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Assessing Drought Scenario over India during Monsoon 2009 – An Approach Based on Standardized Precipitation Index

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Abstract: An attempt has been made in this study to assess drought scenario over India during monsoon 2009, the latest drought of India, employing Standardized Precipitation Index (SPI). Monthly rainfall data, for more than hundred years, for the 36 meteorological subdivisions as well as the country as a whole have been used in the analysis. The study brought out drought scenario over the country in different time scales. SPI for June indicated a gruesome picture of drought when out of 36 only 5 sub-divisions did not suffer from any drought. Though the drought scenario improved in July yet in the subsequent months of August and September the picture became grim. SPI of (June+July), (July+August), (June+July+August) and (June+July+August+September) revealed the continued grim picture of drought during monsoon 2009. SPI, analysed for the individual sub-divisions falling in different homogeneous regions, revealed that the usually surplus sub-divisions of northeast India were worst hit by drought, whereas in the drought prone Saurashtra and Kutch in northwest India drought was minimal.

Key words: Drought, SPI, monsoon 2009.

Introduction

The economy of India is greatly dependent on water resources as well as rainfall. The erratic nature of rainfall gives rise to low rainfall leading to drought in some years and normal to excess rainfall in others. Drought, which may lead to famine, is indeed one of the worst environmental hazards because its onset is slow; the affected area is quite widespread; and the adverse impacts are ruinous. Drought imparts a creeping long term setback to the socio-economic fabric of the society which has the misfortune to be visited by it (Kulshrestha, 1997). During the 30 year period 1963–1992 though the number of deaths directly attributable to drought is quite less (3%) compared to that caused by floods (26%) and tropical cyclones (19%) yet the number of persons affected by drought (33%) is the highest amongst all the natural disasters (number of persons affected by floods and tropical cyclones being 32% and 20% respectively) and the significant damage caused by drought is 22% which is comparable to the corresponding values of floods (32%) and tropical cyclones (30%) (WMO, 1994). India gets nearly 80% of its annual rainfall during the southwest monsoon season. Delayed onset of monsoon, prolonged breaks in the monsoon during the normally most active months of July and August, early withdrawal of monsoon and erratic distribution of rainfall during monsoon season make our country, especially the drier regions, vulnerable to droughts.

Meteorological drought is the earliest and the most explicit event in the process of occurrence and progression of drought. Rainfall is the primary driver of

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the meteorological drought conditions (Naresh Kumar et al., 2009). Numerous rainfall-based indices are in existence for monitoring and assessment of droughts. Deviation of rainfall from normal is the most commonly used index for drought monitoring.

India Meteorological Department (IMD) monitors meteorological drought based on 'percentage of rainfall departure'. In India, according to India Meteorological Department, meteorological drought over an area is defined as a situation when the seasonal rainfall received over the area is less than 75% of its long period average value.

It is further classified as "moderate drought" if the rainfall deficit is between 26%–50% and "severe drought" when the deficit exceeds 50% of the normal. Further, a year is considered to be a drought year in case the area affected by moderate and severe drought, either individually or together, is 20%–40% of the total area of the country and seasonal rainfall deficiency during south-west monsoon season for the country as a whole is at least 10% or more; when the spatial coverage of drought is more than 40% it will be called as all India severe drought year (www.imd.gov.in). Declaring drought based on rainfall deviation varies from country to country. In South Africa, less than 70% of normal precipitation is considered as drought and such a situation for two consecutive years indicates severe drought (Bruwer, 1990). In Poland, rainfall deviation from a multi-year mean (equivalent to the long term mean) forms the criterion for drought monitoring (Naresh Kumar et al., 2009).

Although rainfall deviation from the long-term mean continues to be a widely adopted indicator for drought intensity assessment because of its simplicity, the application of this indicator is strongly limited by its inherent nature of dependence on mean. Rainfall deviations cannot be applied uniformly to different areas having different amounts of mean rainfall since a high rainfall area and low rainfall area can have the same rainfall deviation for two different amounts of actual rainfall. Therefore, rainfall deviations across space and time need to be interpreted with utmost care (Naresh Kumar et al., 2009).

Standardized Precipitation Index (SPI) expresses the actual rainfall as standardized departure from rainfall probability distribution function and, hence this index has gained importance in recent years as a potential drought indicator permitting comparisons across space and time. Computation of SPI requires long term data on precipitation to determine the probability distribution function which is then transformed to normal distribution with mean of zero and standard deviation of one. Thus, the values of SPI are expressed in standard deviations with positive SPI values indicating greater than median precipitation and negative value indicating less than median precipitation (Edwards and Mckee, 1997). Since SPI values fit a typical normal distribution, these values lie within one standard deviation at approximately 68% of the time, within two standard deviations 95% of the time and within three standard deviations 98% of the time. In recent years SPI has been increasingly used for assessment of drought intensity in many countries (Vicente-Serrano et al*.,* 2004; Wilhite et al*.,* 2005; Wu et al*.,* 2007) homogeneous climatic zones were derived using SPI in Mexico (Giddings et al., 2005). Time series analysis of SPI indicated decrease in SPI values during 1970–1999 in the southern Amazon region, reflecting an increase in dry conditions (Li et al., 2007). The interpretation of drought at different time scales using SPI has also been proved to be superior to the palmer drought severity index (Guttman, 1998). Mckee et al. (1993) suggested the SPI ranges corresponding to different severity levels of drought (Table 1).

Table 1: Drought categories from SPI

SPI	*Drought category*
0 to – 0.99	Mild drought
–1.00 to –1.49	Moderate drought
–1.5 to –1.99	Severe drought
–2.00 or less	Extreme drought

Source: McKee et al., 1993

In view of the above, a detailed study, on the latest drought of 2009 over India, has been carried out using SPI as the index.

Data and Methodology

Our country has been divided into 36 meteorological sub-divisions. Monthly actual rainfall data, for more than hundred years, for these subdivisions as well as the country as a whole have been used in the analysis.

Computation of SPI was done at a monthly time scale. The computation was carried out based on the two parameter gamma distribution function. The rainfall data were transformed into log normal values followed by computation of μ statistics, shape and scale parameters of the gamma distribution. The resulting parameters were then used to find the incomplete gamma cumulative probability of an observed precipitation event. The cumulative probability is given by:

$$G(x) = \frac{\int_{o}^{x} x^{\alpha-1} \cdot e^{\frac{-x}{\beta}} dx}{\beta^{\alpha}\Gamma(\alpha)}$$

where α and β are shape and scale parameters, x is the precipitation amount and $\tau(\alpha)$ is the gamma function.

Since, the gamma function is undefined for $x = 0$ and a precipitation distribution may contain zeros, the cumulative probability becomes:

$$H(x) = q + (1 - q)\, G(x)$$

where q is the probability of zero.

