# Weekly response of Rainfall, Soil wetness and Soil Moisture Adequacy over India to ENSO/LNSO events

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**Abstract**

A study on water budget elements has great importance in understanding the agricultural performance. The estimation and analysis of Soil wetness and Soil Moisture adequacy is very useful in understanding the mechanisms involved in the crop growth and yield. The present paper concentrates in understanding the weekly affectivity of ENSO/LNSO on Rainfall, Soil wetness and Soil Moisture adequacy over India and selected stations that are drawn from the climate spectrum of India during the south-west monsoon period of 1951-1980, 1981-91 and 1992-98. The soil wetness and soil moisture adequacy are derived from the water balance model on a weekly basis.

**Keywords:** Soil wetness, Soil moisture adequacy, ENSO/LNSO, SOI, SST of Nino3

**Introduction:** India being an agrarian country, its economic scenario and its growth is modulated by the agricultural performance which depends upon the south-west monsoon rainfall. The soil wetness and soil moisture adequacy will play an important role in sustenance of the crops in the absence of rains as well as in dry situations. To suggest a suitable cropping pattern and for better yields it is necessary to have knowledge of the prevailing environment with respect to the crops. The soil moisture that is necessary for the sustenance of a crop or a vegetation species can be derived from the knowledge of index of moisture adequacy. As the rainfall alone cannot give the picture of the moisture available to the root zone and crop performance, the soil moisture adequacy is taken into consideration to estimate the available soil moisture at the root zone and crop performance. The ratio of actual evapotranspiration to potential evapotranspiration expressed, as a percentage is known as soil moisture adequacy, which varies with the available soil moisture and indicates the soil moisture status of the soil and to be considered in studying the agricultural development of the region. It also speaks about, whether the rainfall is meeting the water need or not.

Torrence and Webster (1998) have reported the consistency in the annual cycle of ElNino and Southern Oscillations. The affectivity of LANINA- Southern Oscillation and ElNino Southern Oscillation signals on the hydrological cycle of India has been reported by Sarma, Srinivas & Karthikeyan (2005). The influence of ocean atmospheric interactions on Indian monsoon circulation, hydroclimatic parameters such as humidity, moisture and aridity indices, length and vagaries in growing periods have been reported by Sivaram and Sarma (2010, 2011).

The soil wetness and soil type has a considerable role in studying the agricultural droughts. The amount of moisture actually present in the soil reflects the antecedent meteorological conditions; soil characteristics and the level of agronomic techniques at any given instant of time are in use in the region (Kulik, 1958). Taking soil moisture content as a criterion Rodda (1965, 1969) made a study of droughts in southeast England. He calculated soil moisture, drought index as a deviation value of available soil moisture and the amounts of runoff and percolation.

The soil wetness is the ratio of the soil water storage and the maximum water holding capacity of the soil or field capacity, which can be derived through the revised water balance mode of Thornthwaite & Mather (1955).

Soil wetness influences the atmosphere by altering the partitioning of the outgoing energy flux at the surface into latent and sensible heat components. Fluctuations of soil moisture result in large variations in these fluxes, and thus significant variations in near surface relative humidity and temperature (Thomas Delworth and Syukuro Manabe, 1989).

The effect of soil wetness on the atmospheric corbandioxide was studied and reported (Manabe and Wetherald, 1986).

The strength of the impact of initial soil wetness differences, as well as the nature of the impact on precipitation and other atmospheric fields, depends on several factors. These factors include the aerial extent and magnitude of the initial soil wetness difference, the persistence of the soil wetness difference, the strength of the solar forcing, the availability of nearby moisture sources, and the strength of the regional dynamical circulation. The results suggest that seasonal atmospheric prediction could be enhanced by using a realistic initial state of soil wetness (Fennessy & Shukla, 1999)

Subrahmanyam (1983), using the concept of moisture adequacy index (IMA) delineated 29 agro ecological zones of India with the possible 36 combinations. Sehgal et.al, (1987) prepared a computerized bio-climatic map of Northwest India, based on the criteria of dry month.

