall was reported and at 10 occasion deficit rainfall was reported at Ludhiana. The findings reported by Cheang (1993) while studying Malaysian rainfall corroborates the results of present study. During *El Nino* year Roop Nagar received deficit rainfall for 9 years out of 13 where as during *La Nina* years 12 out of 15years were deficit years. Bathinda reported deficit rainfall during 11 out of 13 *El Nino* years episode During the La Nina Bathinda received deficit rainfall 11 out of 15 did not follow the general trend (Table 1). Similarly work reported by Singh *et al.,* (2005) The El-Nino and La Nina episodes identified on the basis of specific criteria applied to sea surface temperature (SST) anomaly of peru Ecuador coast following Qunin *et al., (*1978) have been presented above criteria there were 9 El-Nino episodes, 8 La-Nina episodes and remaining 13 nautral year during the 30 years (1970-1999) study period (Table 1).

Excess and deficient rainfall

Annual rainfall analysis of *El Nino* year was done to find out the per cent change in *El Nino* year with respect to normal rainfall for various districts of Punjab. Parthasarathy *et al.,* (1993) also reported relationship between regional climatic parameters and monsoon rainfall on similar lines during the *El Nino* year rainfall was less by 26.82% at Amritsar, 32.8% at Bathinda, 24.04% at Ferozepur, 15.25% at Gurdaspur , 24.80 at Hoshiarpur, 33.25% at Jalandhar, 36.90% at Kapurthala, 47.88% at Ludhiana, 11.79% at Mansa, 31.74% at Moga, 6.5% at Muktsar, 14.9% at Patiala, 13.07% at RoopNagar, 28.26% at Sangrur. The Faridkot received 13.90% more rainfall than normal years (Table 2).

Similarly N. Manikandan *et al.,* (2016) also reported district wise percent change in annual rainfall during all El Nino years irrespective of its intensity. It can be seen that during all El Nino years, there is negative departure of annual rainfall in the range of -1 per cent to - 10 per cent in different districts of the State. However, there is positive deviation in Kanker district of about 1 per cent. In strong El Nino years, negative deviation in rainfall of -3 per cent (Jashpur) to -21 per cent (Dantewada) was observed.

Kumar *et al.,* (1999) had shown that the relation between the Indian monsoon and ENSO weakened in recent decades. In Bathinda districts of Punjab during the 10 El Nino years from 1981-2011 in which 5 years lower yield and other 5 years higher yield received as compare to average yield (3728 kg/ha). Similarly during the La-Nina years 6 years lower yield and other 6 years higher yield has been reported as compare to average yield. In Faridkot districts of Punjab during Similarly during the El-Nino years from 1981-2011 in which 5 years had lower yield and other 5 years had higher yield as compared to average yield (3668 kg/ha). Similarly during the La-Nina years in which 5 years had lower yield and other 7 years had higher yield as compare to average yield (Fig. 1 and 2).

Gupta *et al.,* (2000) reported major area of rice production is rain fed and therefore larger proportions of the variability in yields can be attributed to one of the main elements of the weather i.e. rainfall, in terms of quantum and its pattern of distribution during the monsoon months. It is obvious from that in most of the years rice production is in consonance with quantum of rainfall of monsoon months.

In Sangrur districts of Punjab during the 10 El Nino years from 1981-2011 in which 5 years had lower yield and other 5 years had higher yield as compare to average yield (3905 kg/ha). Similarly during 12 La-Nina years in which 7 years had lower yield and another 5 years had higher yield as compare to average yield. And there for has been affected by the El-Nino.

In Gurdaspur districts of Punjab during the 10 El Nino years in which 5 years had lower yield and other 5 years had higher yield as compare to average yield (2788 kg/ha) during 1980-2011. Similarly during 12 La Nina years, 7 years had lower yield and another 4 years had higher yield as compare to average yield and there for has been affected by the El-Nino.

Ramakrishna *et al.,* (2003) Most of the short term climate variability in tropics is related to the El-Nino/southern oscillation (ENSO) phenomenon, which influences/determines the location of tropical convection and ultimately changes the global atmospheric circulation. The Indian summer monsoon rainfall which is ultimate water resources for the agricultural production in India is known to significant relationship with the southern oscillation index (SOI). In Amritsar districts of Punjab during the 10 El Nino years in which 5 years had lower yield and other 5 years had higher yield as compare to average yield (2745 kg/ha) during 1980-2011.

