Chapter 5

Geo-Statistical Assessment of the Intensity, Duration, Frequency and Trend of Drought over Gangetic West Bengal, Eastern India

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Additional information is available at the end of the chapter

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Abstract

This chapter presents spatio-temporal (1901–2002) appraisal of the intensity, duration, frequency and trend of drought over Gangetic West Bengal (GWB), Eastern India using standardized precipitation index (SPI). The study reveals that, after 1950s the magnitude of deficit precipitation has increased substantially. Stepping up of the mean intensity of most intense drought events; average drought duration; severe and extreme drought frequency in this agricultural tract at the latter half of the twentieth century are also some alarming events. The western degraded plateau is more sensitive to extreme droughts but, the impact is expected to be rigorous over the adjacent areas. In an nutshell this work provides the evidences demonstrating the intensification of aridity in the northern Rarh plain and moribund delta which may corresponds to degradation and lowering of water resources especially ground water which may also lead to increase of socio-economic vulnerability to drought. Such altered hydrolo-meteorological system hence calls for review of the agricultural practices and water use in this counterpart.

Keywords: standardized precipitation index (SPI), drought intensity, drought duration, drought frequency, threshold rainfall

1. Introduction

Monsoon region of South Asia remains one of the important worries with respect to frequency and magnitude of drought in the contemporary scenario of climate change [1]. About 23 million hectares of Asian rice producing areas experience frequent yield loss due to drought [2]. Afghanistan, India, Pakistan and Sri Lanka have reported droughts at least once in every

3 year over the past 5 decades [3]. In India the net sown area is about 140 Mha, out of which as much as 50% area is considered as severely drought prone [4]. Therefore, a comprehensive assessment of drought is needful for monsoon based agro-economy of India.

Gangetic West Bengal (GWB), the leading agricultural hubs of Eastern India, severely experienced the effect of climate change over the last few years [5]. Late monsoon arrival has been observed with less intensity, duration of summer has become longer and drought has become more frequent [6–10]. Moreover, this region is less experienced of coping with droughts resulting in poor preparedness. Growing population, lacking water resource management initiatives etc. further compounded the problem. Therefore, we need to improve our knowledge on drought jeopardy in this densely populated tract with vast agricultural expanse. The present chapter is an attempt in this regard to ensure two folds objectives—i. to portray a comprehensive and holistic picture of droughts over GWB-its intensity-duration-frequency and trend and ii. to identify areas exposed to drought.

2. Geographical personality of the study area

The study focuses on the southern half of West Bengal below Farakka barrage (**Figure 1**) located between latitudes 21°32′23″N to 24°51′20″N and longitudes 85°49′49″ E to 89°8′48″ E (area: 63,879 km^2, elevation range: 0–677 m) surrounded by Jharkhand in the West, Odisha in the Southwest and Bangladesh in the East. Physiographically, GWB forms the transitional zones between Chhotanagpur plateau in the West and Ganga-Brahmaputra delta in the southern and eastern section. River Bhagirathi and its tributaries/distributaries drain this region [11]. The climate is typical sub-tropical monsoon type having four main seasons namely, winter (Jan-Feb); Pre-Monsoon (Mar-May); Monsoon (Jun-Sep) and Post-Monsoon (Oct-Dec) [12]. Out of the total annual rainfall, about 70–80% occurs during the monsoon and contributing as much as 90% to the discharge of the rivers.

GWB is a densely populated (1051 person/km^{-2}) tract, coupled with vast stretch of fertile alluvial soil and is the heart of rice and jute cultivation as well as freshwater fish production of eastern India, the gross cropped area and cropping intensity of this region count about 112 and 184% respectively [13]. Agriculture in this region is mainly rain-fed and rainfall extremities put heavy stress on not merely agricultural activities but also other economic activities. Average water demand in this region varies from about 0.9 to 1.8mm^3 per km^{-2} in compare to the average water availability of 0.5 to 1.0mm^3 per km^{-2} [14]. These demonstrate sensitiveness to drought of this region.

According to the study of Ghosh [9] there is a considerable decrease in rainfall during early monsoonal month June and mid monsoonal month August in this tract. In the year 2010 10 districts of GWB have received <33% of the normal monsoon rainfall, which severely affected the sowing of paddy [15]. In the northern Rarh and moribund delta there are significant decreasing trend of rainfall (**Figure 2**) which is a sign of strengthening of drier condition of these two regions. Nath et al. [16], WBSAPCC [6], RPAPCC [8] etc. have roughly addressed

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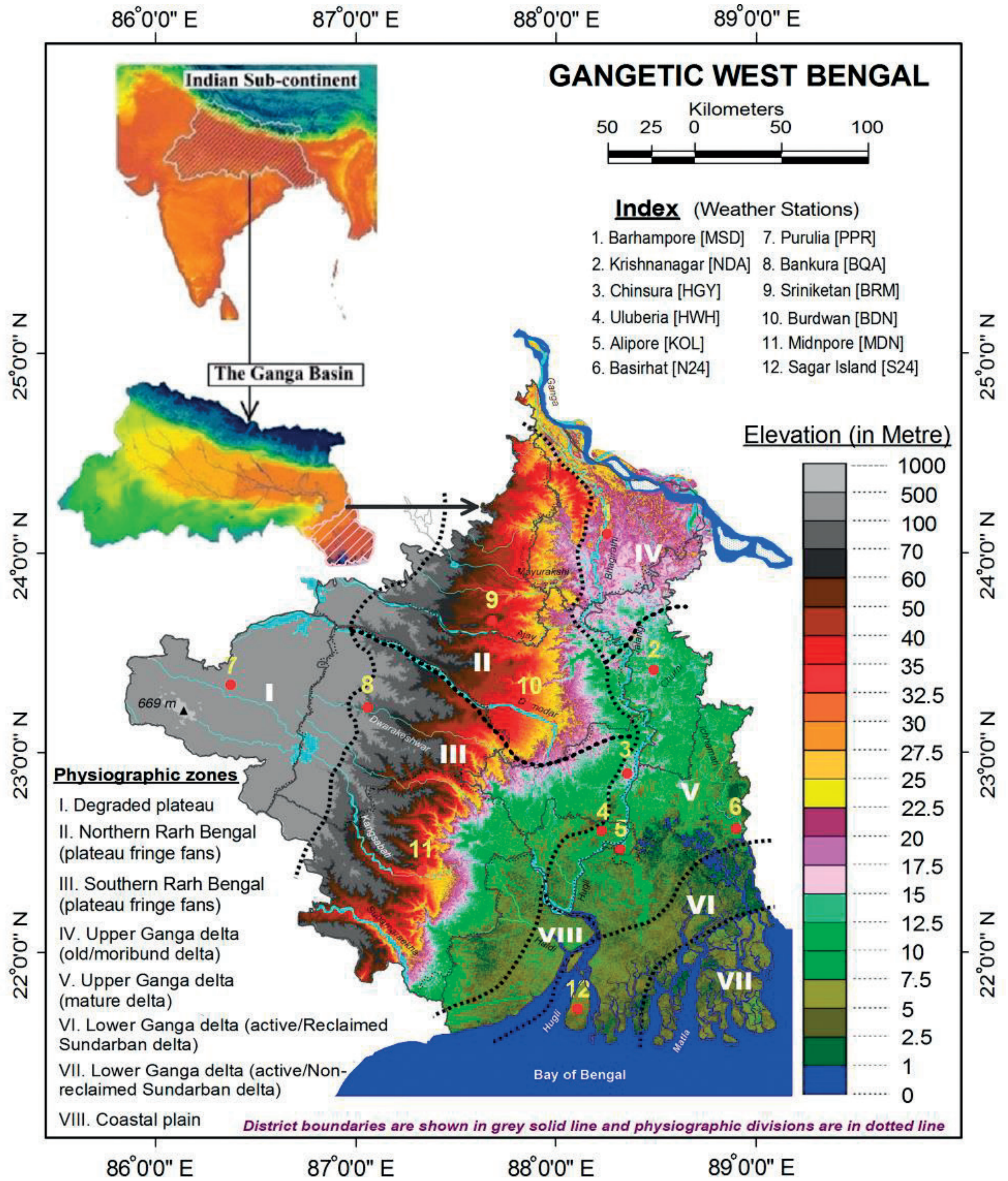