Thorat (2002) found that evapotranspiration and crop coefficient (ET/PET) has lowest values during the harvesting phase.

It was reported that the moisture adequacy index has potentiality to estimate the agricultural potential in terms of irrigation requirements, land use planning and formation of cropping patterns to make best use of available resources (Bishnol et.al, (1995)).

It is widely reported that the ocean–atmospheric interactions through the sea surface temperatures of Nino3 region and Southern Oscillation Index, influence the south-west monsoon circulation pattern that modulates the date of onset, amount of rainfall, continuity and duration of the monsoon (Ropelewski & Halpert, 1996; Smith & Ropelewski, 1997). Chaudhury and Mhasawade (1991) have investigated association between El Nino and rainfall and droughts in India.

The present study illustrates the affectivity of ENSO/LNSO on the precipitation, soil wetness and soil moisture adequacy over India and on the selected stations from the climate spectrum of India during the monsoon period on a weekly basis.

**Material & Methodology:** The revised water balance concept of Thornthwaite & Mather (1955) is followed in computing the water budget elements for 90 stations that are drawn from varied geographical settings of India based on the Normals of Agroclimatic Observatories India (IMD) and the data supplied by the IMD, PUNE on a weekly basis for the standard monsoon period ($22^{nd}$ week to $39^{th}$ week) (Gore & Thapliyal, 1999).

The soil wetness of All India as well as the selected stations from the climate spectrum of India is estimated as the percentage ratio of water storage to field capacity.

i.e., Soil wetness $S_{wt} = (St/Fc)*100$.

The index of moisture adequacy is the ratio of actual evapotranspiration to potential evapotranspiration expressed, as a percentage.

The weekly march of precipitation, soil wetness and moisture adequacy of All India in relation to SOI and SST Nino 3 have been plotted and presented to understand the weekly affectivity of SOI and SST Nino 3 on soil wetness and moisture adequacy. The correlation and regression analysis for the precipitation, soil wetness, moisture adequacy in relation to SOI and SST Nino 3 has been studied and presented.

**Results and Discussion:**

**a) All India Mean weekly precipitation, soil wetness and soil moisture adequacy:** It is evident from the Table -1 that the normal precipitation, soil wetness and soil moisture adequacy are 57mm, 74% and 98%. It is observed that during 1981-91 there is an increase in precipitation by 28% that resulted an increase in soil wetness by 14% and soil moisture adequacy by 1% from the respective normal. During the monsoon period of 1992-1998 All India has experienced 66 mm rainfall, 84% soil wetness and 98% soil moisture adequacy that shows an increase in these rainfall by 15%, accompanied by an increase in soil wetness by 14%, but no change in soil moisture adequacy. An impact of LNSO can be seen from a rise in precipitation, soil wetness and soil moisture adequacy by 30%, 4% and 2%. Depreciation in rainfall by 23% that resulted a drop in soil wetness by 15% and soil moisture adequacy by 2% are associated with an ENSO.

**b) Pehumid Zone:** From the selected two stations of Perhumid Zone there was an increase in the rainfall by 18% accompanied by a rise in the soil wetness by 7% at Chaubatia during LNSO year. Chaubatia witnessed a depreciation in rainfall by 39% that resulted a fall in soil wetness by 1% and soil moisture adequacy by 4% during ENSO year from their respective normal.

In the LNSO year Karjat witnessed an increase in the precipitation by 6%, as a result the soil wetness increased by 2% and soil moisture adequacy shot up by 7% from the normal. On the other hand, in the ENSO year it has experienced depreciation in rainfall, soil wetness and soil moisture adequacy by 35%, 3% and 7% respectively from the corresponding normal.