Table.1 Frequency of excess/deficient rainfall at different locations in *El Nino* and *La Nina* episodes (1971-2011)

Locations	*El Nino* Episodes		*La Nina* Episodes	
	Excess	Deficient	Excess	Deficient
Gurdaspur	4	9	5	10
Ludhiana	0	13	5	10
Roop Nagar	4	9	3	12
Bathinda	2	11	4	11
Mean	2.5	10.5	4.25	10.75
SD	1.91	1.91	0.95	0.95
CV	76.59	18.23	22.52	8.90

Table.2 Per cent change in annual rainfall (mm) during the *El Nino* years from normal rainfall (1971-2011)

Districts	Rainfall (mm)		
	El Nino years	Normal years	Percent change
Amritsar	472	645.0	-26.82
Bathinda	295	439.0	-32.80
Faridkot	449	394.0	+13.95
Ferozpur	338	445.0	-24.04
Gurdaspur	868	1024.0	-15.25
Hoshiarpur	700	931.0	-24.81
Jalandhar	554	830.0	-33.25
Kapurthala	530	840.0	-36.90
Ludhiana	382	733.0	-47.88
Mansa	359	407.0	-11.79
Moga	329	482.0	-31.74
Mukatsar	359	384.0	-6.51
Patiala	611	718.0	-14.90
Roop Nagar	798	918.0	-13.07
Sangrur	363	506.0	-28.26
Mean	451.3	588.4	- 23.30
SD	206.6	263.9	- 21.80
CV	45.80	44.85	+ 2.18

Table.3 Locations receiving excess/ deficient rainfall during *El Nino* episodes (1971-2011)

El Nino	Location Received	
Year	**Excess Rainfall**	**Deficient Rainfall**
1972	--	Gurdaspur , Ludhiana, Bathinda, Roop Nagar
1976	Gurdaspur	Ludhiana, Bathinda, Roop Nagar
1977	Gurdaspur	Ludhiana, Bathinda, Roop Nagar
1982	Roop Nagar	Gurdaspur , Ludhiana, Bathinda
1986	Roop Nagar	Gurdaspur , Ludhiana, Bathinda
1987	--	Gurdaspur , Ludhiana, Bathinda, Roop Nagar
1991	--	Gurdaspur , Ludhiana, Bathinda, Roop Nagar
1994	Gurdaspur , Roop Nagar	Ludhiana, Bathinda
1997	Gurdaspur , Roop Nagar	Ludhiana, Bathinda
2002	--	Gurdaspur, Ludhiana, Bathinda, Roop Nagar
2004	--	Gurdaspur, Ludhiana, Bathinda, Roop Nagar
2006	--	Gurdaspur, Ludhiana, Bathinda, Roop Nagar
2009	--	Gurdaspur, Ludhiana, Bathinda, Roop Nagar