Figure 1. Reference map of the Gangetic West Bengal showing elevations, district boundaries, physiographic divisions and location of the weather stations used in the analysis.

the way for drought management of the state. Nevertheless, comprehensive assessment of drought jeopardy of this region in prime prerequisite before chalking out the management plan and the present chapter opt to do so.

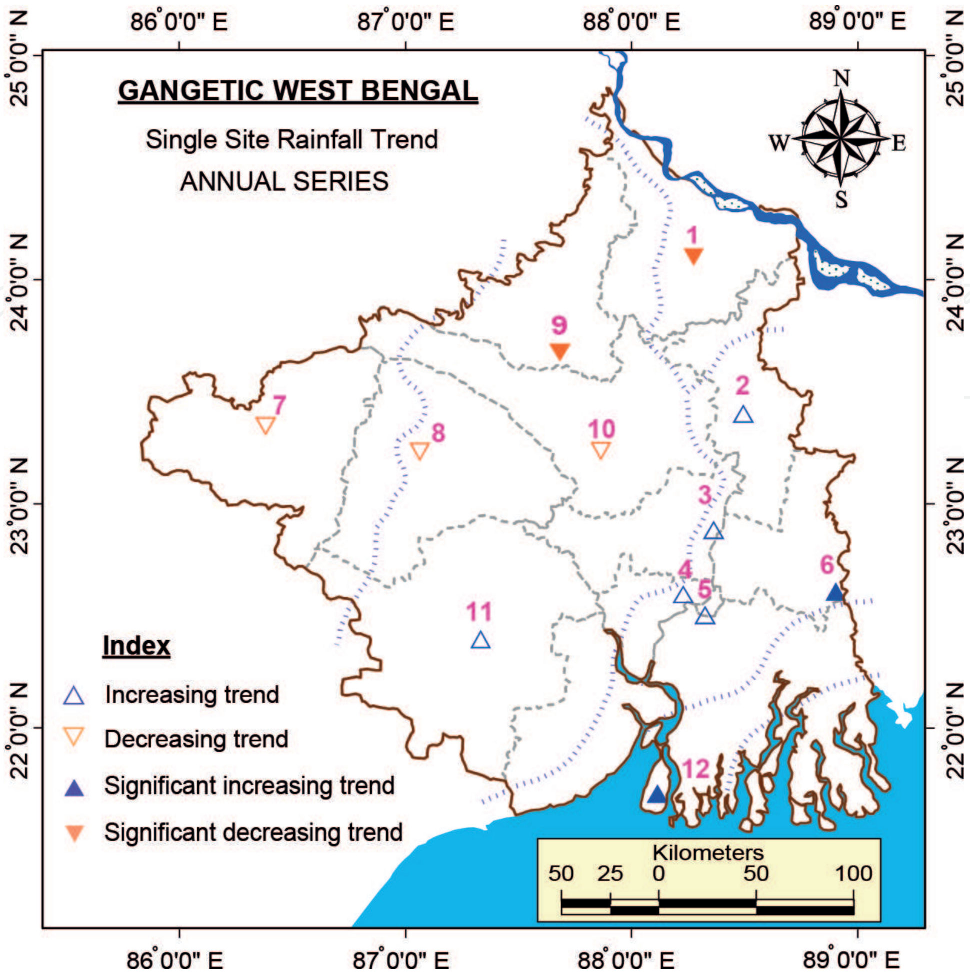

Figure 2. Site (meteorological station) specific annual rainfall trend during 1901–2002.

3. Materials and methods

For the present study continuous time series rainfall data [http://www.indiawaterportal.org/] belonging to 12 meteorological stations (one representative station per district) of the GWB (**Figure 1**) for the period of 1901–2002 have been used. The Indian Meteorological Department (IMD) assembles the data as well as controls the data quality.

Over a geographic area deficit of rainfall from normal during a period is broadly accepted as drought. In this study standardized precipitation index (SPI) has been used to detail the geographical variations of drought at multiple time steps. Different dimensions of drought (like- drought intensity, duration, frequency etc.) following Dracup et al. [17] have been captured for the holistic appraisal.

3.1. Standardized precipitation index (SPI)

SPI, developed by McKee et al. [18, 19] is a simple but flexible tool to monitor drought at multiple time step. SPI is recommended by the WMO as a standard drought monitoring index

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[20] and is calculated by taking the difference of the precipitation, Xi from the mean, $\bar{X}$ for a particular time step, and then dividing it by the standard deviation, σ [21].

$$SPI = \frac{Xi - \overline{X}}{\sigma} \quad (1)$$

SPI is used to monitor both dry and wet conditions [22]. Negative values indicate dry and positive values indicate wet periods [23]. As SPI becomes more negative or positive, the conditions become more severely dry or wet (**Table 1**).

McKee et al. [18] originally calculated the SPI for 3-, 6-, 12-, 24- and 48-month timescales. For the present case, typically SPI for 3- and 12-months step SPI are calculated to explore the drought variation at inter-seasonal and inter-annual time scales.

3.2. Drought evaluation parameters

Drought intensity (I_D): I_D annotates departure of a climate index from its normal value [24]. According to McKee et al. [18] a drought event is defined as a period in which the SPI is continuously negative and SPI reaches a value of −1.0 or less. Hence, I_D indicates the absolute value of SPI less than −1.0. Lesser the value more will be the drought intensity.

Drought duration (D_D): D_D equals the number of months between its start and end [25]. A drought event starts when the SPI is continuously negative and reaches an intensity of −1.0 or less while, the event ends when the SPI becomes positive.

Drought magnitude (M_D) and mean intensity, (MI_D): M_D corresponds to the cumulative water deficit over a drought period [26] and the average of this cumulative water deficit over the drought period is MI_D. Thus, M_D is the absolute value of the sum of all SPI values during a drought event and MI_D refers to magnitude divided by duration.

Drought frequency (F_D): F_D is used to assess the drought liability during a study period [27]. The number of droughts per 100 years was calculated as:

SPI values	Draught severity class	D-scale
2.0+	Extremely wet	W3
1.5 to 1.99	Very wet	W2
1.0 to 1.49	Moderately wet	W1
−.99 to .99	Near normal	N
−1.0 to −1.49	Moderately dry	D1
−1.5 to −1.99	Severely dry	D2
−2 and less	Extremely dry	D3

Source: http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf.