**c) Humid Zone:** In the present study Bhubaneswar and Adhartal are representing the Humid Zone. It is observed that Bhubaneswar witnessed an increase in precipitation by 13%, soil wetness by 10% and soil moisture adequacy by 4% during an LNSO year and a decrease rainfall by 33%, soil wetness by 22% and soil moisture adequacy by 20% in the ENSO year from their normal values.

Adhartal experienced depreciation in precipitation by 10% and 16% during ENSO and LNSO years respectively. As a result, there is a fall in soil wetness by 6% and 3%, soil moisture adequacy by 7% and 10% respectively from the normal values.

**d) Moist subhumid Zone:** It is evident from the Table.1 that Junaghar experienced 71% increase and 2% decrease in rainfall during the LNSO and ENSO years respectively from the normal. As a result there is a 4% increase in soil wetness during LNSO year and the same amount of soil wetness depreciation observed during ENSO year. The soil moisture adequacy increased by 12% and decreased by 7% during LNSO and ENSO years respectively from the normal.

Parbhani witnessed depreciation in soil wetness by 13%, soil moisture adequacy by 29% due to a depreciation in the rainfall by 25% from normal during an ENSO year. On the other hand in the LNSO year, there is an increase in the soil wetness by 22% due to an excess amount of rainfall by 102%, but soil moisture adequacy maintained its normal status.

**e) Dry sub humid Zone:** It is observed that Jhansi from Dry sub humid zone has witnessed 10% depreciation in rainfall during an ENSO year that resulted a 24% fall in soil wetness and 23% dip in the soil moisture adequacy from the normal. During an LNSO year there is no effect on the rainfall but a 15% rise in soil wetness accompanied by 7% fall in soil moisture adequacy can be seen from Table.1.

Anakapalli that hails from Dry sub humid Zone experienced an increase in soil wetness by 253%, in association with an increase in precipitation by 94%, but a fall in soil moisture adequacy by 12% from the respective normal during the LNSO year. In the ENSO year, a though there is a depreciation in precipitation by 19%, an increase in the soil moisture adequacy by 20% accompanied by an increase in soil wetness by 100% from the normal.

**f) Semi arid Zone:** Jodhpur representing the semi arid zone experienced depreciation in precipitation by 80%, soil wetness by 67% and soil moisture adequacy by 84% during the ENSO year. It has also experienced 25% fall in rainfall, which resulted a dip in the soil wetness by 33% and soil moisture adequacy by 30% from the corresponding normal values in the LNSO year.

**Correlation Analysis:** A multiple correlation and regression analysis between SST of Nino3, SOI and agro climatic parameters such as precipitation, soil wetness and soil moisture adequacy are obtained during the south west monsoon period of 1992-1998 (Table.2). It is evident that there is a negative impact of SOI and positive impact of SST, SOI and SST on Indian summer monsoon rainfall which is explainable from the correlation coefficients with SOI, SST and SOI & SST and precipitation. The explainability of soil wetness with SOI, SST is evident from the positive and negative correlation coefficients respectively. The joint or combined affectivity of SOI & SST on soil wetness is very high, evident from the correlation coefficient 0.7983. It is also observed prevalence of decreasing and increasing soil moisture adequacy with rise in SOI and fall in SST of Nino 3. The SOI coupled with SST of Nino 3 is showing much effect on soil moisture adequacy than the individual effect.

**March of All India Precipitation, soil wetness and soil moisture adequacy in response to SOI, SST of NINO 3 during 92-98**: The All India mean weekly soil wetness showed an increasing trend with rising SOI accompanied by falling SST in the first half of each monsoon period and decreasing trend in the rest of the period. The fluctuation in the soil wetness might be due to the monsoon circulation patterns that are affected by SOI and SST of Nino 3. The joint correlation coefficient of mean weekly soil wetness during the monsoon period with SOI and SST of Nino 3 is 0.7983 shows that there is a strong affect of ocean atmospheric interaction on the All India mean weekly soil wetness (Fig.1a &1b).

