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Research Article

ANALYSIS OF TRENDS AND VARIABILITY IN RAINFALL OVER WEST BENGAL

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A B S T R A C T

The scope of the study is to analyse the trends and variability in the rainfall pattern over the West Bengal using non parametric Mann-Kendall test, Sen's slope estimator. Analysis has been carried out for monthly, seasonal and annual rainfall series of 19 districts in the two meteorological sub-divisions of West Bengal using monthly rainfall data of 117 years (1901-2017). It was found that except Darjeeling district, all the other districts in Sub-Himalayan West Bengal showed decreasing trend. On the other hand nine districts in the Gangetic West Bengal showed increasing trend in the rainfall pattern and four districts showed slightly decreasing trend.

INTRODUCTION

Now-a-days increase in global temperature in association with climate change is considered to be among the major challenges of the 21st century. It is strongly considered that this change in climate is not influencing the water resources of any region but also threatening the food security of agriculture based country's economy, both are governing the human life on the earth. Lot of changes in the climatic factors such as rainfall, temperature, etc in different parts of the world has been witnessed in the last century. Day to day the changing pattern in rainfall is becoming serious problem all over the world because of its miraculous behaviour. This in turn not only affects the fresh water availability but remarkably affects the food production (Dore, 2005). IPCC (2007) report also confirms that change in precipitation is due to change in climate causing floods in some part and droughts in other parts. However, this change is not uniform all over the world but large variations are seen at regional level (Parry et al., 2007). In spite of these large variations, monsoon rainfall has been called the *"presiding deity"* of India because by and large, Indian subcontinent is an agricultural country whose economic well being and prosperity exclusively depends to a large extent on the timely arrival and withdrawal of monsoon and the rainfall received during the four monsoon months of June to September.

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It is, therefore, essential to study different aspects of monsoon rainfall which is unique every time and visualize any climate change impact of it its on water resources planning, agricultural production, industries, etc.

Chatfield (2003) defined the trend as long-term changes in the average value of a time series. Many researchers made efforts to study Indian summer monsoon rainfall vagaries. On the basis of observed temperature and rainfall data, Dash et al (2007) inferred that there is decreasing in rainfall during the monsoon season as against the increasing trend in the pre-monsoon and post-monsoon season. Trend analysis study of meteorological sub-divisions made by Guhathakurta and Rajeevan (2008) inferred that Kerala, Jharkhand and Chattisgarh sub-divisions showed significantly decreasing trend whereas Jammu & Kashmir, Uttar Pradesh, Gangetic West Bengal, Konkan & Goa, Madhya Maharashtra, Coastal Andhra Pradesh, Rayalseema and North Interior Karnataka sub-divisions showed significantly increasing trend in rainfall during 1901-2003. In near past, studies made by Singh and Sontakke (2002) over different parts of Indo-Gangetic plains showed decreasing trend over central region since 1939. The increasing and declining trend over western region was observed from 1900 till 1984. Even eastern part showed insignificant increasing trend for1984-1999 period.

On the basis of monthly rainfall data of 1875 to 2005 for 30 meteorological sub-divisions in India, Kumar et al (2010) noticed major decreasing trend in rainfall in Chattisgarh sub-division and significantly increasing trend in annual rainfall in Punjab-Haryana and coastal Karnataka sub-divisions. The study also showed decrease in monsoon and annual rainfall and increase in winter rainfall for the country as a whole. Jain and Kumar (2012) studied trend analysis of rainfall and temperature over India with special reference to river basins. The analysis showed decreasing in annual rainfall by 0.45 to 4.93 mm/year in fifteen river basins while six river basins showed increasing trend in the range of 0.27 to 10-16 mm/year in monsoon rainfall. IMD (2013) reported an increasing trend in average monsoon season rainfall during 1950-2010 in West Bengal (State Level Climate Change Trends in India, 2013).

Drought frequency and intensity analysis made by Kar et al (2012) showed that the western and the central parts of the West Bengal were more prone to drought during 1973-2005 study period. Using IMD's long period data (1961-1990) authors found that Krishnanagar, Malda and Purulia experienced relatively lower rainfall (< 1333 mm). They also showed that extreme northern part has also been reeling under drought in recent years. Using daily gridded data for 1971-2005 of four rainfall stations surrounding the Purulia district spatial pattern of meteorological drought was analysed by Palchaudhuri and Biswas (2013). The Standardized Precipitation Index (SPI) graphs showed high SPI values (i.e. extreme drought) for three stations in 1993. 1976, 1979, 1980, 1982, 1983, 1985, 2001, 2003 were found to be the worst drought years. Central part of the district experienced mild to moderate droughts whereas northeast, northwest and southwest parts experienced severe and extreme droughts.