Table 1. Precipitation excess (wet) or deficit (dry) severity class according to SPI values.

$$F_{D\,i,100} = \frac{Ni}{i.n} \times 100 \ (\%) \tag{2}$$

where $F_{Di,100}$ is the frequency of droughts for timescale i in 100 years; Ni is the number of months with droughts for timescale i in the n-year set; i is timescale (3-, 6-, 12-, 24-months); n is the number of years in the data set.

Trend analysis: The rank-based nonparametric Mann-Kendall test [28–29] is applied to the long-term data in this study to detect statistically significant trends. Sen's nonparametric method [30] is used to estimate the trends slope in the time series data.

Return period or recurrence interval (Tr): Bonaccorso et al. [31] expressed Tr as a function of the statistical characteristics of historical long records of precipitation and of a threshold parameter. In the present study the original concept of the return period [32] is used, i.e. the average number of years between events above a threshold magnitude.

Rainfall threshold/critical rainfall (T_{RD}): To calculate the threshold rainfall, first we have to calculate the $\bar{x}$ and σ (Eq. (1)) for a particular time step (say, for 3 month Dec–Jan–Feb of 30 years of continuous rainfall data), for a given station and specify the desired SPI value (say −1.0) in Eq. (3) for which critical rainfall is to be calculated.

$$Xi = \sigma SPI + \overline{X} \tag{3}$$

3.3. Data processing and related calculations and mapping

The complete set of raw data for the said period (Jan 1901 to Dec 2002) in the current study have been tested to check if there are any missing data or irregularities in the data series. SPI is then calculated for different time steps using 'SPI Calculator' of the National Drought Mitigation Centre (NDMC) as recommended by WMO [20]. Afterwards drought-related indicators as indicated in Section 6.2.2 are calculated. SPSS 14.0 and XLSTAT 2015 Excel plug-in have been used for the MK test and Sen's slope. For the purpose of revealing the spatial variation over GWB Choropleth maps are then prepared using GIS software.

4. Results and discussion

4.1. Spatial and temporal assessment of the drought intensity

4.1.1. Time series assessment of draught intensity

On 12-month time lag 10 significant droughts have occurred during 1901–2002 (**Figure 3a**) among which, 1966–1967 is the most significant with D_D of 14 months; PI_D of −2.82 and a MI_D of −2.06. On 48-month time step the last century roughly exhibit some consecutive surplus and deficit phase (**Figure 3b**): (i) slight deficit (1901–1917), (ii) short surplus (1918–1922); (iii) oscillating or near normal (1923–1940); (iv) short surplus (1941–1953); (v) longest and peak deficit (1954–1970); (vi) peak surplus (1971–1982); (vii) short deficit (1983–1986) and (viii) longest surplus (1987–2001). Noticeably, at the longer time scales,

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droughts become less frequent but their duration increases (**Figure 3b**) and after 1950s the extremities of surplus and deficit as well as duration have increased substantially. Most of the drought event reaches to its maximum intensity during the pre-monsoon months of March to May (**Table 2**).

4.1.2. Spatial character of the drought intensity

During the 102 year time span the MI_D at the 3- and 12-month time step was −0.81 and − 0.77 respectively. MI_D for most stations (69.44%) at all the time scale were ≥−0.8 but did not cross

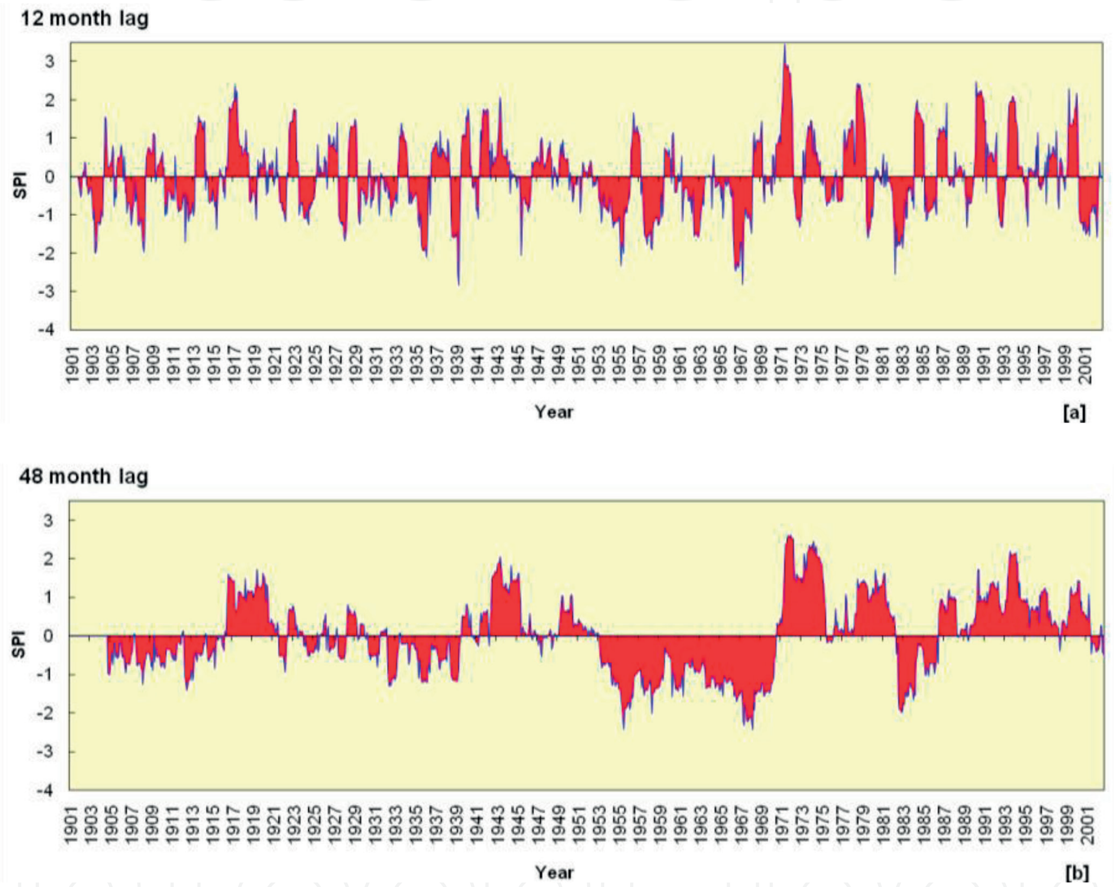

Figure 3. SPI time series (1901-2002) for GWB for (a) 12- and (b) 48- month time scales.

Lag time	Observed peak intensity (PI_D) during 1901–2002			Mean intensity (MI_D)
	SPI	Year	Month	
3-Month	−3.72	1999	April	−2.68 (gross avg. −0.81)
6-Month	−3.65	1922	March	−2.64 (gross avg. −0.77)
12-Month	−2.83	1939	June	−1.68 (gross avg. −0.77)
24-Month	−2.62	1968	January	−2.13 (gross avg. −0.81)
48-Month	−2.43	1968	May	−1.49 (gross avg. −0.79)

Table 2. Drought intensity at different time scale for GWB during 1901–2002.