There is an increasing trend in the All Indian mean weekly soil moisture adequacy in the first half and a downward trend in the second half of the selected monsoon periods due to the prevailed signal from the coupled ocean atmospheric interaction. It is also observed that the prevalence of decreasing and increasing trends in soil moisture adequacy with the rise and fall of SST of Nino 3 respectively. The explainability of soil moisture adequacy with SOI and SST of Nino 3 was 0.22 jointly (Fig.1c & 1d).

From the aforesaid observation it can be concluded that the joint affectivity of SOI & SST of Nino 3 on the mean weekly derived agro climatic parameters such as precipitation, soil wetness and soil moisture adequacy is moderate.

**Summary and Conclusions:** All India mean weekly soil wetness and soil moisture adequacy increased during the monsoon periods of 1981-1991, 1992-1998 and in LNSO year 1988, decreased in the ENSO year 1987. The fluctuations in these agro climatic parameter may be due to the vagaries in the respective monsoonal rainfall.

In the Perhumid zone, Humid Zone soil wetness and soil moisture adequacy showed increasing trends during the monsoon periods of ENSO and LNSO years. From the Moist subhumid zone, Junagarh experienced an increase in soil wetness and soil moisture adequacy during ENSO year and decrease in LNSO year. The Dry subhumid and semi arid climates experienced a rise in soil wetness and soil moisture adequacy during an LNSO year and a fall in these parameters in ENSO year.

In the trend analysis through third degree polynomial fit, it is observed that the All India weekly soil wetness is increasing with increasing SOI accompanied by falling SST of Nino 3. The affect of ocean atmospheric interaction on All India weekly soil wetness is very high, which is evident from the joint correlation coefficient 0.7983.

The combined affect of SOI and SST of Nino 3 on All India mean weekly soil moisture adequacy is moderate that can be seen from the correlation analysis. The All India mean weekly soil moisture adequacy is showing an increasing trend with decreasing SOI, combined with increasing SST of Nino 3 that can be witnessed from the joint correlation coefficient of 0.22.

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***Table. 1. Mean weekly Precipitation, Soil Wetness & Soil moisture Adequacy of All India and selected stations– Monsoon period – Extremities***

| S.No. | Station | Year | Precipitation (P) mm | Soil Wetness (%) | Soil moisture Adequacy (%) |
|---|---|---|---|---|---|
| | | Longterm (1951-1980) | 57 | 74 | 98 |
| 1. | **All India** | 1981-1991 | 73 | 84 | 99 |
| | | 1992 – 1998 | 66 | 84 | 98 |
| | | Enso Year (1987) | 44 | 63 | 96 |
| | | Lnso Year (1988) | 74 | 77 | 100 |
| | **Perhumid Zone (A)** | | | | |
| | | Longterm (1951-1980) | 61 | 91 | 100 |
| 1. | Chaubatia | Enso Year (1987) | 37 | 90 | 96 |
| | | Lnso Year (1988) | 75 | 98 | 100 |
| | | Longterm (1951-1980) | 185 | 87 | 97 |
| 2. | Karjat | Enso Year (1987) | 121 | 90 | 90 |
| | | Lnso Year (1988) | 196 | 89 | 90 |
| | **Humid Zone (B)** | | | | |
| | | Longterm (1951-1980) | 63 | 69 | 97 |
| 1. | Bhubaneswhwar | Enso Year (1987) | 42 | 54 | 78 |
| | | Lnso Year (1988) | 55 | 62 | 93 |
| | | Longterm (1951-1980) | 67 | 70 | 89 |
| 2. | Adhartal | Enso Year (1987) | 60 | 66 | 83 |
| | | Lnso Year (1988) | 56 | 68 | 80 |
| | **Moist subhumid Zone ($C_2$)** | | | | |
| | | Longterm (1951-1980) | 45 | 67 | 84 |
| 1. | Junagarh | Enso Year (1997) | 46 | 70 | 90 |
| | | Lnso Year (1988) | 77 | 64 | 74 |
| | | Longterm (1951-1980) | 44 | 53 | 91 |
| 2. | Parbhani | Enso Year (1987) | 33 | 46 | 65 |
| | | Lnso Year (1988) | 85 | 75 | 91 |

