Vol. 14, No. 1, pp. 50-55 (2014)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Changes in Monsoon Rainfall Pattern in a few Agro-ecological Sub-Regions

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ABSTRACT

Impacts of climate change are likely to inflict more damage in developing and under-developed countries and these will not be uniform across the regions. Hence, it is essential to study the change at regional/ local level. In this paper, we have studied the behaviour of rainfall during the summer monsoon period using standardized precipitation index (SPI) at diversified locations under different agro-ecological sub-regions. This index has the advantage of monitoring and detecting both droughts and floods at different time scales and is also spatially invariant. This is a comparative study, involving gridded data, at two temporal levels: baseline (1951-1990) and current (1991-2007) period. The analysis revealed complete reversal of monsoon rainfall pattern in some locations and change in magnitude of wetness/dryness during *kharif* and affecting the normal course of agricultural practices.

Key words: Standardized precipitation index, Monsoon, Drought, Agro-ecological sub-region

Introduction

India is unique in climatic diversity across its length and breadth. The country receives rainfall due to occurrence of localized atmospheric systems, but the major sunk of annual rainfall is contributed by a seasonal global circulation system called Indian monsoon. The behaviour of monsoon fluctuates every year and plays a vital role in hydrology and there by performance of agriculture and animal husbandry practices in the country.

Climate change impacts on agriculture are being witnessed all over the world, but countries like India are more vulnerable in view of its dependence on agricultural activities and population pressure on natural resources. In India, skewed rainfall distribution has become common in these days with reduction on number of rainy days. Aberrations in monsoon like delay in onset, long dry spells and early withdrawal strongly influence the crop productivity (Lal, 2001; Krishna Kumar, 2009). Rainfed agriculture in India is likely to be more vulnerable in view of its high dependency on monsoon. Nearly 85 Mha net sown area is rainfed. It falls mainly in arid, semi-arid and dry sub-humid zones, where the farmers are generally resource-poor and the extent of farming is subsistance to medium in nature.

There are few studies on climate change involving methods which enable spatially invariant analyses and thus, interpretation of the results. The standardized precipitation index (McKee *et al*., 1993) is one such procedure that

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can be used to detect chnages in pattern of dryness or wetness over various time scales and it is also spatially invariant. In this study, we discuss how the rainfall pattern during the monsoon has changed in recent time using SPI at monthly and seasonal time scales. For this, we have selected a few diversified locations representing different agro-ecological sub-regions (AESRs).

Materials and Methods

Twelve locations from different parts of India were selected for this analysis based on availability of historical bio-physical information as well as to represent the major agro-ecological sub-regions (AESR, Gajbhiye and Mandal, 1983) of India. The locations were *viz.*, Akola, Anand, Bangalore, Kanpur, Ludhiana, Dapoli, Mohanpur, Bijapur, Anantapur, Jorhat, Jabalpur and Samastipur. These locations belongs to different agro-ecological sub-regions, ranging from hot arid to per-humid conditions. The pattern of rainfall distribution and cropping have also varied widely among the locations. Contribution of monsoon rainfall is 57-66% at Bangalore, Bijapur, Ludhiana, Anantapur and Jorhat, where as it is as high as 72-94% at Mohanpur, Samastipur, Akola, Kanpur, Jabalpur, Anand and Dapoli. These show any change in normal rainfall pattern have deep and irreversible impact on the agricultural scenario of these regions. Except Ludhiana, mode of cultivation of crops in other locations is mostly rainfed. Bio-physical attributes of study locations under various locations and their AESR categories have been presented in Table 1.

The SPI represents the total difference of precipitation for a given period of time from its climatological mean and then normalized by the standard deviation of precipitation for the same period computed using data over the entire period of the analysis. Long-term precipitation record was fitted to a probability distribution, which was then transformed into a normal distribution so that the mean SPI for the location and desired period became zero. Positive SPI values indicate greater than median precipitation, while negative values indicate less than median precipitation. A drought event occurs when SPI values are continuously negative and reaches to an intensity where the SPI is -1.0 or less. The event ends when the SPI becomes positive. Thus, duration and intensity of drought was precisely defined.

Long-term daily gridded rainfall dataset (1951 to 2007) from India Meteorological Department (Rajeevan *et al*., 2006) was used. To detect anomaly, rainfall data was divided into two time spells: baseline (1951-1990) and current (1991-2007) period. The choice of baseline period has often been governed by availability of the required climate data and the period between 1961-1990 has been identified as a suitable baseline period by many researchers (Hulme *et al*., 1999).