The gamma probabilities were transformed into standardized normal distribution using equi-probability transformation techniques (Abramowitz and Stegun, 1965).

Results and Discussions

Monsoon 2009

The year 2009 was one of the unusual years in recent times and the third highest deficient with respect to all India monsoon season rainfall during the period 1901–2009. For the country as a whole, seasonal rainfall at the end of the southwest monsoon season (June to September) was 78% of its long period average (LPA) value. The highest ever monsoon rainfall deficiency during this period was observed in 1918 (–25% of LPA) followed by 1972 (–24% of LPA).

On monthly scale the rainfall activity over the country was very subdued during June and the rainfall over the country as a whole was 53% of its LPA. During July, rainfall activity over the country as a whole was near normal with the country receiving 96% of its LPA value. During August, rainfall activity over the country as a whole was again subdued much with rainfall for the country as a whole 73% of its LPA value. During September, rainfall over the country as a whole was significantly below normal. Rainfall activity over the south peninsula, parts of Maharashtra, Gangetic West Bengal, some northern parts, was good, elsewhere, it was subdued. For September 2009, rainfall over the country as a whole was 80% of its LPA value (IMD Met Monograph, 2010).

Drought During the Monsoon 2009

Drought scenario in different monsoon months have been presented in Table 2 and Figures 1(a) and 1(b). The data, therein, reveals the following aspects of drought during the monsoon 2009.

(a) In the month of June, when the rainfall over the country as a whole was 53% of its LPA, only 5 sub-divisions out of 36 did not suffer from any drought. Of the remaining 31 sub-divisions, in 12 sub-divisions drought situation was severe to extreme.

(b) In the month of July when the country received near normal rainfall, there was marked improvement in the drought scenario. In this month, number of sub divisions suffered from severe to extreme drought came down to three. July being the most important month from the point of view of agriculture, the reduced drought intensity in this month brought respite to the farming community of the country.

(c) In August the drought situation deteriorated again and more or less remained so in September due to the subdued rainfall activity in these months.

(d) When SPI for the month of June+July was computed, it was found that 30 meteorological sub divisions were in the grip of drought till July end. Further, SPI value of July+August, June+July+August as well as seasonal SPI value brought out more or less similar grim picture of drought scenario.

Drought in Different Homogeneous Regions During the Monsoon 2009

Meteorological sub-divisions, grouped into different homogeneous regions, have been presented in Table 3. Drought scenario in individual meteorological sub-divisions categorized in different homogeneous regions have been presented in Figures 2(a) to 2(f). The analysis brought forward the following results.

(a) Amongst the four meteorological sub-divisions of northeast India, the worst hit were NMMT and SHWB which suffered from severe drought as reflected in SPI of JJAS. SPI of JA, crucial from the view point of agriculture, however, revealed a much reduced drought intensity.

(b) In the Central Northeast India, except Orissa, in the remaining subdivisions (Jharkhand, Bihar, EUP and WUP) drought was severe during JJAS. The scenario was more or less similar in the crucial period of July+Aug (JA).

(c) In Peninsular India, during JJAS and JA none of the sub-divisions (CAP, RYLM, TN, KER, CK and SIK) was under the grip of severe/extreme drought. However, CK, RYLM and CAP suffered from severe to extreme drought during June, July and June+July.

(d) In the West Central India, except NIK all the remaining sub-divisions faced the drought onslaught as revealed by the SPI of JJAS.

Table 2: SPI during Monsoon 2009

Met. sub divisions	*June*	*July*	*August*	*September*	*June+July*	*June+July +Aug.*	*June+July +Aug.+Sept.*	*July+Aug.*
1	1.11	–0.41	0.18	–0.33	0.56	0.51	0.22	–0.25
2	–1.36	–0.95	–0.48	–1.58	–1.57	–1.45	–1.72	–1.06
3	–1.81	–0.52	0.96	–1.69	–1.76	–0.78	–1.37	0.32
4	–2.19	–0.77	–0.32	–1.03	–1.82	–1.42	–1.56	–0.66
5	–1.38	–0.94	0.24	–2.43	–1.68	–1.13	–1.78	–0.53
6	–2.41	–0.47	0.31	0.63	–1.89	–1.26	–0.78	–0.17
7	–1.71	2.57	–0.44	–1.08	1.26	0.78	0.28	1.78
8	–1.33	–1.40	–0.73	0.51	–2.13	–2.00	–1.65	–1.55
9	–1.69	–0.84	0.31	–1.00	–1.78	–1.20	–1.50	–0.49
10	–1.34	–1.18	–0.94	–0.40	–1.71	–2.03	–1.92	–1.69
11	–1.63	–1.42	–0.69	–0.09	–1.96	–1.97	–1.87	–1.59
12	–1.46	–1.24	–1.44	–0.13	–1.68	–2.17	–1.90	–1.85
13	–1.20	–1.15	–1.57	0.86	–1.67	–2.23	–1.25	–1.93
14	–1.25	0.00	–1.21	0.10	–0.50	–1.17	–0.97	–0.83
15	–1.31	–1.93	–2.13	0.29	–2.40	–2.64	–2.08	–2.34
16	0.18	–0.30	–0.94	–0.33	–0.27	–0.72	–0.80	–0.78
17	–0.12	0.02	–1.04	–0.72	–0.18	–0.93	–1.19	–0.84
18	–0.47	–0.05	–0.87	–0.47	–0.34	–0.94	–1.11	–0.75
19	–1.01	0.35	–1.31	–0.22	–0.22	–1.14	–1.14	–0.71
20	–1.83	–0.30	–2.14	–0.02	–1.12	–2.28	–2.06	–1.66
21	–1.62	0.40	–0.81	–0.57	–0.27	–0.74	–0.91	–0.23
22	0.08	1.52	0.05	–1.23	1.31	1.07	0.68	1.24
23	–1.74	1.00	–1.73	0.28	–0.06	–1.04	–0.82	–0.14
24	–1.79	0.63	–0.41	0.31	–0.22	–0.41	–0.27	0.22
25	–1.41	–0.37	0.09	–0.16	–1.19	–0.79	–0.87	–0.26
26	–1.28	0.12	–1.16	–0.93	–0.74	–1.25	–1.54	–0.72
27	–2.29	0.66	–1.63	–1.95	–0.81	–1.54	–2.21	–0.59
28	–1.26	–1.16	–0.12	–0.12	–1.71	–1.26	–0.93	–0.84
29	–1.47	–1.59	–0.47	–0.47	–2.17	–1.79	–1.41	–1.42
30	0.09	–2.09	0.47	0.47	–1.37	–0.57	–0.17	–0.61
31	–0.97	–0.37	0.20	0.20	–0.93	–0.53	–0.27	–0.13
32	–2.07	1.59	–0.81	–0.81	0.50	–0.04	–0.35	0.95
33	–0.19	–0.32	1.04	1.04	–0.45	0.35	0.66	0.52
34	–0.76	0.72	–0.10	–0.10	0.30	0.17	0.09	0.46
35	–0.99	1.22	–0.82	–0.82	0.42	0.04	–0.23	0.67
36	0.68	0.03	–0.07	–0.07	0.39	0.23	0.10	–0.17