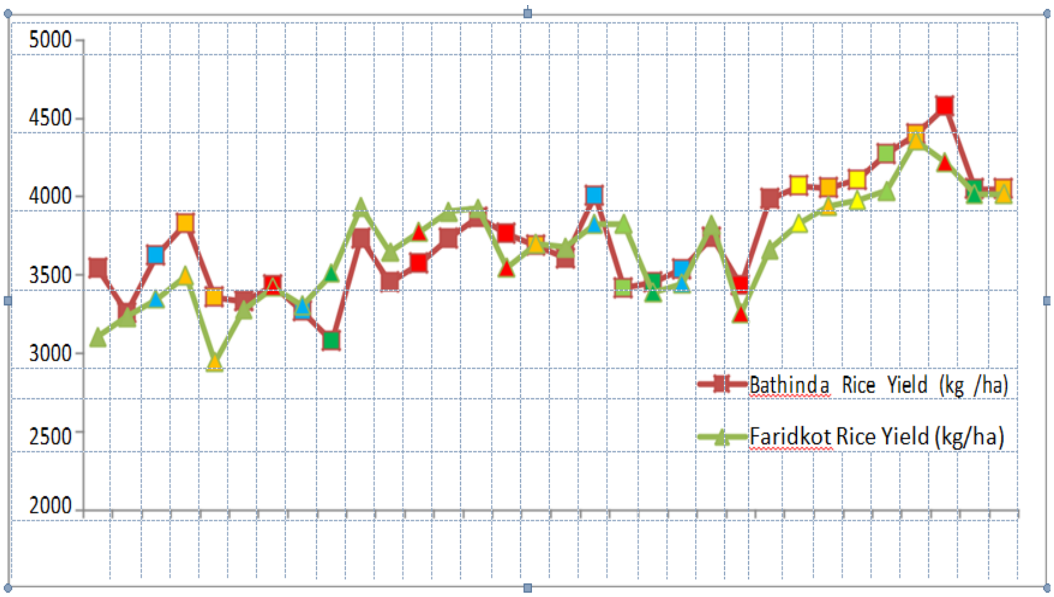
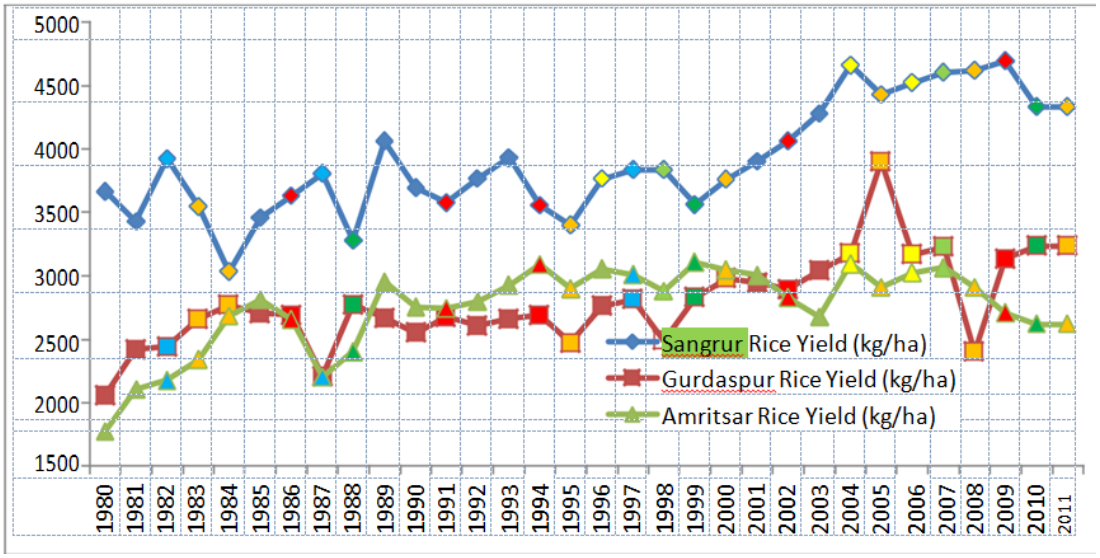


Fig.1 Impact of El-Nino and La-Nina on rice productivity in Bathinda & Faridkot



Sky blue colour denote - Strong El Nino, Red colour -Moderate El Nino, Yellow colour - weak El Nino, Dark Green -Strong La Nina, Light Green -Moderate La Nina, Orange- Weak La Nina

Fig.2 Impact of El-Nino and La-Nina on rice productivity in Sangrur, Gurdaspur and Amritsar

Similarly during 12 La Nina years, 7 years had lower yield and another 4 years had higher yield as compare to average yield. The *El Nino* years rainfall was excess at Gurdaspur in 1976, 1977, 1994 and 1997. However, Roop Nagar rainfall was excess in 1982, 1986, 1994 and 1997.

Gurdaspur, Ludhiana, Bathinda and Roop Nagar received deficit rainfall during 1972, 1976, 1979, 1987, 1991, 2002, 2004, 2006 and 2009. Gurdaspur received deficit rainfall in 1982 and 1986 also. During the *La Nina* year Gurdaspur, Ludhiana and Roop Nagar received excess rainfall in 1971 and 1988. Ludhiana and Gurdaspur both received excess rainfall in 1971, 1983, 1988 and 1995 contrary to the trend (Table 3).

Singh Surender *et al.,* (2005) also reported the different locations in the sub-division with excess/deficient rainfall under El-Nino episodes have been given. During El-Nino years of 1976 and 1995 only many locations received excess monsoon rainfall. These observations were country to the strong association between El-Nino episodes and deficient Indian summer monsoon rainfall. Episodes 1982 and 1987, many locations experienced deficient monsoon rainfall.

Based on the above results it is concluded that 69 percent El-Nino years received deficit rainfall and 57 percent La-Nina years received excess rainfall. El-Nino episodes had more effects on rainfall in Punjab than La-Nina episodes. El-Nino and La-Nina episodes had non-significant effect on rice productivity because of artificial irrigation in Punjab.

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