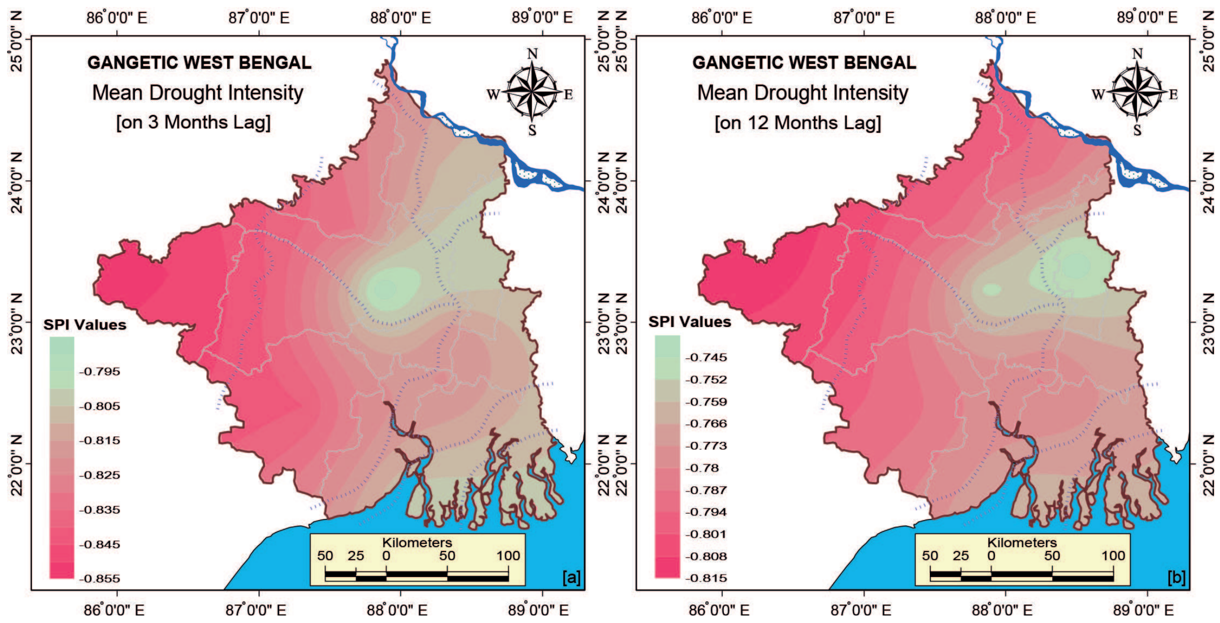

Figure 4. Iso-mean intensity drought map for (a) 3-, (b) 12- month SPI.

the limit of mild drought (i.e. 0 to −0.99). Regional MI_D varies between −0.75 (Krishnanagar) and −0.86 (Purulia). Spatially (**Figure 4a** and **b**), average drought intensity is the greatest in the degraded plateau region and western fringe of the Rarh region; it is less in the mature & active delta region and eastern fringe of the Rarh plain. Roughly the drought intensity gradually decreases from West to East and South East.

At the 3-month step observed peak intensities are maximum in the mature delta region (**Figure 5a** and **b**). At the 12-month step it was greatest in the western degraded plateau region, extreme northern part of moribund delta and Rarh plain region. Thus the western degraded plateau region is more sensitive to long-duration droughts.

4.2. Duration and magnitude of drought events

During 1901–2002, average drought duration identified by SPI on 12-month scale for most stations (>90.0%) was 4–6 months (**Table 3**) and the regional average value was 4.18. The maximum drought duration at all the stations was more than 20 months (**Table 3**) and the regional average of the most intense drought was 7 month. The average magnitude of the longest drought and the most intense drought event on 12 month scale is about −29 and −16 respectively with their mean intensity of −1.37 and −2.29.

Spatially at the shorter time span (3-month lag) the coastal plain followed by the southern Rarh and parts of the lower Ganga plain are sensitive to relatively longer drought duration (**Figure 6a**). At the 12-month lag, it was relatively longer in the degraded plateau and plateau fringe fans of the Rarh Bengal (**Figure 6b**). Noticeably the area suffered from lenghtier drought, magnitude was also counted high there (**Figure 7**).

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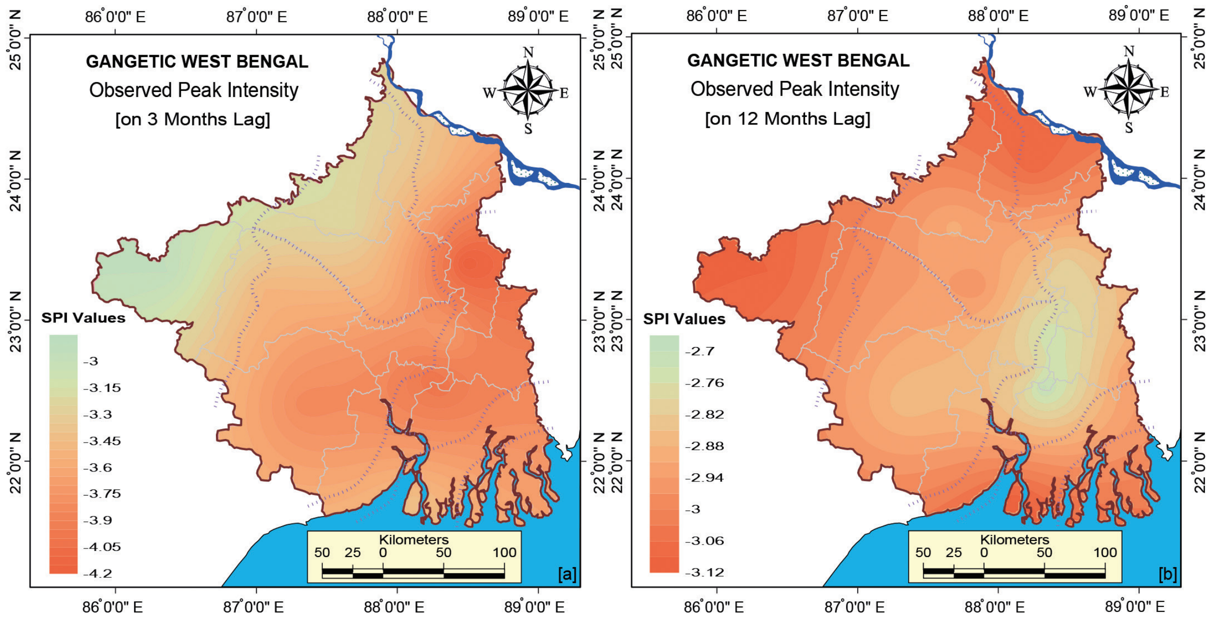

Figure 5. Observed maximum intensity drought map at (a) 3-month and (b) 12-month time scale.

