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Spatio-temporal dynamics of temperature and rainfall across jute growing districts of India

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सार – मौसम परिवर्ती से संबंधित जलवायु विविधताओं ने वैश्विक ध्यान आकर्षित किया है और इस प्रकार तापमान के स्थानिक कालिक गतिकी का अध्ययन, जलवायु परिवर्तनों का आकलन करने तथा व्यवहार्य अनुकूलन योजनाके लिए वर्षा केंद्रीय प्रक्रिया है। इस अध्ययन में पश्चिम बंगाल, भारत के 5 महत्वपूर्ण जूट उत्पादक जिलों में वर्षा और तापमान में परिवर्तन की जांच की गई है। 1980-2019 की अवधि के लिए वर्षा और तापमान दोनों की प्रवृत्ति का विश्लेषण मान-केंडल परीक्षण और सेन स्लोपअनुमानक का उपयोग करके किया गया। 39 वर्षों के आंकड़ों के विश्लेषण से पता चला है कि जहां हावड़ा और हुगली जिले में वर्षा की प्रवृत्तिं कम हो रही थी, वहीं बर्दवान और नादिया जिलों में जूट उगाने की अवधि के दौरान वर्षा की वृद्धि की प्रवृत्ति दिखाई दी। उत्तर-24 परगना में वर्षा में कमी की प्रवृत्तिल देखी गई। बर्दवान को छोड़कर सभी जिलों में वर्षा की तुलना में तापमान में कम परिवर्तनशीलता दर्ज की गई। नादिया और उत्तर-24 परगना द्वारा प्रदर्शित सकारात्मक सेन स्लोप में तापमान में वृद्धि की प्रवृत्तित देखी गई। इसके परिणाम बताते हैं कि काल बैसाखी के कारण होने वाली वर्षा और इष्टतम तापमान (25-35 °से.) का लाभ उठाने के लिए जूट की बुवाई मार्च अंत से अप्रैल तक की जानी चाहिए। इस प्रकार, पश्चिम बंगाल के जूट उगाने वाले राज्यों में तापमान और वर्षा की स्थानिक कालिक गतिकी का अध्ययन जलवायु परिवर्तन अनुकूलन और अच्छी फसल के लिए सहायक होगा।

ABSTRACT. Climate variations in relation to meteorological variables has received global attention and thus study of the spatiotemporal dynamics of temperature, rainfall is the central process to assess climate-induced changes and advocate feasible adaptation strategies. The present study examines changes in rainfall and temperature over 5 important jute growing districts of West Bengal, India. Both rainfall and temperature trend for period of 1980-2019 were analysed using Mann-Kendall test and Sen's slope estimator. Analysis of the data for 39 years revealed that while Howrah and Hooghly district had decreasing rainfall trend, Burdwan and Nadia districts showed increasing trend of rainfall during jute growing period. North-24 Parganas recorded negative rainfall trend. Compared with rainfall, lesser variability of temperature was recorded for all the districts except Burdwan. The positive Sen's Slope exhibited by Nadia and North-24 Parganas showed an increasing temperature trend. The results herein suggests that jute sowing should be done by March end-April to take advantage of the optimum temperature (25-35 °C) and rainfall due to Norwesters. Thus, studying spatio- temporal dynamics of temperature and rainfall across jute growing states of West Bengal will be helpful for climate change adaptation and successful cropping.

Key words – Jute, Mann-Kendall test, Rainfall trend, Sen's slope estimator, Temperature deviation, Trend analysis.