***Table. 1. Mean weekly Precipitation, Soil Wetness & Soil moisture Adequacy of All India and selected stations– Monsoon period – Extremities (continued)***

| | | | | | |
|---|---|---|---|---|---|
| | **Dry subhumid Zone ($C_1$)** | | | | |
| | | Longterm (1951-1980) | 40 | 46 | 81 |
| 1. | Jhansi | Enso Year (1987) | 36 | 35 | 62 |
| | | Lnso Year (1988) | 40 | 53 | 75 |
| | | Longterm (1951-1980) | 32 | 13 | 81 |
| 2. | Anakapalli | Enso Year (1987) | 26 | 26 | 65 |
| | | Lnso Year (1988) | 62 | 46 | 71 |
| | **Semi Arid Zone (D)** | | | | |
| | | Longterm (1951-1980) | 20 | 3 | 50 |
| 1. | Jodhpur | Enso Year (1987) | 4 | 1 | 8 |
| | | Lnso Year (1988) | 15 | 4 | 35 |

**Table 2. Correlation coefficients of agro meteorological parameters with SOI and SST of Nino 3 – Monsoon period - 1992 – 1998.**

| S.No. | Parameter (X) | Correlation Coefficient with | | |
|---|---|---|---|---|
| | | SOI | SST | SOI & SST |
| 1 | Precipitation (P) | -0.064 | 0.113 | 0.19 |
| 2. | Soil wetness (SW) | 0.087 | -0.457 | 0.7983 |
| 3. | Soil moisture adequacy (Adq) | 0.12 | -0.47 | 0.22 |