Weather station	Longest duration (≤ − 1.0 for consecutive months)			Most intense duration (≤ − 2.0 for consecutive months)			$D_DA(M)$
	$D_DL(M)$	Year	M_D	$D_DL(M)$	Year	M_D	
Berhampore	24	Sept, 2000 to Aug, 2002	−32.18	11	July, 1982 to May, 1983	−27.87	4.57
Krishnanagar	23	July, 1966 to May, 1968	−42.33	8	Sept, 1982 to April, 1983	−18.09	4.19
Chinsurah	21	Sept, 1957 to May, 1959	−28.13	7	Oct, 1935 to April, 1936	−15.53	3.93
Uluberia	20	Oct, 1957 to May, 1959	26.05	8	Oct, 1935 to May, 1936	−19.97	4.46
Alipore	21	Sept, 1957 to May, 1959	−28.28	7	Oct, 1935 to April, 1936	−16.72	3.98
Basirhat	23	Sept, 1957 to July, 1959	−37.63	8	Oct, 1935 to May, 1936	−21.02	4.55
Purulia	25	Aug, 2000 to Aug, 2002	−46.23	12	July, 1966 to June, 1967	−33.34	5.17
Bankura	23	Sept, 2000 to July, 2002	−36.58	12	July, 1966 to June, 1967	−31.59	5.08
Sriniketan	23	Sept, 2000 to July, 2002	−34.06	7	Aug, 1966 to Feb, 1967	−16.15	5.15
Burdwan	23	Sept, 2000 to July, 2002	−31.73	8	Aug, 1966 to Mar, 1967	−19.4	4.55
Midnapore	20	Sept, 1957 to April, 1959	−25.75	8	Sept, 1935 to April, 1936	−20.55	5.07

Weather station	Longest duration (≤ − 1.0 for consecutive months)			Most intense duration (≤ − 2.0 for consecutive months)			$D_DA(M)$
	$D_DL(M)$	Year	M_D	$D_DL(M)$	Year	M_D	
Sagar Island	20	Oct, 1957 to May, 1959	−24.52	9	Sept, 1935 to May, 1936	−29.43	4.17
GWB	21	Sept, 1957 to May, 1959	−28.76	7	Sept, 1966 to Mar, 1967	−16.05	4.18

Note: ***DD(M):*** duration (month); ***DDL(M):*** observed longest duration (month); ***DDI(M):*** observed most intense duration (month); ***DDA(M):*** average duration (month); ***MD:*** magnitude.

Table 3. Drought duration and magnitude at 12 month time scale for different weather stations of the GWB during 1901–2002.

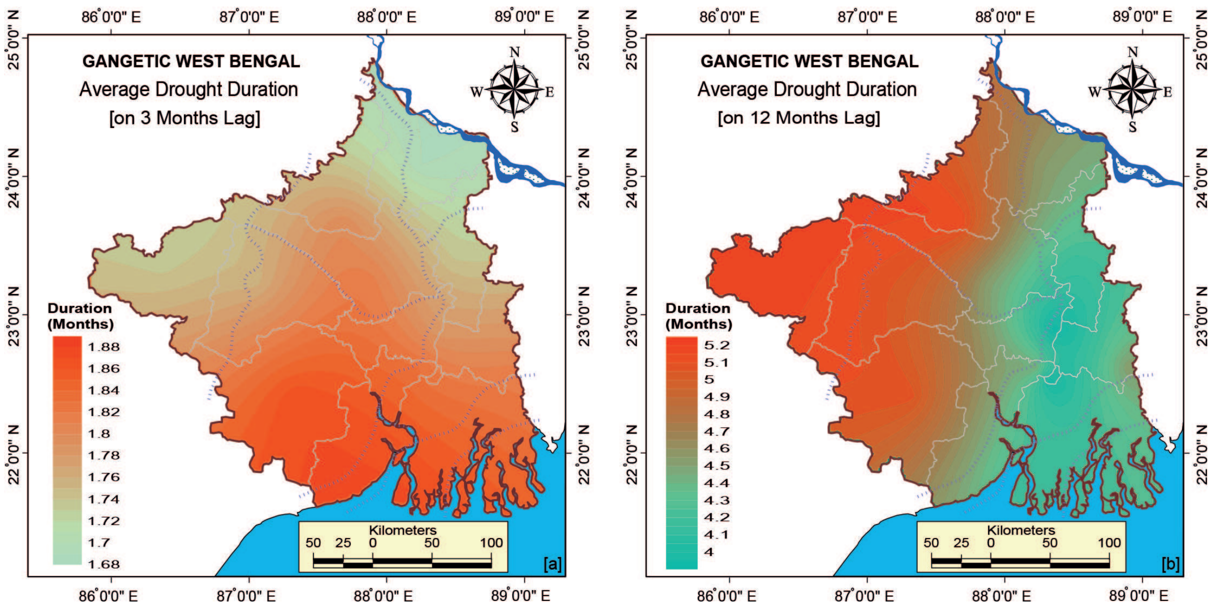

Figure 6. (a) Average duration of drought events for (a) 3-, (b) 12-month time scale.

4.3. Assessment of the frequency of drought occurrences

4.3.1. Regional average frequency

Percentage frequencies of drought occurrences of varying drought categories at different time steps have been outlined in **Table 4**. At all the time steps, more or less 16% years (i.e. once in every 6 year) have recorded drought of all categories.

4.3.2. Spatial character of the frequency of drought occurrences

At the 12-month time steps the moribund delta followed by parts of northern as well as southern Rarh has experienced higher occurrence severe droughts (**Figure 8a**). Extreme drought occurrences, on the other hand, are more pronounced in the western degraded plateau region (**Figure 8b**). This means that the western degraded plateau suffers from extreme drought condition frequently while parts of Rarh Bengal and northern extreme of the deltaic Bengal suffer from frequent severe drought conditions.

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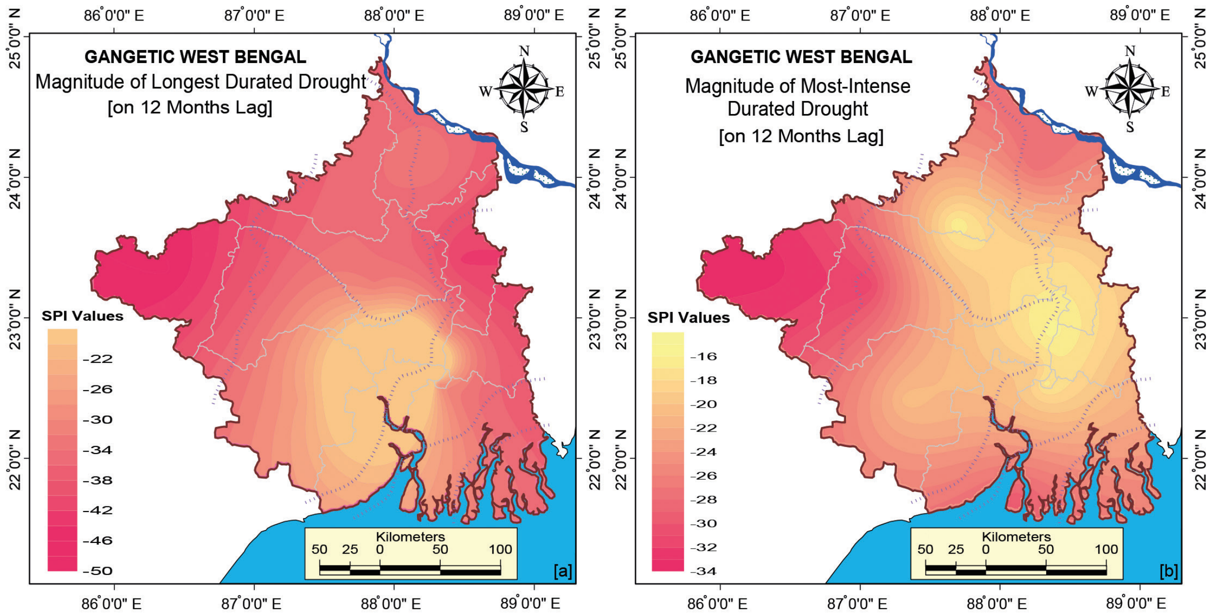

Figure 7. Magnitude for (a) longest and (b) most most-intense duration draughts on 12-month time step.