1. Introduction

The impact of environment variations on climatic factors varies across global spatiotemporal scales and has led to worldwide redistribution of ecosystem and water resources. Thus, knowledge of recent and past climatic trend deserves urgent and systematic attention through analysis of sophisticated and diverse datasets (Kumar *et al*., 2010) while would help in the implementation of suitable adaptation strategies. Rainfall and temperature (Singh *et al*., 2013) are the most crucial environmental parameters since they are the fundamental determining factors affecting the agricultural productivity (Kumar and Gautam, 2014). Increase in temperature owing to global warming are projected to affect the aspects of hydrological cycle (Tabari and Talaee, 2011) and has been one of the most debated problem in the light of threatened human existence in the foreseeable future. Over the course of the twentieth century, the Intergovernmental Panel on Climate Change (IPCC) reported that there was an increase in the earth's surface temperature by 0.6 ± 0.2 °C (Obiekezie *et al*., 2010). In India, a 2 °C more warming would lower the net income of farmers by about 4 per cent and a 3.5 °C more warming causes 8 per cent decline of the land value (Mendelsohn and Dinar, 2013). For each 1 °C increase in temperature, the yield of rice, mustard, wheat, soybean, groundnut and potato is expected to decrease by 3-7% (Agrawal, 2009). Temperature extremes exhibit larger impact on soil enzymatic properties since temperature and water are vital physical elements for plant growth and productivity. Non-ideal temperature conditions and water levels can unequivocally hinder plant growth at the early development phase, which has substantial implications for future food production. Thus, understanding the potential temperature effect on climate change is imperative for ecological conservation and developing operative adaptation strategies to offset consequences of extreme events associated with climate change. The changing of long term rainfall pattern (Gajbhiye *et al*., 2016) on a regular basis is becoming grave issue throughout the globe which is negatively putting pressure on the fresh water availability and upsurging the potent threat of drought and flood occurrence (Pal *et al*., 2017). Indian subcontinent and especially the Gangetic West Bengal is an agricultural area whose economic prosperity are vulnerable to erratic rainfall during the monsoon months of June to September, which affects crop productivity. Rainfall analysis in terms of spatial and seasonal distribution would hence augment the management and utilization of water resources which can accordingly be used to check floods and droughts and plan water resources related engineering such as reservoir design, flood control work, drainage design and soil and water conservation planning. Thus, study of different aspects of rainfall is critical to visualize any climate change impact on water resources planning, agricultural production, etc.

Jute (*Corchorus* sp.), the golden fibre of India (Datta *et al*., 2020) is produced with an estimated average production of 3.4 million tonnes per year (FAOSTAT, 2016). India, the largest jute producer in the world, contributes about 60% of the global production and generates income for 4.85 million farm families, industrial workers and traders (Singh *et al*., 2018). West Bengal alone accounts for 71% of area and 73% of total raw jute production. Jute acreage witnesses significant fluctuation in recent years chiefly due to the extent and time of onset of summer rain, water logging condition due to cyclone and stress condition post cyclone. Jute, a rainfed crop requires about 500 mm water and thus, erratic rain exposes this crop to early season drought (Singh *et al*., 2019). Again, heavy rain due to cyclone may make this crop susceptible to water logging condition. Temperature deviation, *i.e*., short day length and prolonged drought may result in premature or untimely flowering which is not desirable for good fibre quality. Thus, tremendous weather variations resulting from the environmental change have become an increasingly vital focal point globally. The trend analysis of climate variables like rainfall (Partal and Kahya, 2006; Addisu *et al*., 2015) and temperature (Arora *et al*., 2005; Karanurun and Kara, 2011; Meshram *et al*., 2018) on different spatial scales will help in the prediction of future climate scenarios. Further, this will aid to assess the year-wise variation of yield and determine the crop management options.

Hence, the objective of this study is to investigate the variability of the rainfall and temperature in the major jute growing districts of West Bengal. Seasonal trend of these parameters has been investigated and the fluctuations have been calculated on monthly and weekly basis with major focus on jute growing season, *i.e*., April to August. Understanding the uncertainties linked with these parameters will generate information base for effective management of agriculture, irrigation and other practices in the selected area.