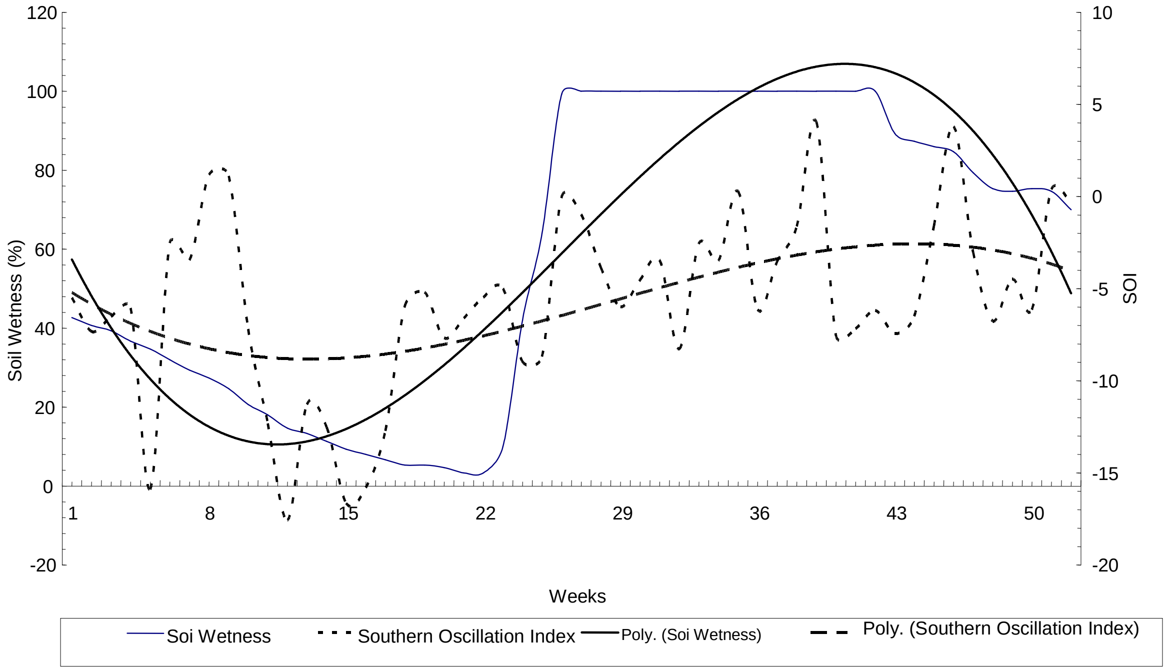


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Fig.1a . March of All India mean weekly soil wetness (%) and SOI for the period 1992-1998.

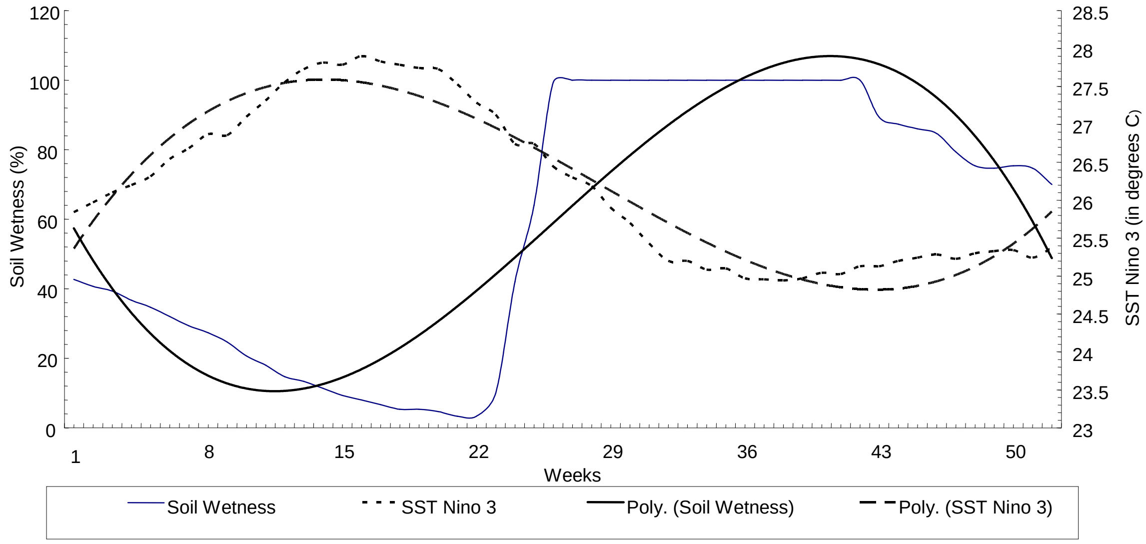


Fig.1b. March of All India mean weekly soil wetness (%) and SST Nino 3 (in degrees C) for the period 1992-1998