Using 100 years monthly rainfall data (1901-2000), Pal et al (2015) estimated long term trend for Gangetic West Bengal. Their analysis showed significantly increasing trend in annual rainfall in South 24 Parganas and the entire sub-division. The noteworthy finding of their analysis is increasing trend in September rainfall and post-monsoon months of October-December as well. Temperature and rainfall trend analysis carried out by Biswas (2016) over Nadia district of West Bengal showed maximum variation in average rainfall in the June month indicating high irregularities for the period 1901-2002. The district wise rainfall trend analysis of West Bengal during the 1901-2000 showed decreasing trend in the Malda district of SHWB (Mukherjee, 2017).

From the foregoing it is seen that numbers of studies have been carried out to study trends in rainfall at seasonal or annual level at sub-divisional or national level in India. However, in order to know the climate change impact on regional scale, the present study dealt with the changes in rainfall variation in West Bengal at district level confined to two meteorological sub-divisions of Sub-Himalayan West Bengal (SHWB) and Gangetic West Bengal (GWB) using 117 years monthly rainfall data. In the increasing trend of sea surface temperature (SST) scenario and increase or decrease in the frequency of low pressure systems during the last century, long term rainfall trend analysis over the state will definitely be useful in knowing rainfall variation and hydro-economic conditions over the state.

MATERIALS AND METHODS

Study Area

The West Bengal State situated in the eastern part of India cover an area 88752 sq.km which is about 3% of the total area of the Indian region. It is bounded to the east by Bangla Desh, to the south by the Bay of Bengal, to the southwest by Odisha (Orissa) state, the state of Jharkhand to west, to the northwest by the Bihar state and Nepal, to the north by Sikkim state and Bhutan and Assam in the northeast (Fig.1). The state experiences inherent climate diversity because of its vast physiographic features. The major part of the state falls in the Gangetic West Bengal (GWB) covering thirteen districts. The river Ganga bifurcates here separating Sub-Himalayan West Bengal (SHWB) from the GWB. The SHWB is a part of Tarai lowland belt between the Himalayan ranges and the plain area. Southwest monsoon (Jun-September) advances over the state by June 7 and withdraws around October 10 comprising of nearly 125 monsoon days. The average seasonal rainfall over SHWB and GWB is in the range of 77%-80% and 73%-81% respectively.

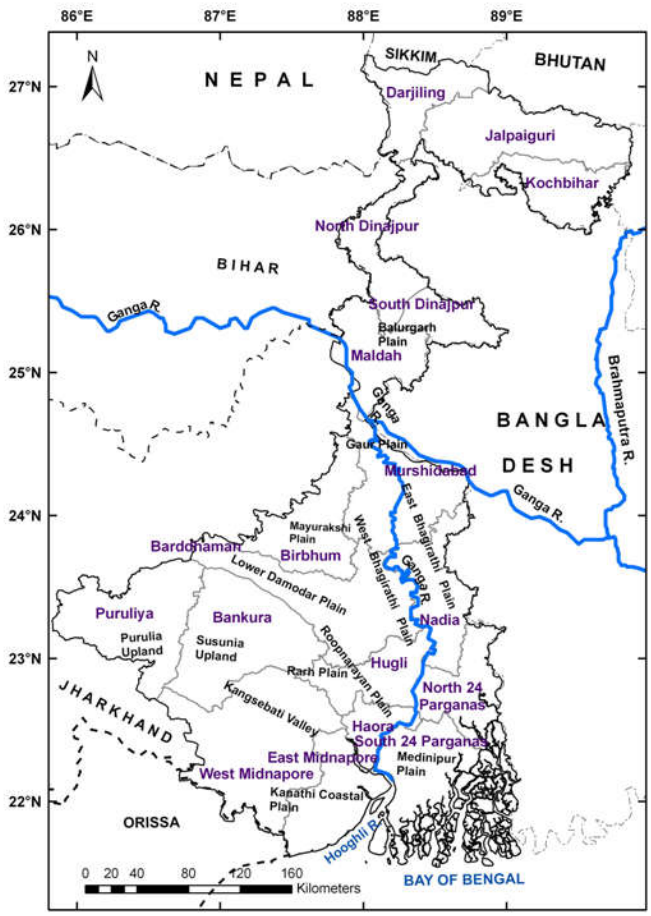


Fig 1 District map of West Bengal with major Ganga river

The SHWB which is located in the foot-hills of Himalayas in the north consists of six districts (viz. Darjeeling, Jalpaiguri, Cooch Behar, Dinajpur N, Dinajpur S and Malda) (see Fig.1) and thirteen districts of GWB (viz. Murshidabad, Birbhum, Bardhman, Nadia, Manbhum Purulia, Bankura, Hoogly, Howrah, Midnapore E, Midnapore W, 24 Parganas N, 24 Parganas S and Kolkata) in the Gangetic plains experience different types of climatic conditions all through the year. Therefore, in order to assess spatial and temporal distribution of rainfall pattern, district wise rainfall variation has been studied.