2. Materials and method

2.1. *Study area*

West Bengal, situated in the eastern part of India covers an area 88,752 km² which is about 2.7% of the total area of India. It is bounded to the east by Bangladesh, to the south by Bay of Bengal, to the southwest by 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, Assam in the northeast and thus, experiences inherent climate diversity due to its vast physiographic features. Howrah (22.5958° N, 88.2636° E), Hooghly (22.8963° N, 88.2461° E), North 24 Parganas (22.6168° N, 88.4029° E), Nadia (23.4710° N, 88.5565° E) and Burdwan (23.4595° N, 87.6186° E) are the major jute growing districts of West Bengal (Fig. 1). These districts in the Gangetic plains experience intensely hot summer and very cold winter. The hot season starts from March to May followed by the South-West monsoon from June to September. The southwest monsoon is the principal rainfall source of rainfall in these districts with 80% of the total rainfall received during the June to September. The average annual rainfall is 1530 mm with different districts having rainfall of 1313 mm (Burdwan), 1683 mm (Howrah), 1500 mm (Hooghly), 1750 mm

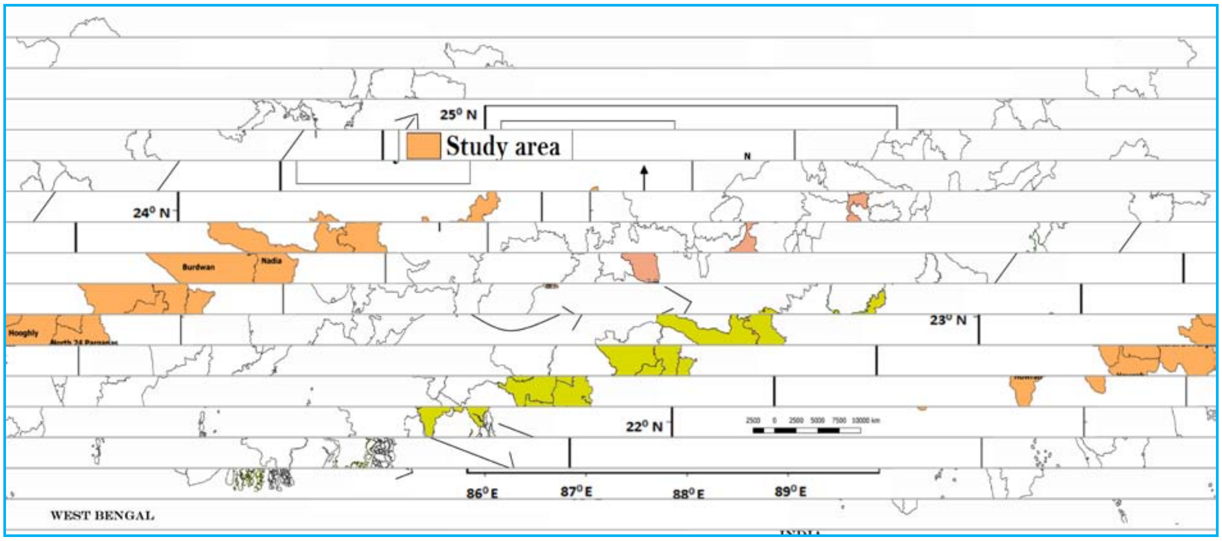


Fig. 1. Map showing the location of the study area - 5 major jute growing districts of West Bengal