Trend of seasonal and monthly SPI from June to September for baseline (40 years) and current (17 years) periods were analyzed using Mann-Kendall test (Mann, 1945; Kendall, 1975). Statistical significance of time series at 1% ($P<0.01$) and 5% ($P<0.05$) levels of probabilities were considered for the respective Z-values of Mann-Kendall test.

Results and Discussion

Trend of seasonal and monthly rainfall during monsoon

Our analysis suggests that all the locations have undergone some sort of changes in recent period compared to the baseline period (Fig. 1). A complete reversal of trend, from a regime of dryness (negative values) to wetness (positive values), is observed in Akola, Ludhiana, Dapoli and Mohanpur ($P<0.01$). Besides, seasonal wetness has further been increased in Anand and Bijapur. On the other hand, complete reversal from wet to dry regime is observed in Jorhat. Further, the degree of wetness reduced in Bangalore, Kanpur, Anantapur and Samastipur. Degree of dryness has further increased in case of Jabalpur. The trend indicates that the above places are likely to receive either greater or lesser rainfall during the recent monsoon months compared to their respective baseline period. This may invite suitable change in usual crop option and management schedule of the farmers in these places.

Table 1. Bio-physical attributes of study locations

Location	Agro-ecological sub-region	Latitude/ longitude/ altitude	Soil type	Average annual rainfall (mm)	Average rainfall during summer monsoon season (June-September) (mm)	Major crops grown during summer monsoon season
Akola	Hot moist semi-arid	20°42' N/77°02' E/272 m	Clayey black soils	819	692	Cotton, Pulses
Anand	Hot moist semi-arid	22°33' N/ 72°58' E/ 45 m	Clayey black soils	837	785	Groundnut, Pigeon pea
Bangalore	Hot moist semi-arid	12°58' N/ 77°35' E/ 930 m	Red loamy soils	937	539	Finger millet, Groundnut, Pigeon pea
Kanpur	Hot moist semi-arid	26°26' N/ 80°22' E/126 m	Loamy soils	898	782	Rice, Sorghum
Ludhiana	Hot semi-arid	30°56' N/ 75°52' E/ 247 m	Loamy soils	868	551	Rice, Soybean, Groundnut, Sunflower, Green gram
Dapoli	Hot moist sub-humid to humid	17°46' N/ 73°12' E/250 m	Loamy to clayey red and lateritic soils	2700	2539	Rice, Black gram, Soybean, Groundnut
Mohanpur	Hot moist sub-humid	21°52' N/ 87°26' E/10 m	Loamy to clayey soils	1715	1244	Rice
Bijapur	Hot arid	16°49' N/ 75°43' E/594 m	Loamy to clayey soils	646	398	Pearl millet, Sunflower
Anantapur	Hot arid	14°41' N/77°37' E/350 m	Loamy to clayey soils	594	383	Groundnut, Pigeon pea
Jorhat	Warm to hot per humid	26°47' N/ 94°12' E/86 m	Loamy soils	1723	1135	Rice
Jabalpur	Hot dry sub humid	23°09' N/ 79°58' E/ 393 m	Clayey black soils	1331	1182	Soybean, Chickpea
Samastipur	Hot dry to moist sub-humid	25°53' N/85°48' E/52 m	Loamy soils	1192	996	Rice

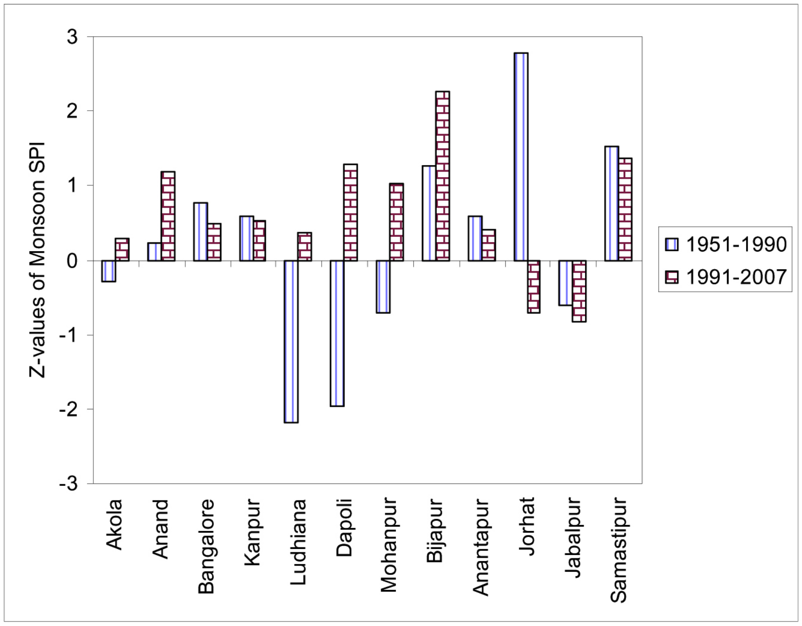

Fig. 1. Change in seasonal monsoon wetness/dryness trend, as depicted by Z-values of monsoon SPI, for different locations in two time scales, 1951-1990 and 1991-2007