Data source

Long term monthly rainfall data for all the districts and the two Sub-divisions of the state for the period of 1901 to 2017 obtained from the India Meteorology Department (IMD) forms the major data source.

METHODOLOGY

In order to assess a trend in the given time series generally parametric or non-parametric distribution are fitted. In the present study the annual and seasonal time series was subjected to normal, log-normal, Gamma Type II, Poisson and Pearson Type III distributions. The magnitude of the trend in the time series is determined by Sen's Slope estimator (Sen, 1968).

$$T_i = \frac{x_j - x_k}{j-k} \quad \text{for } i=1,2,.....N \quad (j>k) \qquad ....(1)$$

Where T_i is Sen's Slope, x_j and x_k are data values of the same observational unit at time j and k respectively. The median of these N values of Ti is represented as Sen's estimator of slope which is given as:

$$Q_{median} = \begin{cases} \dfrac{T_{(N+1)}}{2} & \text{if N is odd} \\ \dfrac{T_{\frac{N}{2}} + T_{\frac{(N+2)}{2}}}{2} & \text{if N is even} \end{cases} \qquad ....(2)$$

The sign of Q_{median} reflects the data trend direction and its value gives the magnitude of slope of the trend. A positive value indicates increasing and negative value indicate decreasing trend in the time series.

The rainfall time series is further subjected to a popular Mann-Kendall non parametric test to determine any statistically significant trend as illustrated below-

Null Hypothesis: There is no trend in the series meaning data are independent and randomly selected. S statistic is calculated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(\chi_j - \chi_i) \quad \text{for } j > 1 \qquad .....(3)$$

Where, x_i and x_j are the values of the data at time i = 1,2…., n-1 and j = i+1, 2,…., n respectively. The null hypothesis is rejected when the test is two sides at a level of significance.

Each of the data point x_i is taken as a reference point which is compared with the rest of the data points x_j so that,

$$Sign(x_j - x_i) = \begin{cases} -1 \text{ for } (x_j - x_i) < 0 \\ 0 \text{ for } (x_j - x_i) = 0 \\ +1 \text{ for } (x_j - x_i) > 0 \end{cases} \qquad ...(4)$$

When n ≥ 8, the statistic S is approximately normally distributed with the mean E(S) = 0 and variance is given as

$$\text{Var}(S) = \frac{1}{18} n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5) \qquad ......(5)$$

Where, t_p is the number of ties for the p^{th} values and q is the number of tied values. The test statistics Zc which is known as Kendall's Tau (τ) (Kendall, 1975) is computed as

$$Z_c = \begin{cases} \dfrac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S>0 \\ 0 & \text{if } S=0 \\ \dfrac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S<0 \end{cases} \qquad ......(6)$$

Here Zc follows a standard normal distribution. A positive value of Z signifies an increasing trend and negative value as decreasing trend. Kendall's tau is comparable to the correlation coefficient in regression analysis and varies between -1 to +1.

The drawback of the Mann-Kendall test (distribution free test) is that it is only able to detect monotonic trend in the data. In order to assess the trend in the large variable data set of rainfall series from 1901-2017 for the districts in West Bengal, second degree polynomial was found to be best fit indicating increase and decreasing periods in the given time series. The percentage change has been computed by

$$\text{Percentage Change}(\%) = \frac{\beta * \text{Period of length}}{\text{Mean}} \text{x}100$$

Computation of monthly data for trend analysis and descriptive statistical analysis was done using XLSTAT 2016 and MS Excel. Results of spatial distribution were shown using GIS technique.

RESULTS AND DISCUSSION

On the basis of 117 years monthly rainfall data, mean monthly, seasonal and annual rainfall has been estimated for all the districts in the West Bengal. The mean annual rainfall over the SHWB varies from maximum of 3871 mm (Dist. Jalpaiguri) in the extreme north to minimum 1471 mm (Dist. Malda) in the extreme south of the SHWB sub-division (Table 1 &2). Similarly average maximum Jun-Sept rainfall is received by Jalpaiguri district (3024 mm) and minimum by Malda district (1125 mm). About 77 to 80% of annual rainfall is received in this sub-division. The northern districts receive comparatively heavy rainfall due to Himalayan topography. CV shows more variation during monsoon season (Table 2) than annual rainfall. It is higher in Dinajpur North and South, Malda districts for annual and seasonal rainfall (see Fig.2).

In GWB, average annual and seasonal maximum rainfall is noted by 24 Pargana S district (1765 mm and 1328 mm respectively) and minimum by Nadia district (1309 mm and 956 mm respectively). Around 74 to 81% of the annual rainfall is contributed by Jun-Sept rainfall (Table 1&3). It is also seen from Table 1 that pre-monsoon months of Mar-May and post-monsoon month October also substantially contribute to annual total. This is mostly related to thunderstorm activity during the pre-monsoon months locally known as 'Kal Baisakhi' (norwesters). High variation in annual and seasonal rainfall is seen in Nadia, Howrah and 24 Pargana S districts (see Table 3 and Fig.2) and low variation in Bardhman (Burdwan), Purulia and Midnapore W districts. It is seen from Table 3 that data is positively skewed in both the sub-divisions except Howrah district in GWB.