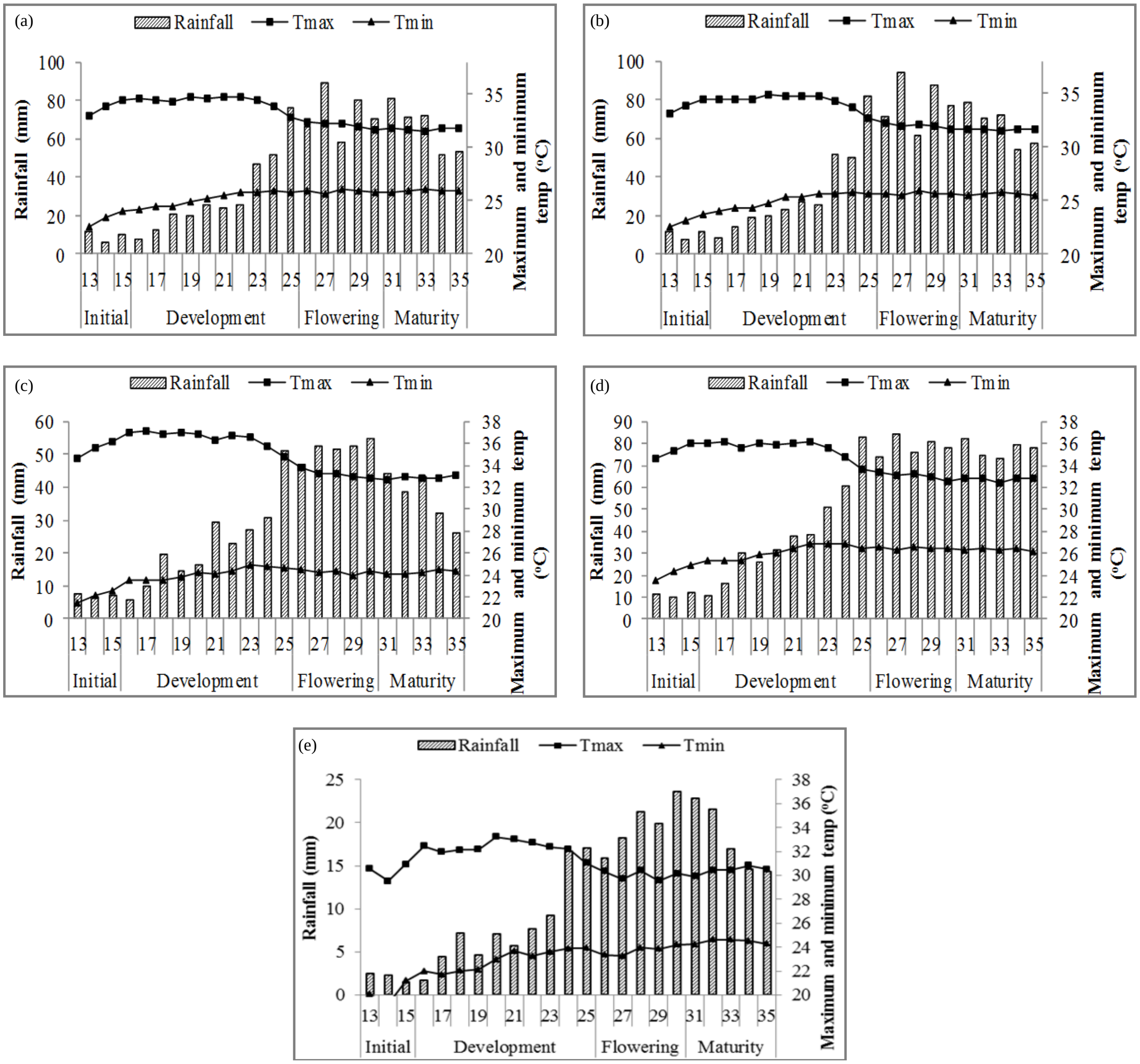
(North 24 parganas) and 1443 mm (Nadia). Copious rainfall or absence of it directly affects the jute productivity and quality. Therefore, in order to assess spatial and temporal distribution of rainfall pattern, district wise rainfall and temperature variation has been studied.