Draught severity class	SPI values	3-M lag	12-M lag	24-M lag	48-M lag
Moderately dry	(−1.0 to −1.49)	8.76	10.80	7.83	13.08
Severely dry	(−1.5 to −1.99)	4.09	4.20	5.66	3.91
Extremely dry	(−2 and less)	3.11	1.24	2.66	1.10
Total (%) of all categories drought		15.96	16.24	16.15	18.10

Table 4. Frequency of drought occurrences (%) in GWB at different time steps.

4.4. Phase-wise pattern of drought intensity, duration and frequency

To evaluate the Phase-wise change of drought variables during 1901–2002, the annual rainfall data series have been fitted with LOWESS or locally weighted regression curves [33, 34] to identify the patterns over time (**Figure 9**) and thereby to divide the entire time span into some clearly distinct phases (**Table 5**).

Regional average as well as peak drought intensity has increased significantly during first two consecutive phases. Meanwhile, there is no obvious change in average and maximum drought intensity between phase-II and Phase-III. The average drought duration has increased from 2.6 months in the phase-I to 5.5 month in the Phase-II and again has decreased to 4.4 months in the phase-III. Meanwhile, the most intense duration has increased from 8 month (Phase-I) to 11 month (Phase-II) again has equalized to 7 months in Phase-III. This may seem to be a good sign, but there is significant increase in mean intensity in the most intense duration drought from −1.46 in phase-I to as maximum as −2.06 in phase-III. This signifies that extreme drought events become short duration but its intensity is escalating as a signature of climate change. The regional extreme drought frequency during 1965–2002 compared to 1901–1933 has increased from 0 to about 2%.

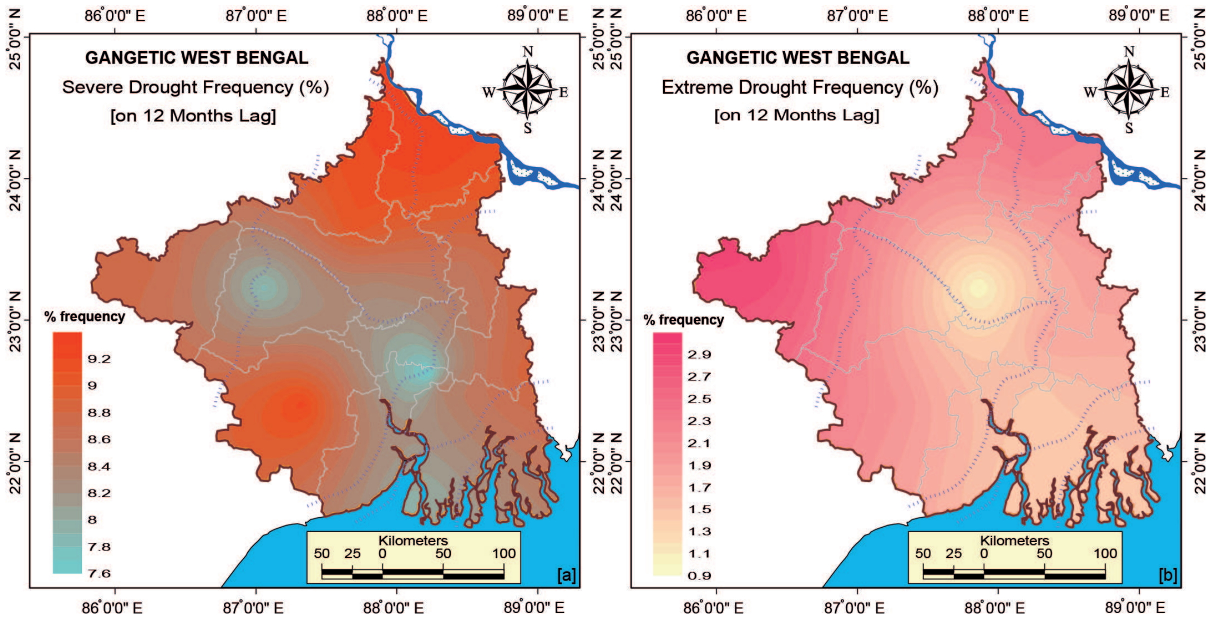

Figure 8. (a) Severe and (c) extreme drought occurrences at 12-month time steps.

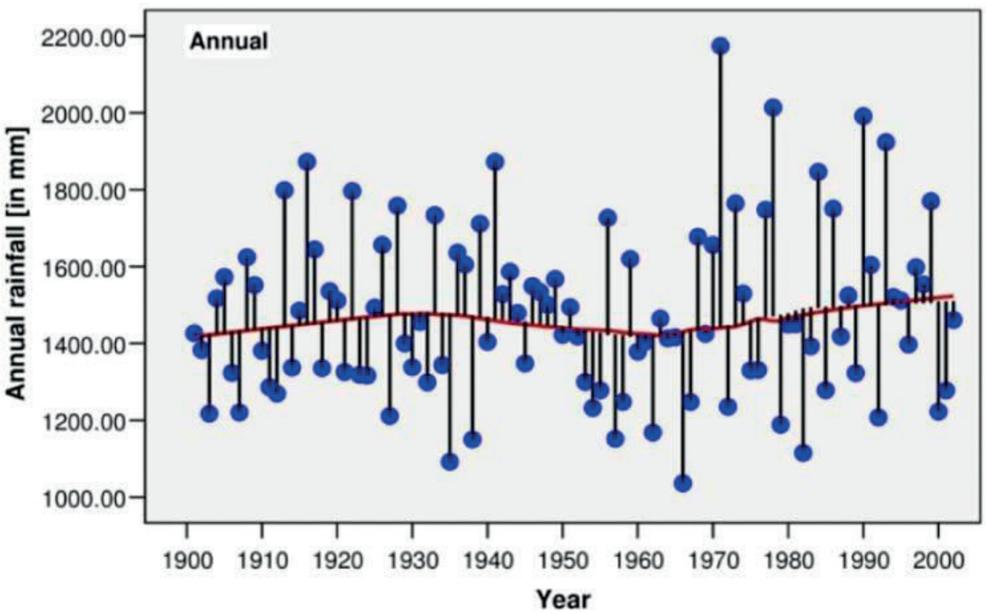

Figure 9. Locally weighted regression (LOWESS) and scatter plots of the average annual rainfall in GWB for the period 1901–2002.

4.5. Drought trend assessment

The MK test has been used to identify trend of drought intensity (**Table** 6). Here, in case of drought analysis, positive trend will indicate intensification of wet condition and negative change will indicate amplification of dry condition because trend of drought intensity is inversely related to the rainfall trend i.e. if rainfall declines drought event will amplify.