Table 1 Average seasonal and annual rainfall (mm) in the districts of West Bengal

	Districts	Jan-Feb	Mar-May	Jun-Sept	Oct-Dec	Average Annual	Jun-Sept as % of Annual
	Sub-Himalayan West Bengal						
1	Cooch Behar	25.9	538.0	2523.81	181.4	3269.06	77
2	Jalpaiguri	32.7	588.6	3049.58	199.2	3871.16	79
3	Darjeeling	40.1	410.2	2498.51	159.0	3107.81	80
4	Dinajpur N	20.8	179.2	1232.25	106.7	1538.98	80
5	Dinajpur S	21.7	210.6	1224.03	135.6	1584.35	77
6	Malda	25.6	167.0	1152.26	126.7	1471.34	78
	Gangetic West Bengal						
7	Murshidabad	26.5	179.4	1045.2	123.7	1374.5	76
8	Birbhum	29.4	154.5	1071.7	121.6	1377.1	78
9	Bardhman	32.0	167.7	1034.0	115.8	1349.6	77
10	Nadia	30.8	198.9	956.3	125.4	1309.3	73
11	Purulia	38.9	112.4	1073.0	103.9	1328.2	81
12	Bankura	33.7	145.4	1032.4	110.3	1321.9	78
13	Hoogly	37.5	201.2	1042.5	127.1	1408.0	74
14	Howrah	35.5	197.0	1150.8	147.3	1530.8	75
15	Midnapore E	40.2	189.5	1173.9	176.8	1579.8	74
16	Midnapore W	40.0	200.4	1149.5	141.3	1530.5	75
17	24 Parganas N	35.9	226.5	1176.2	158.3	1596.6	74
18	24 Parganas S	36.1	191.7	1328.1	210.0	1765.3	75
19	Kolkata	37.9	209.5	1263.8	180.9	1692.3	75