2.2. *Weather data used and analytical procedure*

Rainfall and temperature have been analysed for five districts of West Bengal from 1980 to 2019 (39 years), which have been collected from India Meteorological Department, Pune. Trend is defined as the general movement of a series over an extended period of time or it is the long-term change in the dependent variable over a long period of time (Hawkins and Webber, 1980). The statistical method such as regression analysis and coefficient of determination (R^2) has been used for analysing the significance of temperature and rainfall trend. The coefficient of determination ranges from 0 to 1 and compares estimated and actual *y*-values. Value of 1, implies a perfect correlation in the sample and no difference between the estimated and actual *y*-value. At the other extreme, the regression equation is not helpful in predicting a *y*-value if the coefficient of determination is 0. The trend was tested by Mann-Kendall (M-K) trend test and slope of the regression line using the least squares method. The mean, SD and coefficient of variation (CV), skewness and kurtosis of rainfall and temperature have been calculated to analyse the relationship. CV denotes the degree of variability as less (CV < 20%), moderate (20 < CV < 30%), high (CV > 30%), very high (CV > 40%) and CV > 70% indicate extremely high inter-annual variability of rainfall (Panda and Sahu, 2019). It shows the individual data position differing from the mean value. Skewness measures the symmetry in data. The distribution represented by S is perfectly symmetric, if skewness of S is zero; negatively skewed if distribution is skewed to the left and positively skewed if distribution is skewed to the right. A symmetric distribution has mean = median, while positively skewed and negatively skewed distribution has mean > median and mean < median, respectively. Thus, when coefficient of skewness < 0.5, there is symmetry, 0.5<CS<1 = moderate skewness, CS > 1 = high skewness. Kurtosis represents measurement of the extremities (*i.e.*, tails) of the distribution of data and henceforth indicates the presence of outliers. Positive kurtosis value indicates data are heavy tailed and negative indicates data are light tailed. The magnitude of change in rainfall trend is shown for different periods of analysis by Box and whisker plot. The central box line represents median and the upper and lower lines represent the 75th and 25th percentile, respectively. Also, the upper and lower lines represent the maximum and minimum values of rainfall slopes. The position of box with whisker and line in the box represents whether values are symmetric or skewed to the left or right. The descriptive statistics and box plot was analysed in SAS 9.4 (Indian NARS Statistical Computing Portal).

2.3. *Mann-Kendall's test*

The Mann-Kendall test, suggested by Mann (1945) is a statistical nonparametric test used for identifying trends in climatological and hydrological time series data on account of its simplicity and robustness (Partal and Kahya, 2006; Chandniha *et al.*, 2017; Zamani *et al.*, 2017; Meshram *et al.*, 2018). The test is advantageous since the data need not conform to any particular distribution and has been extensively used with environmental time series. In addition, the MK test fits missing values and involves no measurable dispersion. According to



Figs. 2(a-e). Rainfall and temperature during jute growing season in (a) Hooghly, (b) Howrah, (c) Nadia, (d) N24 Parganas and (e) Burdwan

this test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered). This is tested against the alternative hypothesis H_1, which assumes that there, is increasing or decreasing monotonic trend. The M-K statistics (S) is computed as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k)$$

where, x_k and x_j are values of the data at time k = 1, 2, 3,…, n−1, j > k. Each of the data points x_j is taken as a reference point. The value of S determines whether the trend is positive (increasing) or negative (decreasing).

If $x_j - x_k > 0$, $\operatorname{sgn}(x_j - x_k) = +1$

If $x_j - x_k = 0$, $\operatorname{sgn}(x_j - x_k) = 0$

If $x_j - x_k < 0$, $\operatorname{sgn}(x_j - x_k) = -1$

For example, if $x_j - x_k > 0$, observation at time j denoted by x_j is greater than at time k, denoted by x_k. If $n < 10$, the value of |S| is compared directly to the theoretical distribution of S derived by Mann and Kendall (Gilbert, 1987). For $n \geq 10$, the statistic S is approximately

TABLE 1(a)

Descriptive statistics of monthly rainfall during jute growing season in Hooghly

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	0.0	218	50	47	93.6	-0.75	NO	1.44	2.68
May	8.0	246	98	55	55.8	-0.63	NO	0.70	0.57
June	75.0	1048	273	175	64.3	-2.24	NO	2.35	8.82
July	110.8	721	307	157	51.2	-0.85	NO	1.22	1.20
August	107.0	647	335	118	35.1	-3.99	YES	0.45	0.27