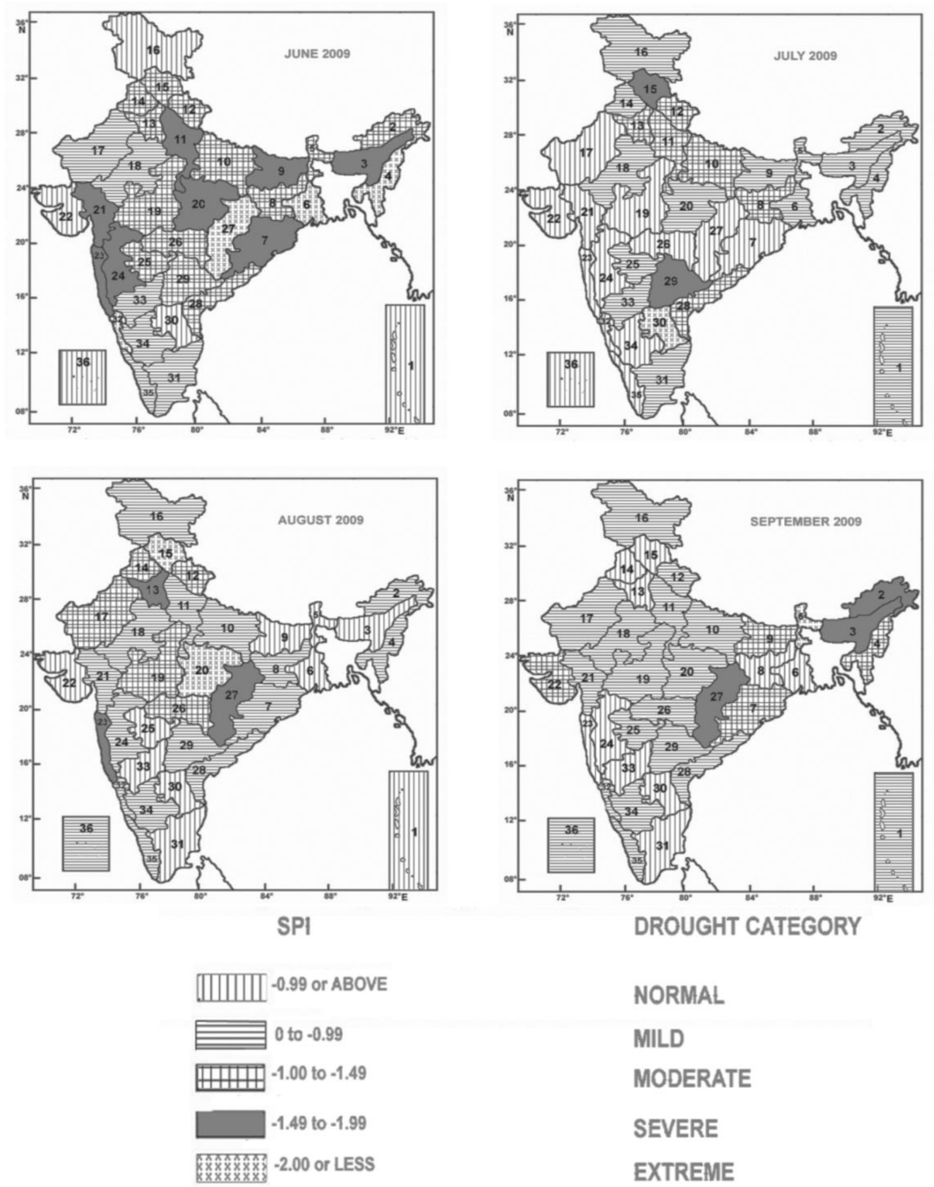
(e) In northwest India, surprisingly S&K, a drought prone sub-division, did not face any drought except in September, whereas, all the remaining (HAR, ERAJ, WRAJ, GUJ, and PUNJAB) suffered from various kinds of drought intensity.

(f) In the hilly region comprising of J&K, HP and Uttarakhand the latter two sub-divisions were under the grip of severe/extreme drought during JJ, JA, JJA and JJAS.

Conclusion

(i) The study brought out drought scenario over the country, during the monsoon 2009, in different time scales based on the Standardized Precipitation Index (SPI).