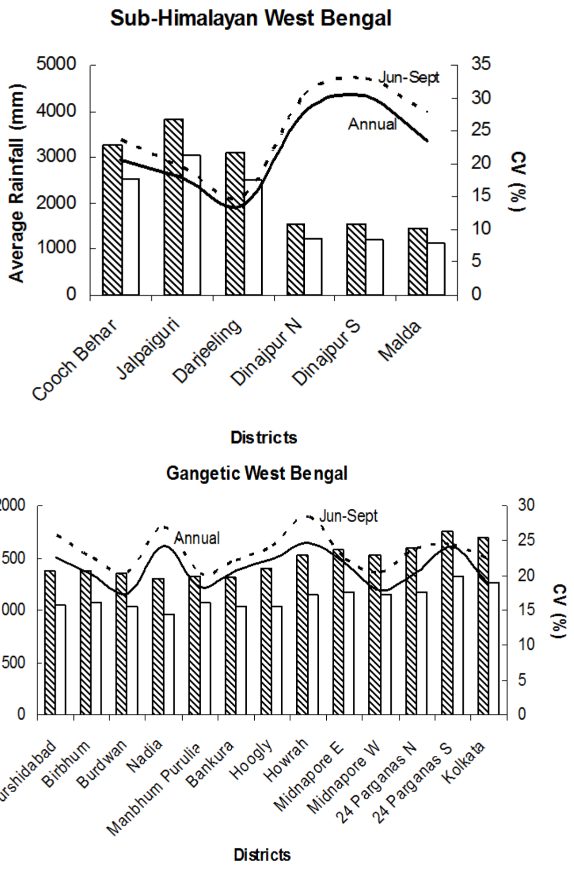


Fig 2 Annual and Jun-Sept rainfall variation in two sub-divisions of West Bengal

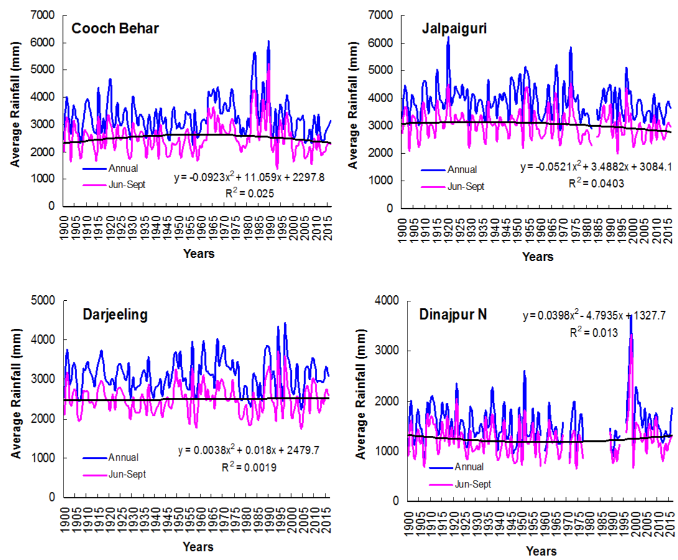
The trend in yearly average annual and seasonal rainfall for all the districts (see Fig.3 & 4) during the period of 1901-2017 is assessed by fitting second degree polynomial distribution. In SHWB sub-division, Darjeeeling and Malda districts do not show any specific trend in rainfall pattern as these districts directly come in the path of monsoon disturbances originating from the Bay of Bengal and Himalayan topography.

Table 2 Descriptive statistics of annual and seasonal rainfall (mm) of SHWB

No.	District	Mean	SD	CV (%)	Range	Stnd Error	Coef. Skew	Coef. Kurt
1	Cooch Behar	3269.06	672.36	20.6	3900.70	62.16	1.25	2.77
2	Jalpaiguri	3871.16	630.23	16.3	3435.90	58.52	0.81	1.14
3	Darjeeling	3107.81	424.10	13.6	2184.90	39.21	0.51	0.33
4	Dinajpur N	1538.98	428.65	27.9	2872.00	42.65	1.50	5.45
5	Dinajpur S	1584.35	436.52	27.6	2414.8	40.88	0.71	0.81
6	Malda	1471.34	346.56	23.6	1747.30	32.18	0.17	0.02
	Ave Ann	**2473.78**	**489.74**	**21.6**	**2759.27**	**45.93**	**0.83**	**1.75**
1	Cooch Behar	2523.81	598.49	23.7	3823.80	55.33	1.18	3.09
2	Jalpaiguri	3049.58	523.26	17.2	2521.20	48.58	0.57	0.44
3	Darjeeling	2498.51	373.68	15.0	1967.20	34.55	0.51	0.42
4	Dinajpur N	1232.25	373.02	30.3	2657.80	37.12	1.82	8.37
5	Dinajpur S	1224.03	372.52	30.4	2645.90	35.96	1.03	2.73
6	Malda	1152.26	319.43	27.7	1722.20	29.66	0.63	0.80
	Ave Jun-Sept	**1946.74**	**426.73**	**24.0**	**2556.35**	**40.20**	**0.96**	**2.64**

Table 3 Descriptive statistics of annual and seasonal rainfall (mm) of GWB

No.	District	Mean	SD	CV (%)	Range	Stnd Error	Coef. Skew	Coef. Kurt
1	Murshidabad	1374.50	310.27	22.6	1721.10	28.68	0.62	1.05
2	Birbhum	1377.15	278.46	20.2	1301.00	25.74	0.34	-0.27
3	Bardhman	1349.58	235.75	17.5	1154.40	21.79	0.43	-0.04
4	Nadia	1309.32	317.18	24.2	1687.80	29.45	0.19	0.23
5	Purulia	1328.17	244.90	18.4	1369.40	22.64	0.28	-0.03
6	Bankura	1321.87	274.83	20.8	1670.10	25.41	0.21	0.77
7	Hoogly	1408.03	314.30	22.3	1889.40	29.06	0.19	0.93
8	Howrah	1530.80	377.47	24.7	1881.00	35.67	0.03	-0.06
9	Midnapore E	1591.24	323.41	21.8	1619.80	30.03	0.56	0.07
10	Midnapore W	1530.50	273.93	17.9	1440.00	25.43	0.61	0.14
11	24 Parganas N	1596.57	326.04	20.4	1647.70	30.14	0.42	0.11
12	24 Parganas S	1765.31	424.42	24.0	2694.20	39.24	1.59	4.64
13	Kolkata	1692.26	317.08	18.7	1687.40	29.44	0.45	0.08
	Ave Ann	**1475.02**	**309.08**	**21.0**	**1674.10**	**28.67**	**0.45**	**0.59**
1	Murshidabad	1045.17	270.72	25.9	1664.70	25.03	0.62	1.09
2	Birbhum	1071.66	242.82	22.7	1213.80	22.45	0.61	0.25
3	Bardhman	1033.98	211.15	20.4	1114.60	19.52	0.75	0.59
4	Nadia	956.32	257.47	26.9	1568.40	24.01	0.87	1.55
5	Purulia	1073.03	217.83	20.3	1070.70	20.14	0.34	-0.19
6	Bankura	1032.44	228.43	22.1	1255.60	21.12	0.46	0.27
7	Hoogly	1042.53	253.24	24.3	1471.00	23.41	0.15	0.47
8	Howrah	1150.78	328.06	28.5	1678.70	31.00	-0.06	-0.01
9	Midnapore E	1182.76	246.50	22.5	1353.50	22.89	0.48	0.47
10	Midnapore W	1149.50	236.13	20.5	1128.90	21.92	0.90	0.96
11	24 Parganas N	1176.17	281.12	23.9	1526.80	25.99	0.61	0.26
12	24 Parganas S	1328.13	324.75	24.5	2142.00	30.02	1.30	4.09
13	Kolkata	1263.85	282.77	22.4	1264.30	26.25	0.61	-0.24
	Ave Jun-Sept	**1115.87**	**260.08**	**23.5**	**1419.46**	**24.13**	**0.59**	**0.74**