Drought indicators	Phase-I: 1901–1933	Phase-II: 1934–1964	Phase-III: 1965–2002	1901–2002
Average drought intensity (MID)	−0.71	−0.82	−0.77	−0.77
Maximum drought intensity (PID)	−1.98, 1903, July	−2.83, 1939, June	−2.82, 1967, June	−2.83, 1939, June
Average drought duration (DDA(M)) (SPI: ≤ −1.0 for consecutive months)	2.61	5.54	4.39	4.18 month
Maximum drought duration (DDL(M)) (SPI: ≤ −1.0 for consecutive months)	10 month (August, 1927 to May, 1928)	21 month (Sept, 1957 to May, 1959)	14 month (July, 1966 to August, 1967)	21 month (Sept, 1957 to May, 1959)
Most intense duration (DDI(M)) (SPI: ≤ −2.0 for consecutive months)	8 month (July, 1903 to Feb, 1904). Mean intensity: −1.46	11 month (Sept, 1938 to July, 1939). Mean intensity: −1.68	7 month (Sept, 1966 to March, 1967). Mean intensity: −2.06	7 month (Sept, 1966 to March, 1967): Mean intensity: −2.06
Moderate drought frequency (%)	10.65	10.65	12.73	10.80
Severe drought frequency (%)	2.69	6.72	4.30	4.20
Extreme drought frequency (%)	0	1.32	1.97	1.24

Table 5. Regional intensity, duration and frequency of drought events identified from SPI values at a 12-month scale for different periods in GWB.

At all the time steps, stations Berhampore, Purulia, Bankura, Sriniketan and Burdwan, irrespective of their level of significance, have experienced amplification of dry condition over the assessed period. For the 3-month step, significant positive trends (on 95% sig. level) have been detected at Berhampore, Sriniketan and Purulia of the Moribund delta, northern Rarh and western degraded plateau respectively (**Figure 10a**). For the station Sriniketan and Purulia the trend remains analogous for the 12- and 24-month time series also (**Figure 10b** and **Table 6**). However, on longer time span of 24-month scale, station Berhampore of the Moribund deltaic Bengal has experienced insignificant growth on 95% level of significance unlike the 3- and 12-month scale (**Table 6**).

4.6. Drought returns periods

In case of mod drought, the return periods are lesser in parts of deltaic Bengal and Rarh plain (**Figure 11a**). However, the circumstances roughly reversed in case of the extreme drought (**Figure 11b**) and the western degraded plateau and some parts of the plateau fringe fans and moribund delta part return periods count lesser. Thus, on entire regional scale the deltaic Bengal & Rarh plain are more sensitive to frequent attack of severe drought but extreme drought attack more recurrently in the western degraded plateau and some adjacent parts of the Rarh plain.

Weather stations	SPI-3			SPI-12			SPI-24		
	Z	**Q**	**Tr**	**Z**	**Q**	**Tr**	**Z**	**Q**	**Tr**
Berhampore	−1.30*	−0.21	*In**	−2.05*	−0.49	*In**	−1.87$^+$	−0.59	*In*$^+$
Krishnanagar	0.44	0.07	De	0.94	0.22	De	1.49	0.39	De
Chinsurah	1.17	0.17	De	1.86	0.48	De	2.52$^+$	0.75	De$^+$
Uluberia	1.75$^+$	0.24	De$^+$	2.77$^+$	0.71	De$^+$	3.23*	0.99	De*
Alipore	1.46$^+$	0.22	De$^+$	2.40$^+$	0.61	De$^+$	2.98*	0.91	De*
Basirhat	1.98*	0.32	De*	3.27*	0.81	De*	3.88*	0.15	De*
Purulia	−1.26	−0.18	*In*$^+$	−1.79$^+$	−0.44	*In*$^+$	−1.95$^+$	−0.60	*In*$^+$
Bankura	−0.53	−0.10	*In*	−0.80	−0.18	*In*	−0.63	−0.20	*In*
Sriniketan	−1.49*	−0.24	*In**	−2.53*	−0.63	*In**	−2.77*	−0.85	*In**
Burdwan	−0.45	−0.06	*In*	−0.81	−0.18	*In*	−0.61	−0.16	*In*
Midnapore	1.33	0.20	De	2.22	0.55	De	2.81$^+$	0.80	De$^+$
Sagar Island	2.17*	0.34	De*	3.48*	0.89	De*	4.00*	0.25	De*
GWB Avg.	0.53	0.08	De	0.92	0.24	De	1.56	0.44	De

Note: ***Z*:** standardized test statistics of MK test; ***Q*:** Sen's slope estimate; ***Tr***: trend of drought; ***In*:** increasing and ***De*:** decreasing trend of dry condition.*Significant trend at 0.05 level of significance.
$^+$Significant trend at 0.1 level of significance.

Table 6. Result of MK test, Sen's slope and trend of drought (1901–2002) over GWB.

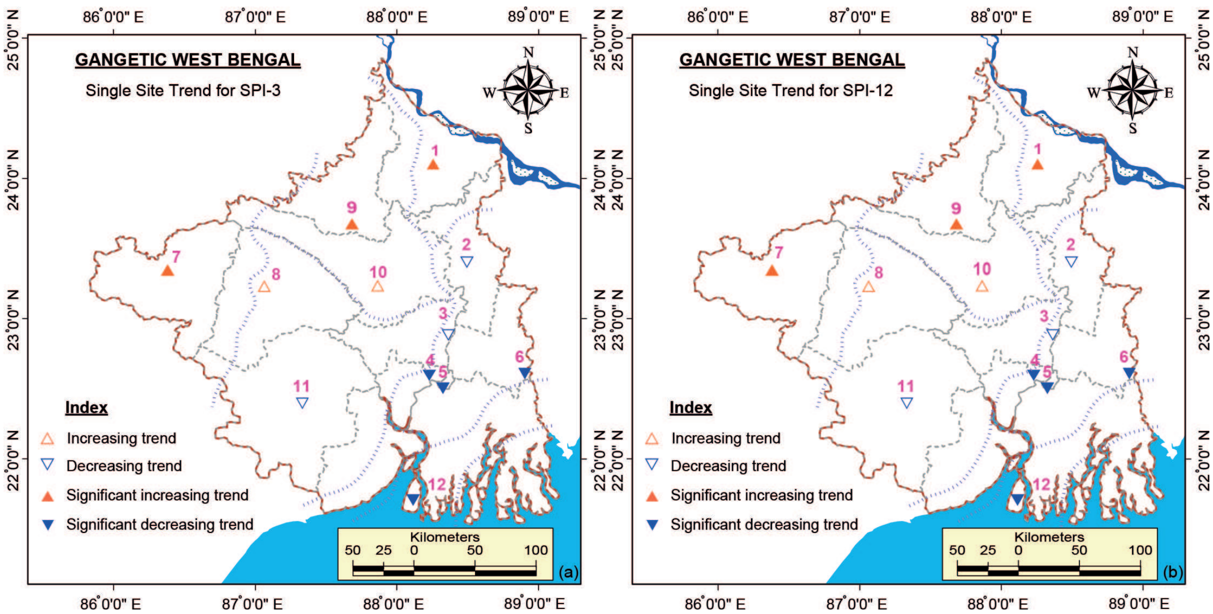

Figure 10. Single-site trend of drought intensity for SPI at different time scales.