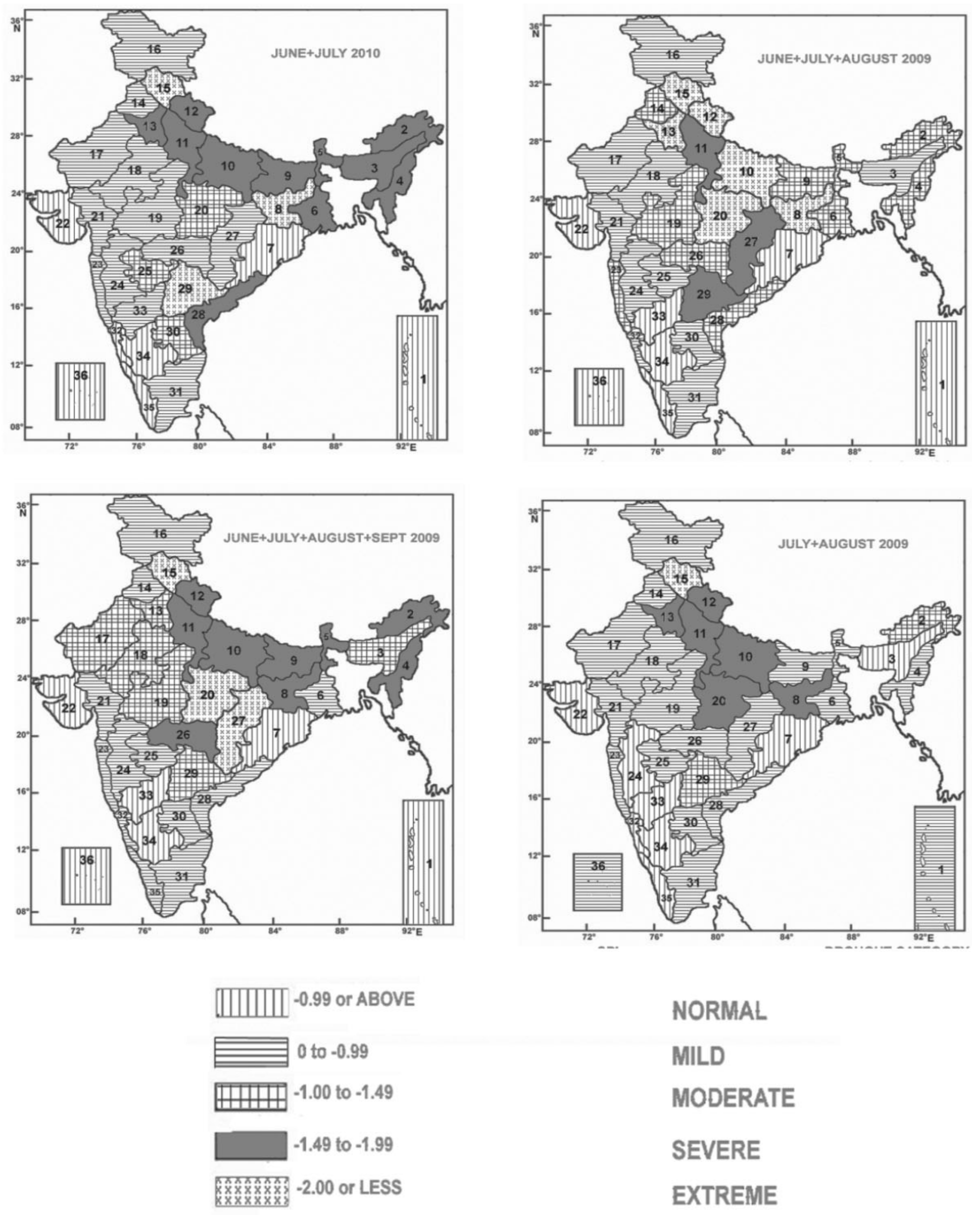
(ii) SPI for June indicated a gruesome picture of drought when out of 36 only five sub-divisions did not suffer from any drought.



NAMES OF METEOROLOGICAL SUB-DIVISIONS

1. Andaman & Nicobar Islands, 2. Arunachal Pradesh, 3. Assam & Meghalaya, 4. Nagaland, Manipur, Mizoram & Tripura, 5. Sub-Himalayan West Bengal & Sikkim, 6. Gangetic West Bengal, 7. Orissa, 8. Jharkhand, 9. Bihar, 10. East Uttar Pradesh 11. West Uttar Pradesh, 12. Uttaranchal, 13. Haryana, 14. Punjab, 15. Himachal Pradesh, 16. Jammu & Kashmir, 17. West Rajasthan, 18. East Rajasthan, 19. West Madhya Pradesh, 20. East Madhya Pradesh, 21. Gujarat Region, 22. Saurashtra & Kutch, 23. Konkan & Goa, 24. Madhya Maharashtra, 25. Marathwada, 26. Vidarbha, 27. Chattisgarh, 28. Coastal Andhra Pradesh, 29. Telangana, 30. Rayalaseema, 31. Tamil Nadu, 32. Coastal Karnataka, 33. North Interior Karnataka, 34. South Interior Karnataka, 35. Kerala, 36. Lakshadweep.

Figure 1(a): SPI in different months during the monsoon 2009.