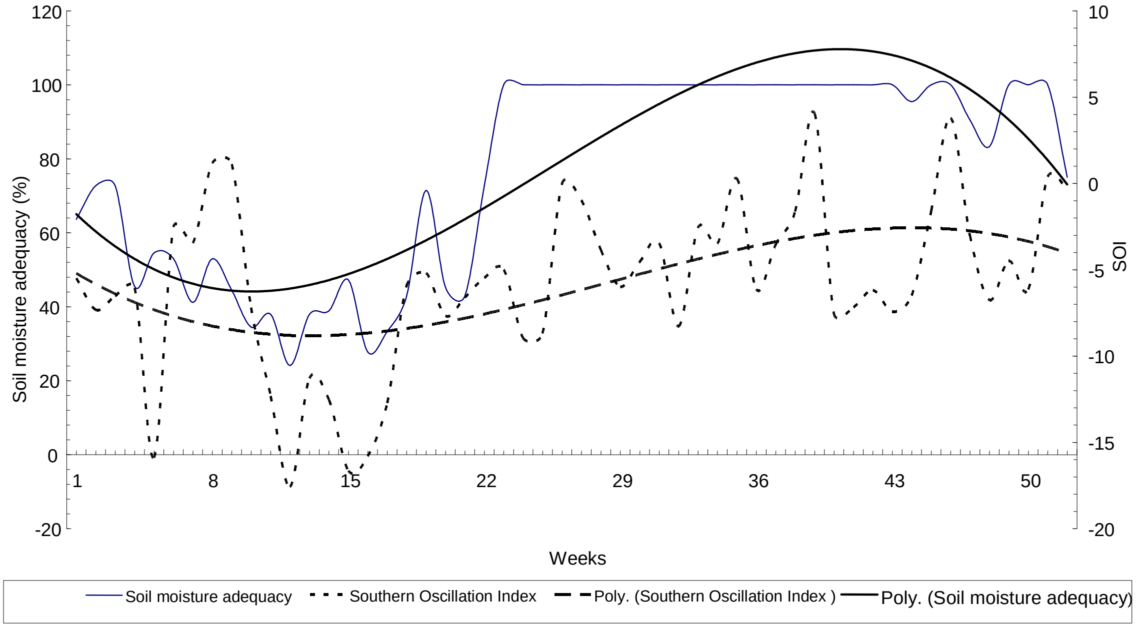


Fig.1c. March of All India mean weekly soil moisture adequacy (%) and SOI for the period 1992-1998.

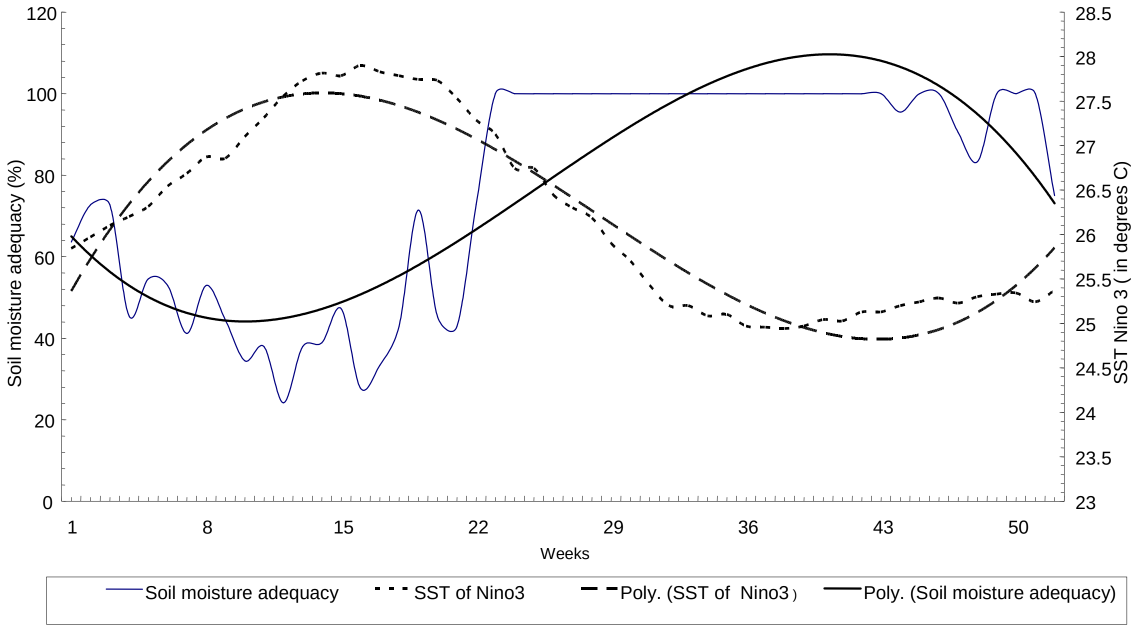


Fig.1d. March of All India mean weekly soil moisture adequacy (%) and SST of Nino 3 for the period 1992-1998.