A better picture of rainfall distribution pattern change within a season evolves when the analysis was done at monthly level (June to September) (Table 2). During June, dryness is increasing in Akola, Bangalore, Mohanpur, Anantapur, Jorhat and Samastipur. These locations may face problems of delayed sowing or transplanting of crops due to insufficient soil moisture availability. On the contrary, excessive wetness during July in Bangalore ($P<0.01$) and Kanpur ($P<0.05$) may lead to problem of water stagnation in standing crop. Similar situation may occur in Anand

Table 2. Change in monthly wetness/dryness trend, as depicted by Z-values of monthly SPI during the monsoon season for different locations in two time scales, 1951-1990 and 1991-2007

	Z-value of Mann-Kendall test							
	1951-1990				1991-2007			
	June	July	August	September	June	July	August	September
Akola	-0.07	-1.247	1.084	-0.781	-0.618	-0.206	0.371	0.494
Anand	0.221	-0.408	0.932	-1.025	1.277	-0.700	1.812*	0.206
Bangalore	-0.699	-0.501	-0.513	1.293	-1.607*	2.183**	0.206	0.082
Kanpur	0.291	1.689	-1.363	1.142	0.865	1.771*	-0.453	-0.865
Ludhiana	0.210	-2.19*	-1.55	-1.363	0.783	0.124	0.206	0.536
Dapoli	0.722	-2.75**	-0.594	-0.816	1.565	-1.030	1.442	0.989
Mohanpur	0.454	0.513	-1.270	-1.386	0	0.247	0.700	1.607*
Bijapur	1.829	-1.713	0.594	0.990	0.577	1.03	2.183**	1.359
Anantapur	-0.408	-0.443	-0.105	0.699	-0.536	1.236	0.947	0.989
Jorhat	0.513	3.868**	-0.186	1.806	-0.700	0.330	0	-1.195
Jabalpur	1.049	-0.816	0.652	-1.142	1.359	-0.165	-1.771*	0.330
Samastipur	0.629	2.284*	0.711	-0.058	0.783	1.524	-0.741	-1.195

* and ** indicates statistical significance at $P<0.05$ and $P<0.01$ levels, respectively ('+' for increasing and '–' for decreasing trend)

($P<0.05$) and Bijapur ($P<0.01$) during August and Mohanpur ($P<0.05$) during September. Ludhiana, Mohanpur and Bijapur are likely to become wetter. Jorhat and Samastipur are vulnerable to drought of varying extent during late season *i.e.*, September.

Detecting rainfall variability through change in range of SPI

During June 1991-2007, all locations have recorded reduction in extreme negative values, barring Jorhat and Jabalpur (Table 3). Jorhat and Jabalpur observed extreme dry events during 1991-2007 period, which were absent during previous years (1951-1990). On the other hand, Bijapur, Anantapur and Samastipur have recorded extreme wet events during 1991-2007, which were absent earlier. Wider range of SPI during 1991-2007 has also been observed during the month of July at few locations. During July, Anand, Dapoli, Jorhat and Jabalpur have recorded extreme dry events in some of the years. In contrast, Bangalore, Bijapur and Anantapur have recorded extreme wet events, which are well in excess of minimum limit of extreme conditions.

Compared to June and July, August had lesser fluctuations in SPI at most of the locations during 1991-2007. Even Jorhat, which is drifting towards drier climate in June and July, has experienced a wetter condition in August. During September, the range of SPI continued to reduce at Akola, Anand, Kanpur, Ludhiana, Mohanpur, Jabalpur and Samastipur. Jorhat turned back again to a wider range of SPI with more negative values during this month. In general, June and July have experienced wider rainfall variability as compared to August and September during 1991-2007.