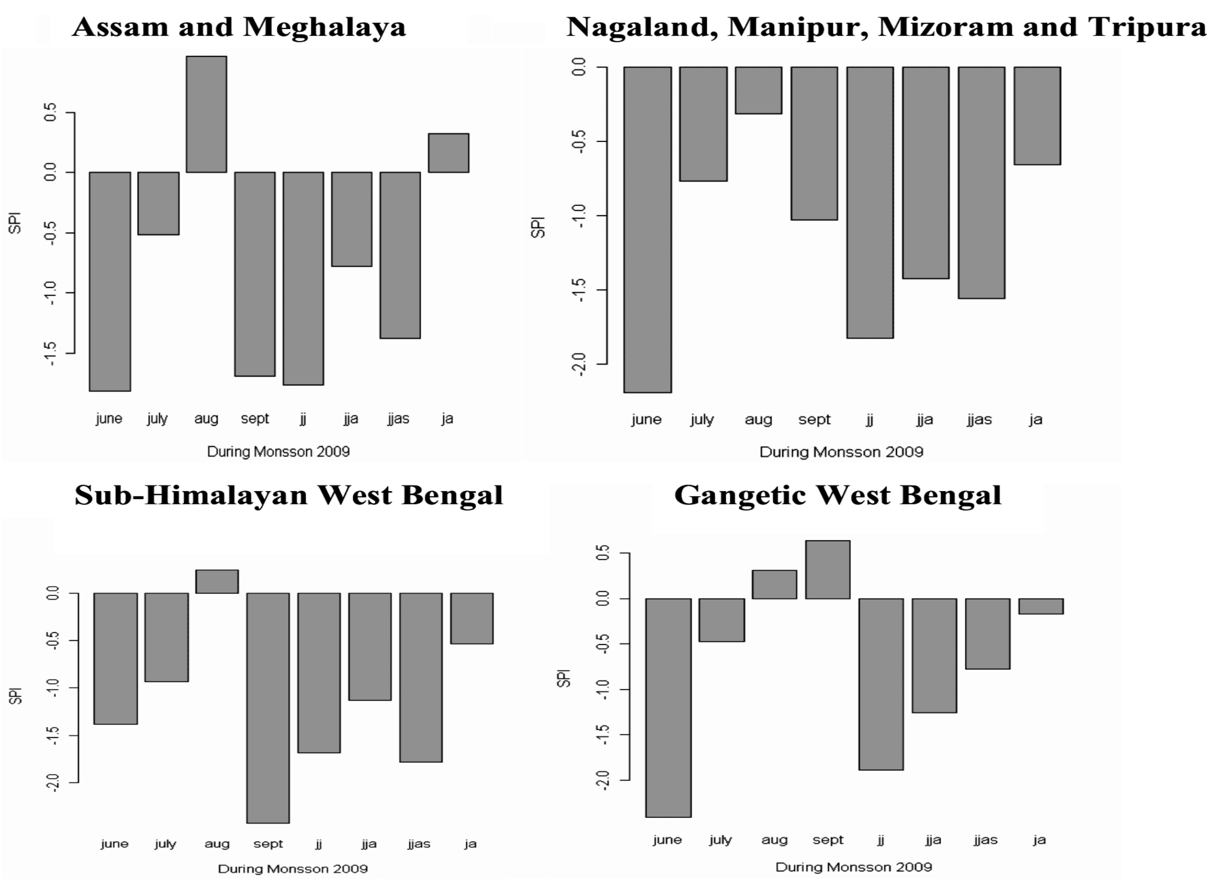
NAMES OF METEOROLOGICAL SUB-DIVISIONS

1. Andaman & Nicobar Islands, 2. Arunachal Pradesh, 3. Assam & Meghalaya, 4. Nagaland, Manipur, Mizoram & Tripura, 5. Sub-Himalayan West Bengal & Sikkim, 6. Gangetic West Bengal, 7. Orissa, 8. Jharkhand, 9. Bihar, 10. East Uttar Pradesh 11. West Uttar Pradesh, 12. Uttaranchal, 13. Haryana, 14. Punjab, 15. Himachal Pradesh, 16. Jammu & Kashmir, 17. West Rajasthan, 18. East Rajasthan, 19. West Madhya Pradesh, 20. East Madhya Pradesh, 21. Gujarat Region, 22. Saurashtra & Kutch, 23. Konkan & Goa, 24. Madhya Maharashtra, 25. Marathwada, 26. Vidarbha, 27. Chattisgarh, 28. Coastal Andhra Pradesh, 29. Telangana, 30. Rayalaseema, 31. Tamil Nadu, 32. Coastal Karnataka, 33. North Interior Karnataka, 34. South Interior Karnataka, 35. Kerala, 36. Lakshadweep.

Figure 1(b): SPI in combination of different months during the monsoon 2009.

Table 3: Meteorological sub-divisions grouped into different homogeneous regions

	Region	*Sub-divisions*
1.	Northwest India	Haryana, Chandigarh and Delhi (HAR), East Rajasthan (ERAJ), West Rajasthan (WRAJ), Gujarat Region(GUJ), Saurashtra & Kutch(S&K) and Punjab (PUNJAB).
2.	West Central India	East Madhya Pradesh(EMP), West Madhya Pradesh (WMP), Chhattishgarh, Konkan and Goa (K&G), Madhya Maharashtra (MM), Marathwada(MAR), Vidarbha (VID), Telangana(TEL) and North Interior Karnataka (NIK).
3.	Peninsular India	Coastal Andhra Pradesh (CAP), Rayalaseema(RYLM), Tamilnadu and Puducherry(TN), Kerala (KER), Coastal Karnataka (CK), South Interior Karnataka (SIK).
4.	Central Northeast India	Jharkhand(JHK), Bihar(BHR), Orissa(ORS), East Uttar Pradesh (EUP), West Uttar Pradesh (WUP).
5.	Northeast India	Assam and Meghalaya (ASSAM), Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura (NMMT), Sub-Himalayan West Bengal and Sikkim (SHWB) and Gangetic West Bengal (GWB).
6.	Hilly region	Jammu and Kashmir(J&K), Himachal Pradesh (HP), Uttarakhand (UTK).



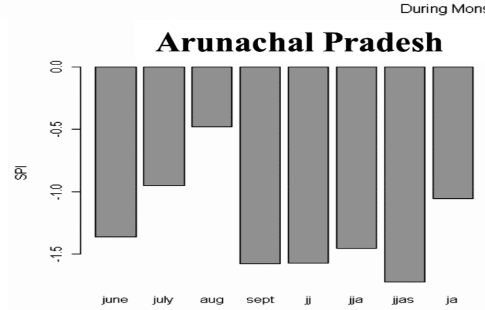


Figure 2(a): Drought during the monsoon–2009 in northeast India.

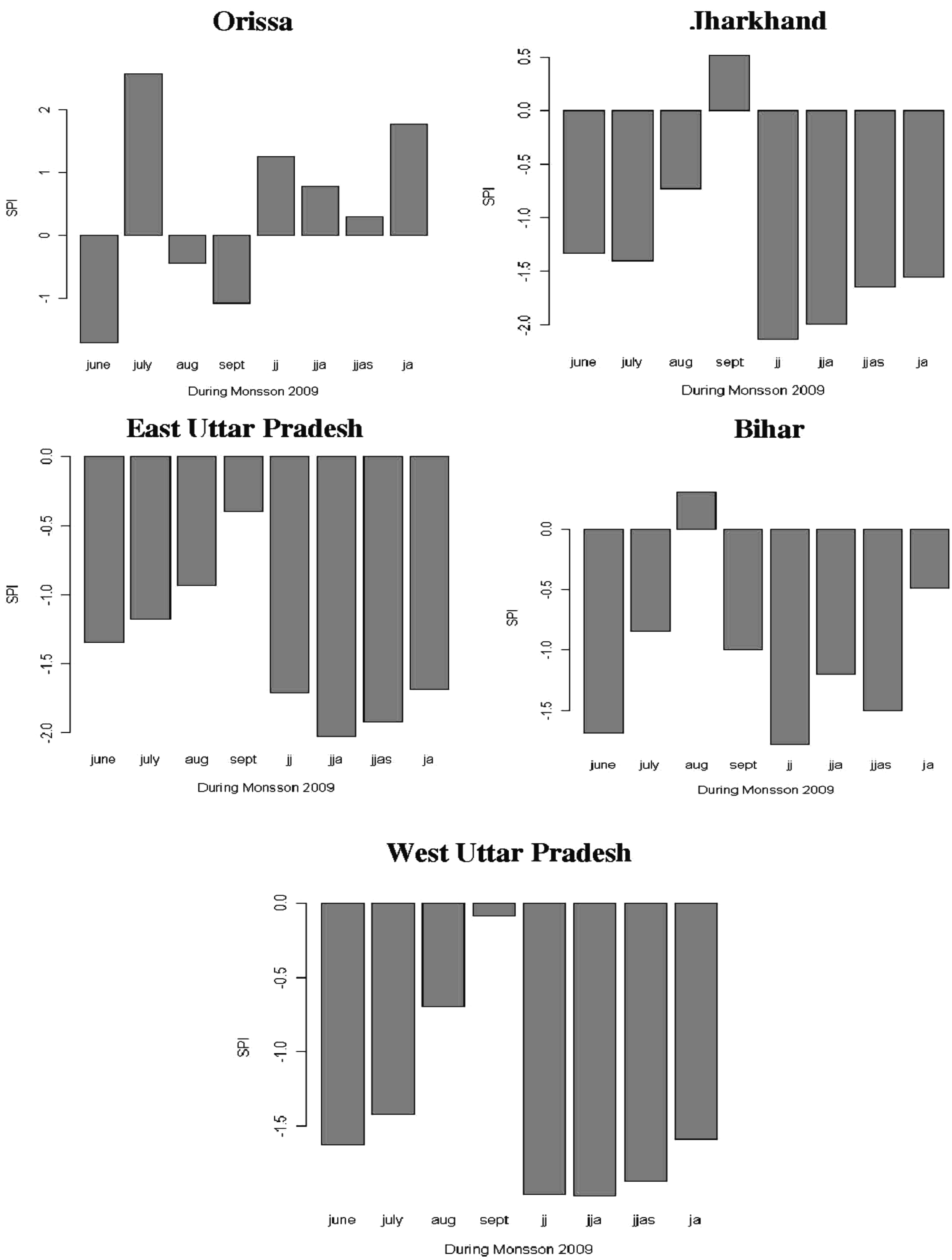


Figure 2(b): Drought during the monsoon–2009 in central and east India.