TABLE 1(b)

Descriptive statistics of monthly rainfall during jute growing season in Howrah

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	0.0	218	53	53	99.2	-0.96	NO	1.28	1.22
May	8.0	246	88	60	67.6	-1.96	YES	0.89	0.43
June	26.6	1048	279	176	63.0	-1.92	NO	2.21	8.49
July	67.9	903	320	183	57.2	-0.54	NO	1.46	2.06
August	107.1	647	332	127	38.3	-4.66	YES	0.44	-0.27

TABLE 1(c)

Descriptive statistics of monthly rainfall during jute growing season in Nadia

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	0.0	182	37	41	102.6	0.17	NO	1.69	3.2
May	0.0	294	81	73	80.4	0	NO	1.0	1.0
June	0.0	520	177	140	72.4	3.38	NO	0.7	0.0
July	0.0	625	211	145	64.9	3.45	NO	0.7	0.2
August	0.0	551	186	145	74.1	5.54	YES	0.8	0.2

TABLE 1(d)

Descriptive statistics of monthly rainfall during jute growing season in N24 Parganas

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	0.1	215	61	48	79.1	-0.44	NO	1.28	1.86
May	10.2	290	125	71	56.8	-1.45	NO	0.62	-0.18
June	0.0	1016	306	181	58.8	-2.83	NO	1.99	5.88
July	95.9	647	319	136	42.7	2.29	NO	0.71	-0.03
Aug	153.7	700	387	129	33.3	1.53	NO	0.48	-0.13

TABLE 1(e)

Descriptive statistics of monthly rainfall during jute growing season in Burdwan

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	0.0	105	15	25	169.9	0	NO	2.4	6.0
May	0.0	233	33	47	142.3	0.73	YES	2.7	8.2
June	3.0	347	74	84	112.6	1.48	NO	1.7	2.6
July	6.0	555	91	116	127.4	2.62	YES	2.5	7.0
August	4.8	472	99	113	114	1.43	NO	1.6	2.2

normally distributed with the mean and variance as follows:

$$\text{Var (S)} = \frac{[n(n-1)(2n+5) - \sum_{g=1}^{m} tg(tg-1)(2tg+5)]}{18}$$

where, m is the number of tied groups, *tg* is the number of data values in the g^{th} group, n is sum of available data, Var (S) is the variance of statistics Mann-Kendall. This test has been calculated using XLSTAT software. The *p* value has been used to evaluate the presence of a statistically significant trend, where the null hypothesis gets accepted when *p* value is less than the significance level α = 0.05.

2.4. *Sen's slope test*

The magnitude of a trend in a time series can be determined using a slope estimator known as Sen's estimator. For estimation of the true slope of an existing trend, Sen's nonparametric method is used and the following test has been performed using XLSTAT software. For all data pairs, slope (Qi) can be calculated as follows:

$$Qi = \frac{x_j - x_k}{j - k}, \text{ for } i = 1, 2, 3\ldots\ldots N,\ j > k$$

where, Qi is Sen's Slope, x_j and x_k are data values of the same observational unit at time j and k respectively. Qi is represented by median of N values and is given as:

$$Q = Q_{(N+1)/2} \text{ if N is odd}$$

$$Q = 1/2[Q_{N/2} + Q_{(N+2)/2}] \text{ if N is even}$$

A negative value of Sen's slope indicates a downward or decreasing trend whereas an upward or increasing trend in the time series is denoted by a positive value. It is calculated at 100(1-α)% confidence interval and by a two sided test. The Theil-Sen's estimator is a hearty gauge of the size of a trend that has been used for recognizing the trend line slope in hydrological time series.