From seasonal SPI, it is clear that the climate change impact is not necessarily spatially uniform. Some low rainfall semi-arid regions have become wetter, where as some wetter locations are now receiving lesser rainfall. The crops react differently to the instant weather conditions depending on the phenological stage it has achieved and that depends on there inherent mechanism of natural adaptability. According to a study, production of rice, maize and wheat in

Table 3. Observed change in range of SPI in two time spells, 1951-90 and 1991-2007 in different locations

	Range of SPI							
	June		July		August		September	
	1951-1990	1991-2007	1951-1990	1991-2007	1951-1990	1991-2007	1951-1990	1991-2007
Akola	-2.69 to 2.43	-2.07 to 1.70	-2.24 to 2.64	-2.05 to 1.55	-1.67 to 2.45	-2.31 to 2.40	-1.71 to 2.15	-2.01 to 1.88
Anand	-1.62 to 2.16	-1.62 to 2.66	-1.86 to 1.87	-4.01 to 1.60	-2.89 to 2.16	-1.97 to 2.40	-1.62 to 2.22	-1.62 to 2.07
Bangalore	-2.57 to 1.81	-2.07 to 1.92	-2.11 to 1.08	-1.15 to 4.93	-1.90 to 1.37	-1.93 to 3.51	-1.58 to 2.19	-2.30 to 2.63
Kanpur	-3.28 to 2.16	-1.62 to 0.94	-2.61 to 2.07	-2.61 to 1.5	-2.33 to 1.53	-1.60 to 1.72	-2.77 to 2.06	-1.67 to 1.38
Ludhiana	-2.11 to 1.59	-1.24 to 1.84	-1.93 to 2.78	-1.80 to 1.59	-1.87 to 1.85	-2.55 to 1.81	-1.47 to 2.73	-1.08 to 1.73
Dapoli	-2.26 to 2.02	-1.87 to 1.25	-1.94 to 2.31	-2.33 to 1.57	-1.92 to 2.80	-2.14 to 2.11	-1.52 to 1.42	-1.96 to 4.61
Mohanpur	-2.07 to 2.24	-0.96 to 1.72	-2.10 to 1.33	-1.80 to 2.39	-2.11 to 1.67	-1.69 to 2.66	-2.56 to 2.21	-2.47 to 1.47
Bijapur	-2.69 to 1.80	-0.88 to 2.40	-1.50 to 1.87	-1.63 to 3.34	-2.54 to 1.58	-1.26 to 1.94	-2.80 to 2.02	-1.64 to 1.60
Anantapur	-2.64 to 1.78	-1.63 to 2.37	-1.28 to 2.48	-1.73 to 4.45	-2.28 to 1.30	-1.07 to 2.92	-1.86 to 1.68	-2.98 to 2.06
Jorhat	-1.62 to 1.86	-3.46 to 0.91	-3.31 to 2.04	-2.04 to 0.48	-1.89 to 2.38	-2.09 to 2.54	-1.48 to 2.08	-3.29 to 1.08
Jabalpur	-1.84 to 2.58	-3.10 to 1.35	-1.01 to 2.55	-3.63 to 2.24	-1.85 to 1.75	-1.72 to 1.94	-3.02 to 1.82	-1.35 to 2.00
Samastipur	-3.86 to 1.85	-1.63 to 2.04	-2.95 to 1.91	-1.10 to 1.91	-2.47 to 1.94	-1.00 to 1.48	-2.05 to 2.76	-1.47 to 1.45

the past few decades has declined in many parts of Asia due to increasing water stress, arising partly from increasing temperature, increasing frequency of El Niño events and reduction in the number of rainy days (Bates *et al*., 2008). A broader range of SPI could be an evidence of increasing rainfall variability. Barring two locations, (Jorhat and Jabalpur), the range of SPI reduced during the month of June between 1991 and 2007, indicating lesser rainfall extremities. This is mostly due to reduction in extreme negative values. This implies that at the begining of monsoon, these locations are likely to have less severe dry events making the condition suitable for seed germination and seedling establishment. But in Bangalore, due to increasing tendency of dryness in June, initial cultural practices will be difficult and challenging. July and August are the period of active vegetative growth for most of the crops, and we found increasing extreme wet events in some locations. In some locations, extreme dryness (or wetness) are moderated to varying extent and the same trend could be observed in September as well. Any increase of dryness in later period of monsoon is expected to cause terminal water stress to the crops. At the same time extreme wetness can also severely damage the crops.

In recent years, floods and droughts have been experienced world wide with higher peaks, severity and frequency (Lettenmaier *et al*., 1996). The anomalies in rainfall pattern, manifested either through change in seasonal trend or the range of dryness/wetness, further substantiate the impact of global climate change. Increase of high intensity rainfall, as evidenced in our study, may spoil the crops like cotton, pulses, millets and groundnuts grown in heavy clay soils, including black soils. The soils are also likely to become more prone to water erosion along with decrease in biological activities and ultimately lead to progressive decline in soil health and crop productivity (Kulshrestha, 1997).

Conclusions

The findings may be used effectively to evolve strategies of suitable adaptation to climate change through changes in farming practices, and cropping patterns, which may in turn help to ease the impact of climate change on the farming community.

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Received: 7 February 2014; Accepted: 16 June 2014