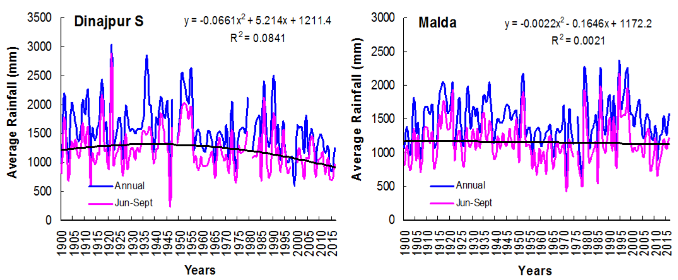
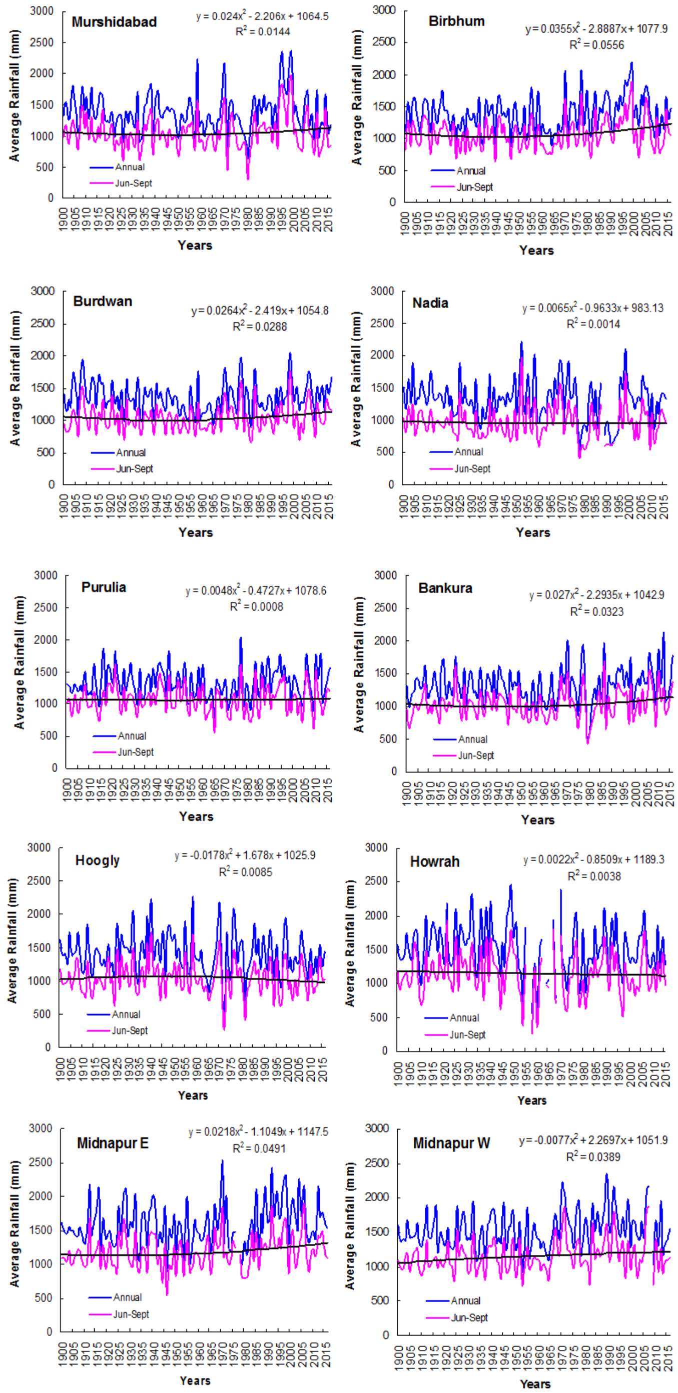


Fig 3 Yearly trend variation in average annual and Jun-Sept rainfall over SHWB districts

(Note: More than 75% of annual rainfall is received during the monsoon season; trend line is applied to Jun-Sept rainfall only)