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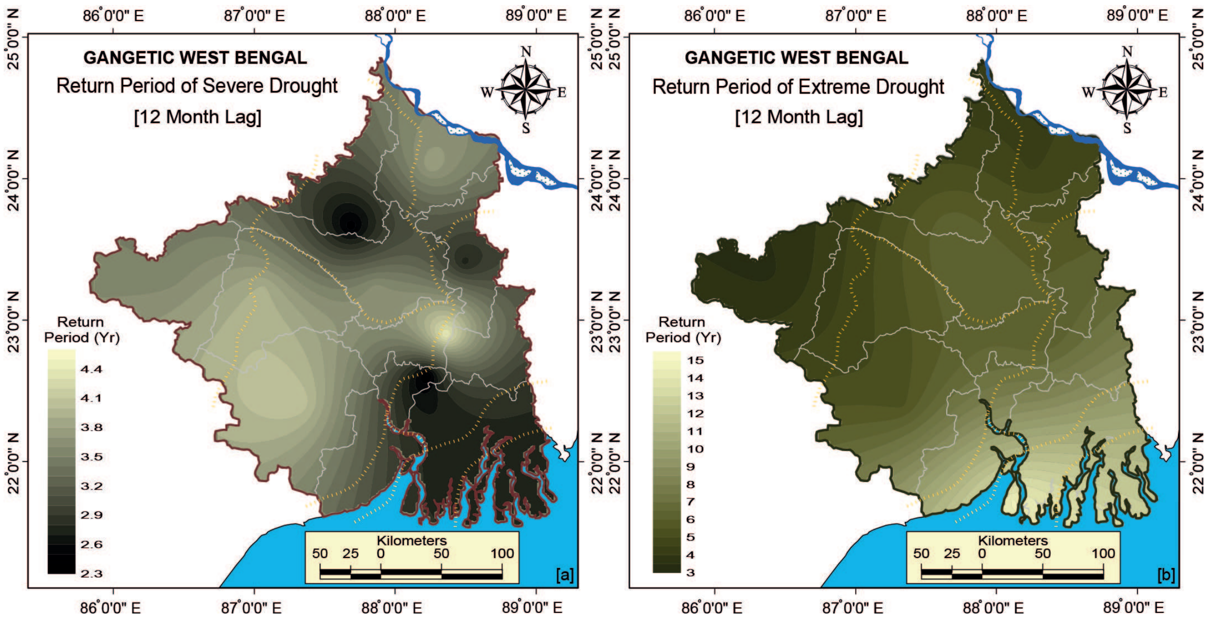

Figure 11. Return period of (a) severe drought (SPI < −1.5 to −1.99) and (b) extreme drought (SPI < −2.0) on 12-month time steps.

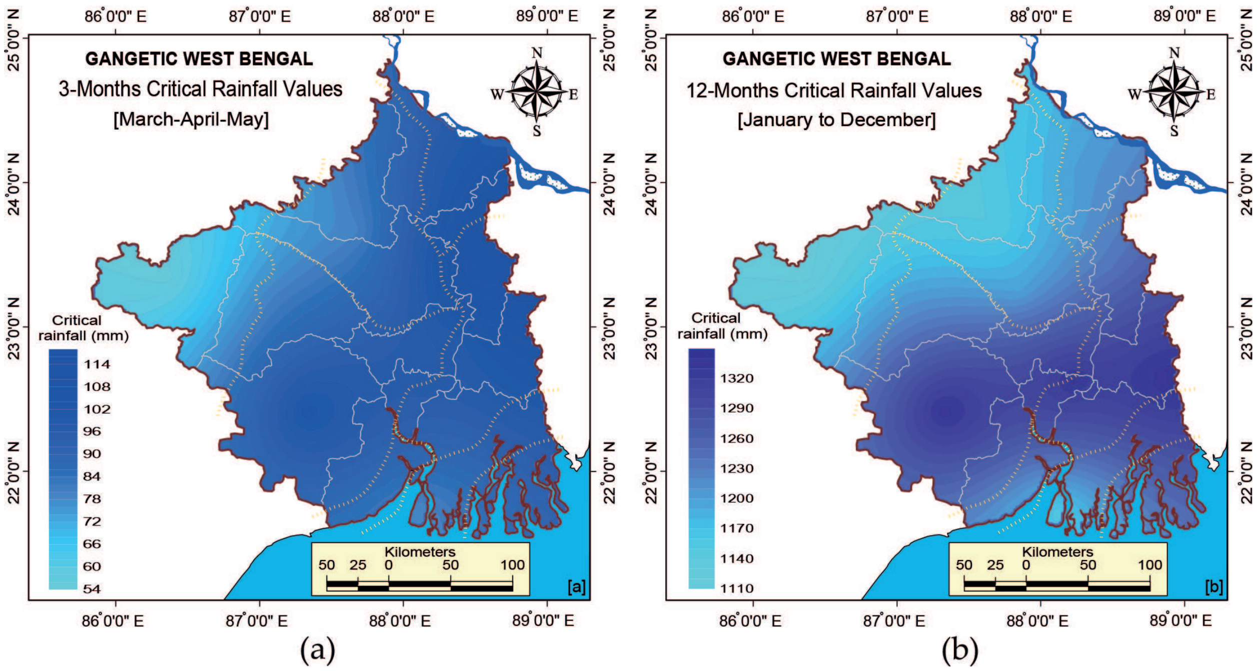

Figure 12. Critical rainfall values for (a) 3-months and (b) 12-month time lag.

4.7. Critical (threshold) rainfall analysis

Critical rainfall is the least amount of rainfall below which can initiate drought. The critical rainfall demands for no-drought occurrences roughly increases from West to East and

South-east (**Figure 12a** and **b**). Therefore, it is likely that the interior region immediately after the coastal and lower Ganga delta will be more exposed to droughts particularly the non-irrigated croplands due to relatively more demand of water.

5. Summary and conclusion

This chapter has provided results on the assessment meteorological drought condition for the Gangetic West Bengal of Eastern India over the last century in the context of climate change. The patterns of drought frequency, magnitude, trend etc. portrayed through statistical assessment, visually interpretive maps and geographic description so as to improve our understanding of drought jeopardy of this region.

The study confirmed that, the last century exhibits some consecutive deficit and surplus phases and after 1950s extremity of surplus and deficit as well as duration have been increased substantially. Stepping up of the maximum drought intensity; mean intensity of the most intense drought event; average drought duration; severe and extreme drought frequency from 1940s in this agricultural tract are some alarming events to think over. At the intra-regional scale, average drought intensity as well as duration was the greatest in the western degraded plateau and Rarh region and are also sensitive to extreme droughts. The impact of drought is expected to be rigorous at or adjacent areas of the western degraded plateau, particularly the northern Rarh and moribund delta where the drought intensities are tend to increase while the rainfall as well as recurrence interval of drought are tend to lessen. The western degraded plateau is widely known for its drought proneness [35]. But, this work provides evidences demonstrating the extension and intensification of dryness at and in the adjacent areas of this traditional drought prone region namely, towards the northern Rarh plain and moribund delta. All of these indicate potential threat to the rain-fed agriculture, food security and socio-economic vulnerability to drought of this region. Therefore, a more detailed study to explore the drought risk as well as trend and pattern of other hydro-climatic variables is essential. Work related to this issue is in progress and will be reported elsewhere.

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Conflict of interest

The author states that there is no conflict of interest.

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