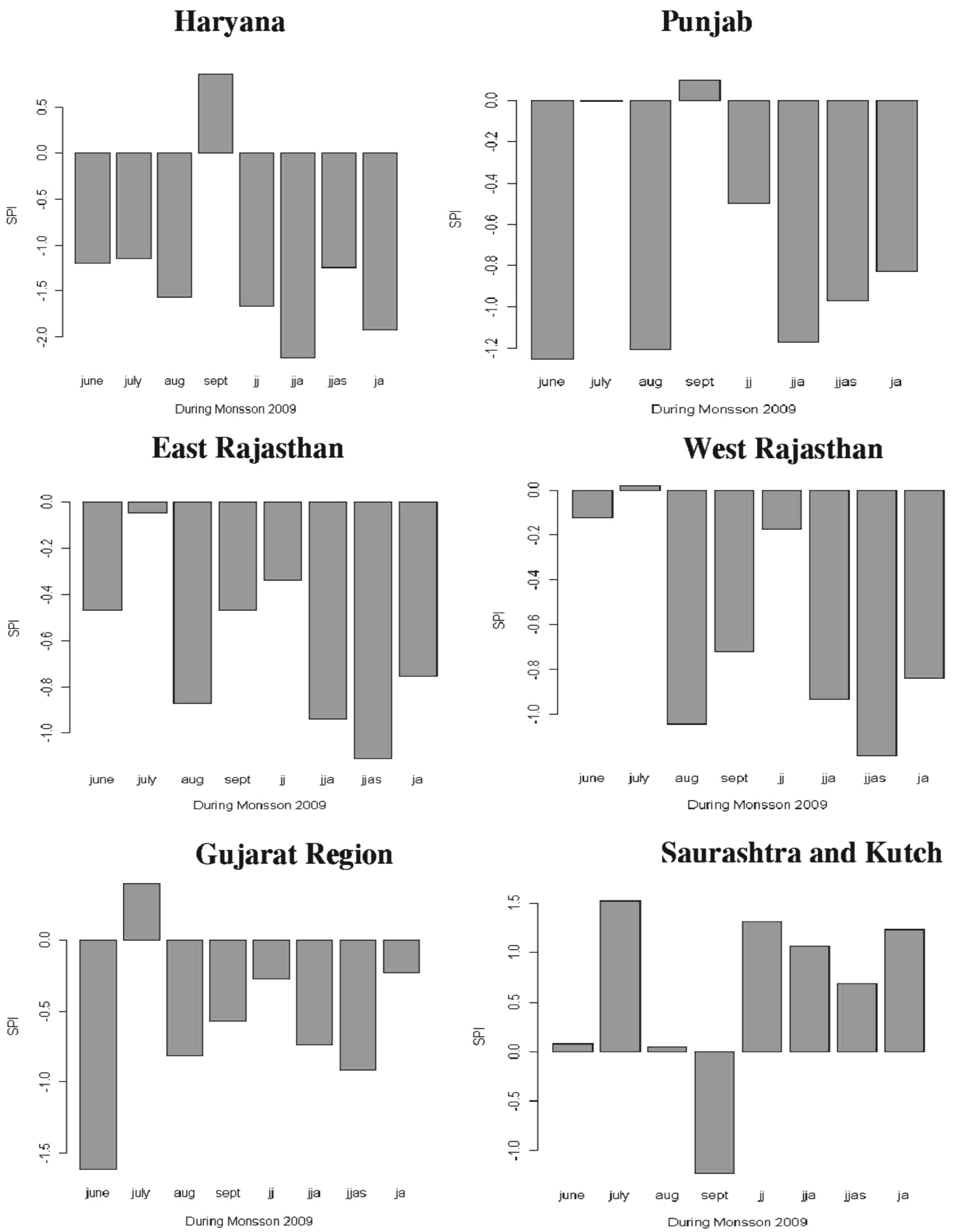


Figure 2(c): Drought during the monsoon–2009 in western India.