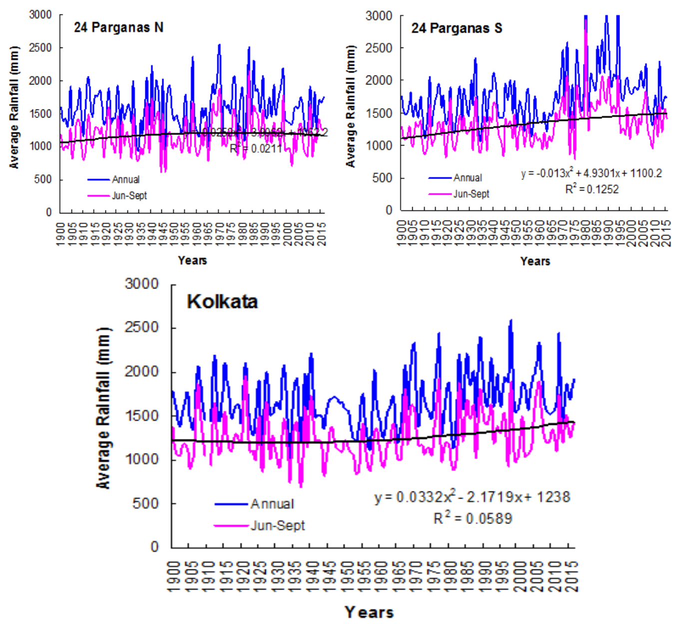


Fig 4 Yearly trend variation in average annual and Jun-Sept rainfall over GWB districts

(Note: More than 75% of annual rainfall is received during the monsoon season; trend line is applied to Jun-Sept rainfall only)

The similar result was also reported by Mukherjee (2017) but negative Sen's slope indicates that rainfall is decreasing. Cooch Behar and Jalpaiguri districts showed decreasing trend 1990 onwards. Dinajpur N district showed decreasing trend from 1931- 1990 (Fig.3) and thereafter there is slight increase in rainfall whereas Dinajpur S showed increasing trend up to 1970 and then there is sharp decrease in rainfall from 1991.

The results of the statistical analysis (Table 2) showed that in SHWB Dinajpur S and Jalpaiguri districts have shown significant decreasing trend during monsoon (-2.61 mm /year and -2.18 mm/year respectively) and annual (-3.80 mm/year and -3.22 mm/year respectively) rainfall. This is also supported by Kendall's tau and p-value indicating strong positive correlation between rainfall and duration. No significant trend was noted in Darjeeling district rainfall although z statistics and Sen's slope show slightly increasing trend. All the districts in the SHWB showed deficient rainfall for more than 25 years causing decrease in rainfall which is mostly related to decrease in frequency of formation of monsoon disturbances in the last century.

In GWB sub-division 24 Pargana S and Kolkata districts showed significant increasing trend during monsoon (2.96 mm/year and 1.52 mm/year respectively) and annual (3.38 mm/year and 2.07 mm/year respectively) rainfall supported by the Sen's slope estimator. The other districts which showed increasing trend in seasonal and annual rainfall are Birbhum, Bardhman (Burdwan), Bankura from 1981 onwards, Midnapore East and West, 24 Pargana N from 1940 onwards (see Fig.4 and Table 4). Mishra and Chaterjee (2009) also indicated increase in seasonal and annual rainfall over the West Midnapore districts using gridded data for 1951-2004). Slightly decreasing trend was noticed in the Nadia and Howrah districts. This is because in these districts, numbers of excess and deficient years were found to be more or less same. Similar results were noted by Dash et al (2007) using data for the period 1871-2002. Increasing trend in seasonal and annual rainfall is also described by Guhathakurta and Rajeevan (2008) using 1871-2002 GWB sub-division rainfall data.

Table 4 Results of Mann-Kendall test with Sen's slope (Q, mm/year) for annual and seasonal rainfall over West Bengal