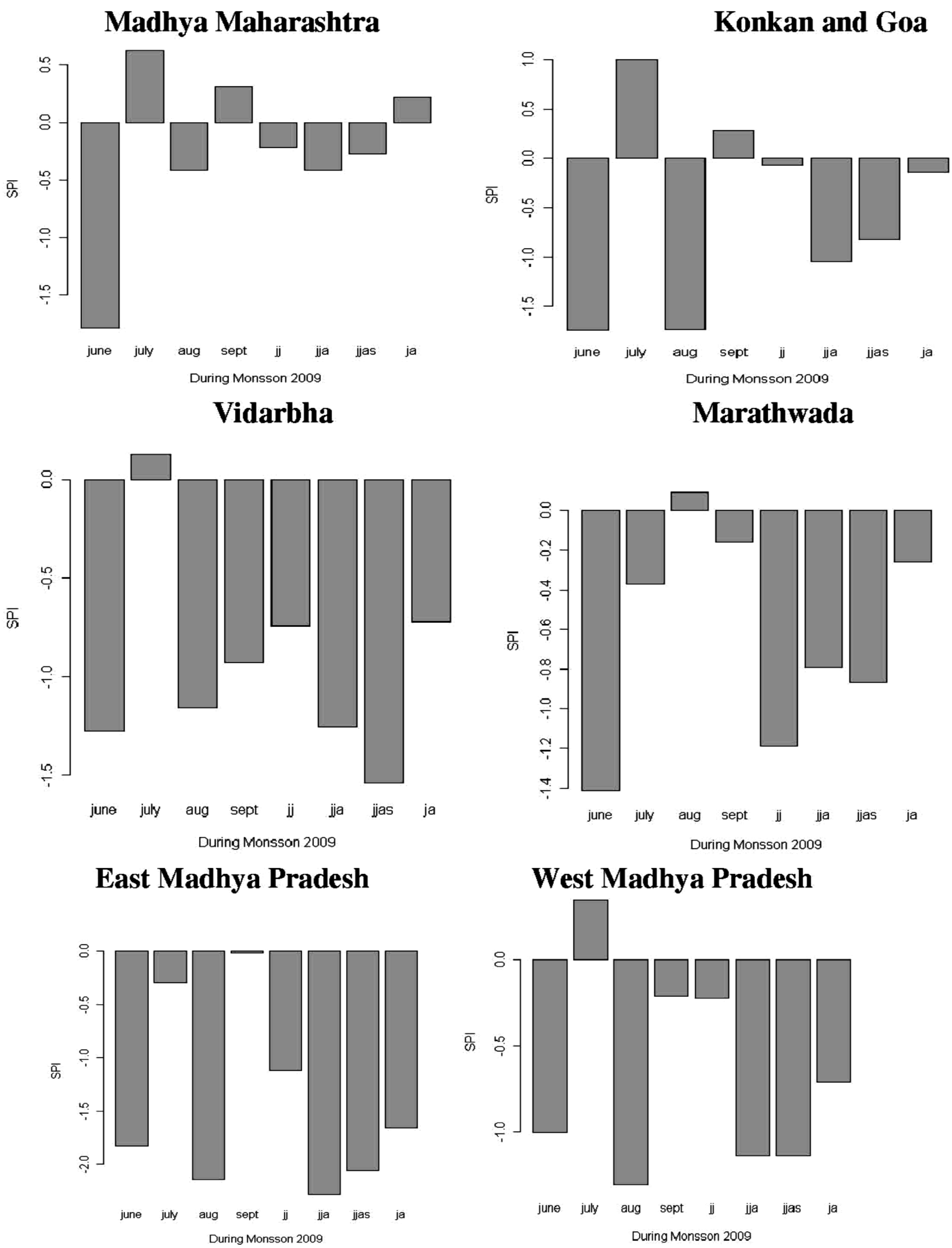


Figure 2(d): Drought during the monsoon–2009 in east central India.

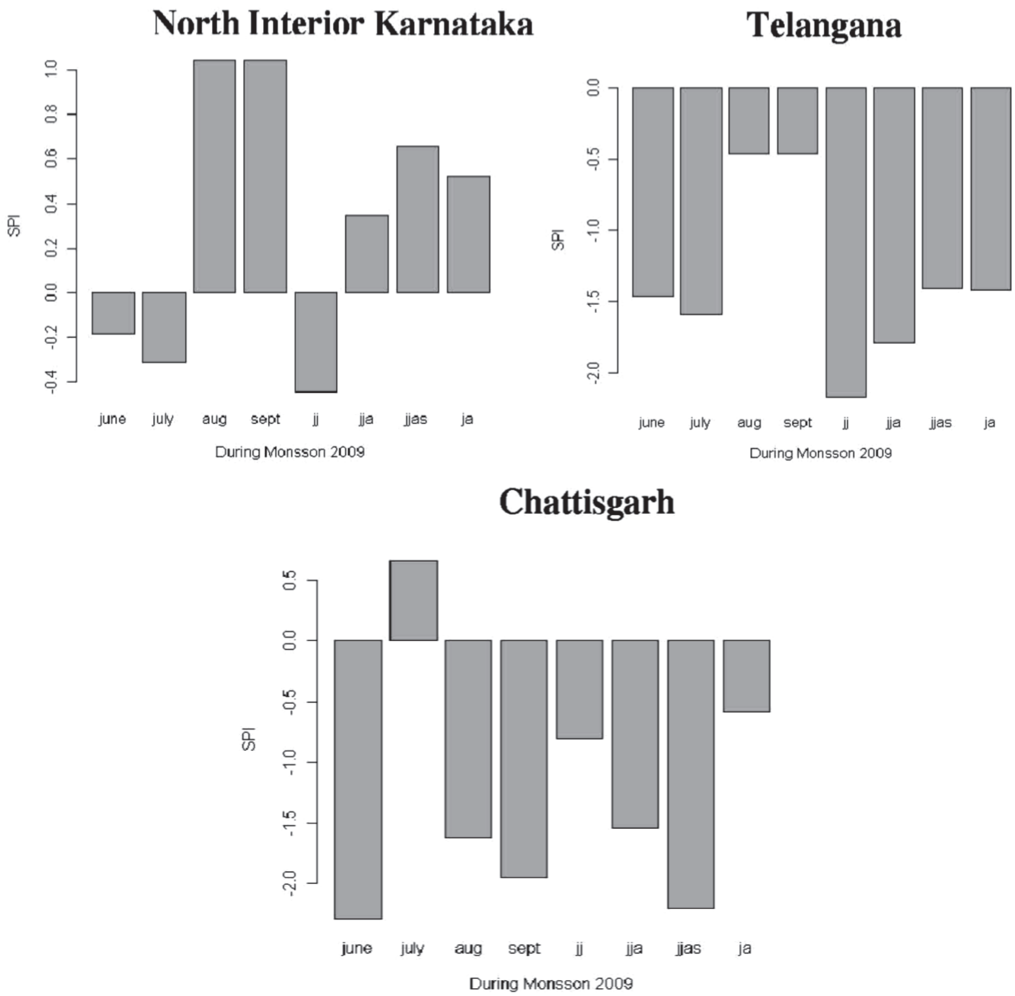


Figure 2(d): contd. Drought during the monsoon–2009 in east central India.

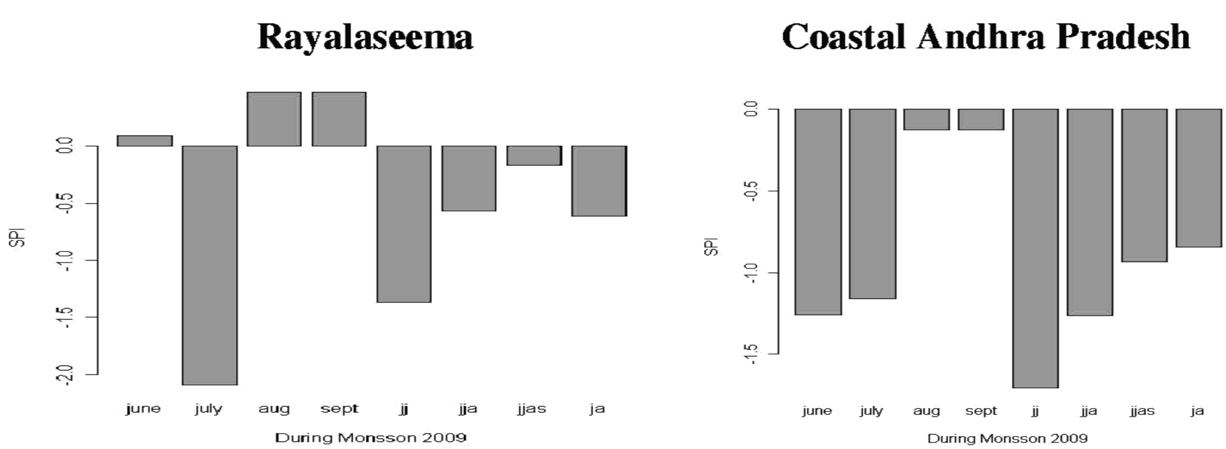


Figure 2(e): Drought during the monsoon–2009 in Peninsular India.