		Annual Rainfall				Jun-Sept Rainfall			
No.	Districts	Kendall's tau	p-value	Sen's slope	MK Test	Kendall's tau	p-value	Sen's slope	MK Test
		τ		Q	Z	τ		Q	Z
	Sub-Himalayan West Bengal								
1	Cooch Behar	-0.038	0.546	-0.96	-0.60	-0.044	0.486	-0.97	-0.69
2	Jalpaiguri	-0.125	0.047	-3.22	-1.98	-0.137	0.029	-3.02	-2.18
3	Darjeeling	0.012	0.851	0.22	0.19	0.013	0.834	0.23	0.21
4	Dinajpur N	-0.043	0.522	-0.64	-0.64	-0.054	0.421	-0.79	-0.80
5	Dinajpur S	-0.212	0.001	-3.80	-3.35	-0.166	0.009	-2.20	-2.61
6	Malda	-0.050	0.423	-0.80	-0.80	-0.068	0.279	-0.81	-1.08
	Gangetic West Bengal								
7	Murshidabad	-0.024	0.696	-0.37	-0.39	0.016	0.799	0.18	0.25
8	Birbhum	0.108	0.085	1.39	1.72	0.088	0.159	0.91	1.41
9	Burdwan	0.009	0.886	0.09	0.14	0.069	0.271	0.61	1.10
10	Nadia	-0.083	0.186	-1.33	-1.32	-0.048	0.449	-0.55	-0.75
11	Purulia	0.020	0.747	0.21	0.32	0.001	0.983	0.01	0.02
12	Bankura	0.053	0.399	0.68	0.84	0.075	0.232	0.84	1.19
13	Hoogly	-0.099	0.114	-1.23	-1.58	-0.027	0.665	-0.26	-0.43
14	Howrah	-0.072	0.261	-1.14	-1.12	-0.028	0.660	-0.36	-0.44
15	Midnapore E	0.104	0.097	1.37	1.66	0.125	0.047	1.34	1.98
16	Midnapore W	0.100	0.110	1.05	1.60	0.114	0.070	1.12	1.81
17	24 Parganas N	0.057	0.359	0.83	0.91	0.069	0.270	0.75	1.10
18	24 Parganas S	0.220	0.000	3.38	3.52	0.235	0.000	2.96	3.75
19	Kolkata	0.161	0.010	2.07	2.57	0.140	0.026	1.52	2.22

(Note: The bold entries in Tables 4 indicate values are significant at 5% level and the associated magnitude of trend)

Seasonal and annual rainfall for 1901-2017 showed noteworthy decreasing trend in Hoogly district after 1970. Slightly decreasing trend is noted for Murshidabad and Howrah district with negative Sen's slope for annual rainfall series. However Murshidabad district showed increasing trend during Jun-Sept monsoon season. Although no significant trend was seen for Nadia district, Mann-Kendall tests showed negative trend to the higher side than the other three districts mentioned above. This can be explained as the district experienced dry Jun-Sept monsoon season during 1901-1910, 1931-1940, 1951-1960, 1961-1970 and 1991-2002 decades (Biswas, 2016).

Percentage change in annual rainfall series (Fig.5) showed > -10% change in Dinajpur S (SHWB), Nadia and Hoogly (GWB) districts. Positive increase >10% is seen in Birbhum, Midnapore E, 24 Pargana S and Kolkata districts of GWB.

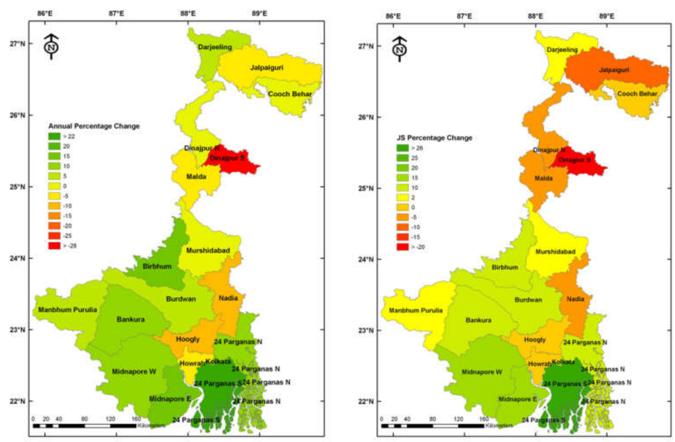


Fig 5 Percentage change in annual and seasonal rainfall series over West Bengal districts

Seasonal rainfall series showed negative percentage change >-10% in Jalpaiguri and Dinajpur S districts of SHWB and positive increase >10% Midnapore E, Midnapore W, 24 Pargana S and Kolkata districts of GWB. The high negative percentage change in Dinajpur S and Jalpaiguri districts during annual and seasonal rainfall is mostly related with the decrease in rainfall from 1980 onwards. Similarly in GWB Nadia and Hoogly districts showed high negative percentage change due to decrease in rainfall activity during Jun-Sept monsoon months.

CONCLUSION

In the light of climate change, it is essential to study rainfall variation at small regional scale for better water management, understanding hydrology and agriculture of the region from administrative point of view. The present study highlights the results of the trend analysis using monthly rainfall data for 117 years (1901-2017) of the 19 districts in the West Bengal at seasonal and annual scale because more than 75% of rainfall is received during the monsoon season. Alternative positive and negative trend in the rainfall pattern, equal number of excess and deficient years etc show mixed scenario in rainfall trend indicating the climate change in rainfall variation over the West Bengal state. Nine districts showed decreasing trend in rainfall pattern hence it is high time for undertaking some alternative measures to overcome the situation. As the state is situated in close vicinity of Bay of Bengal and due to increase in Sea Surface Temperature (SST) in recent past (Sudhir, 2015), the results obtained from the present analysis would be meaningful in water resource management, proper agricultural planning, marine life, flood management and economy of the West Bengal.

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Conflicts of Interest

There is no conflict of interest.

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