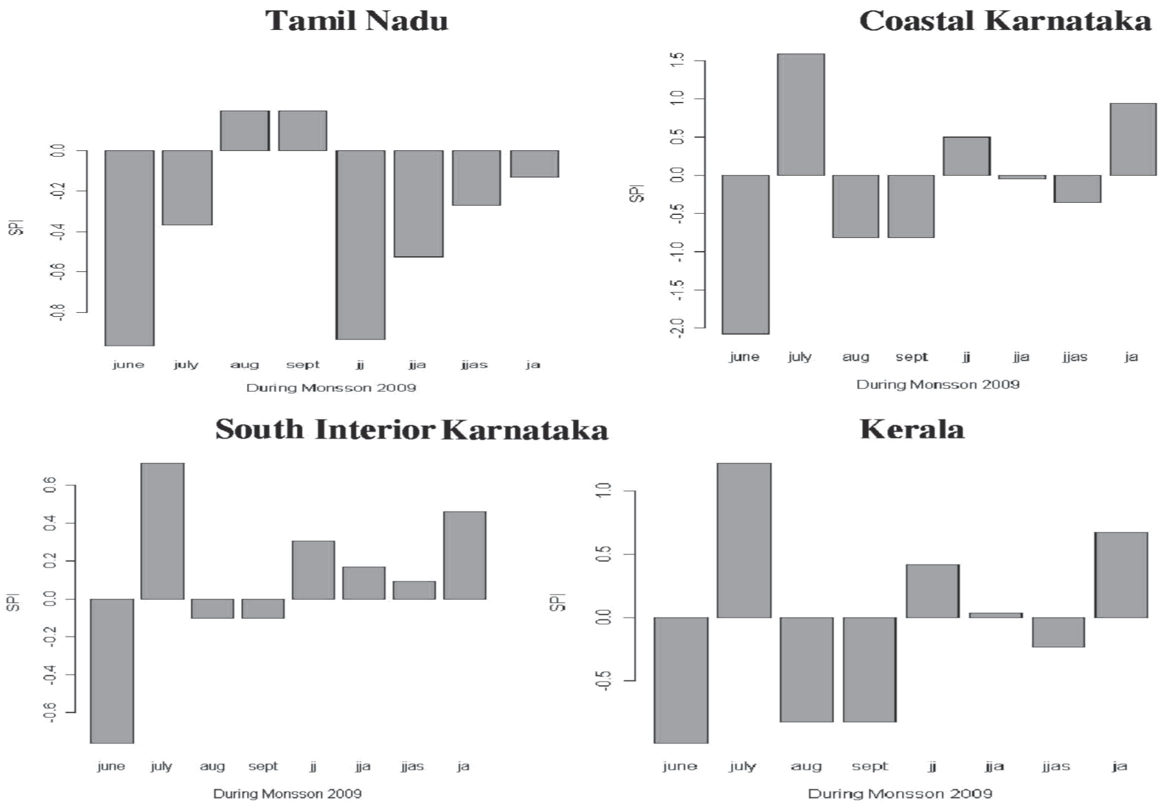
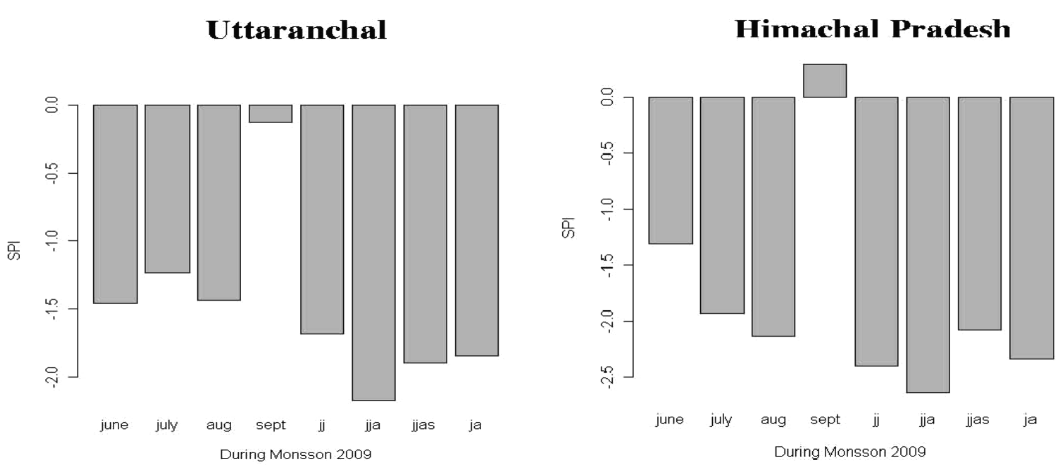


Figure 2(e): contd. Drought during the monsoon–2009 in Peninsular India.



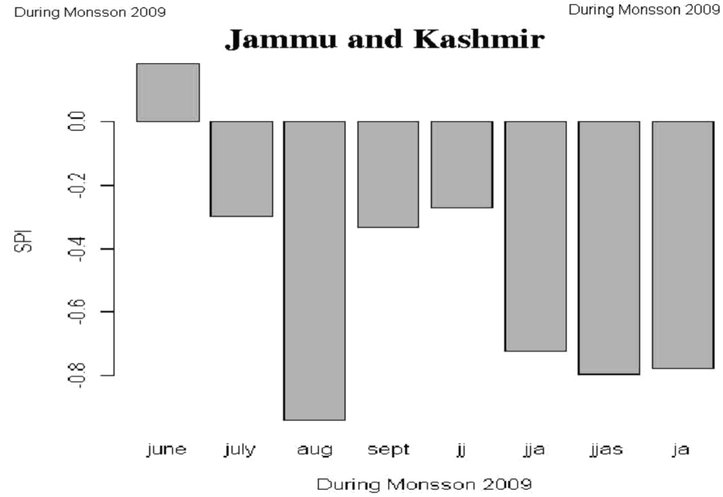


Figure 2(f): Drought during the monsoon–2009 in Himalayan region.

(iii) Though the drought scenario improved a lot in July yet in the subsequent months of August and September the picture became grim. SPI of (June+July), (July+August), (June+July+August) and (June+July+August+September) revealed the continued grim picture of drought during monsoon 2009.

(iv) SPI, analysed for the individual sub-divisions falling in different homogeneous regions, further revealed that the usually surplus sub-divisions of northeast India were worst hit by drought, whereas in the drought prone Saurashtra and Kutch in northwest India drought was minimal.

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