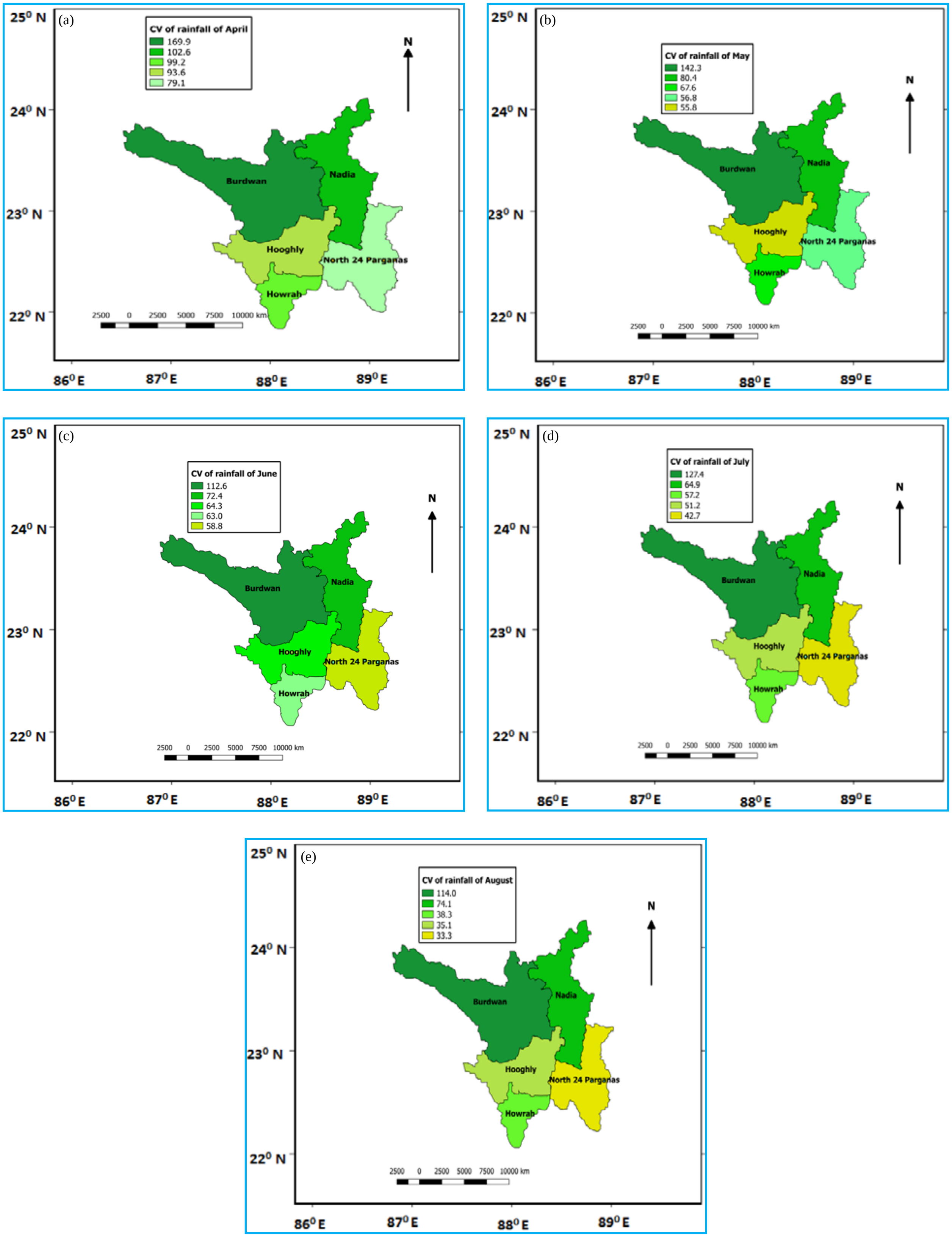
3. Results

3.1. *Temperature and rainfall variation during jute growing season*

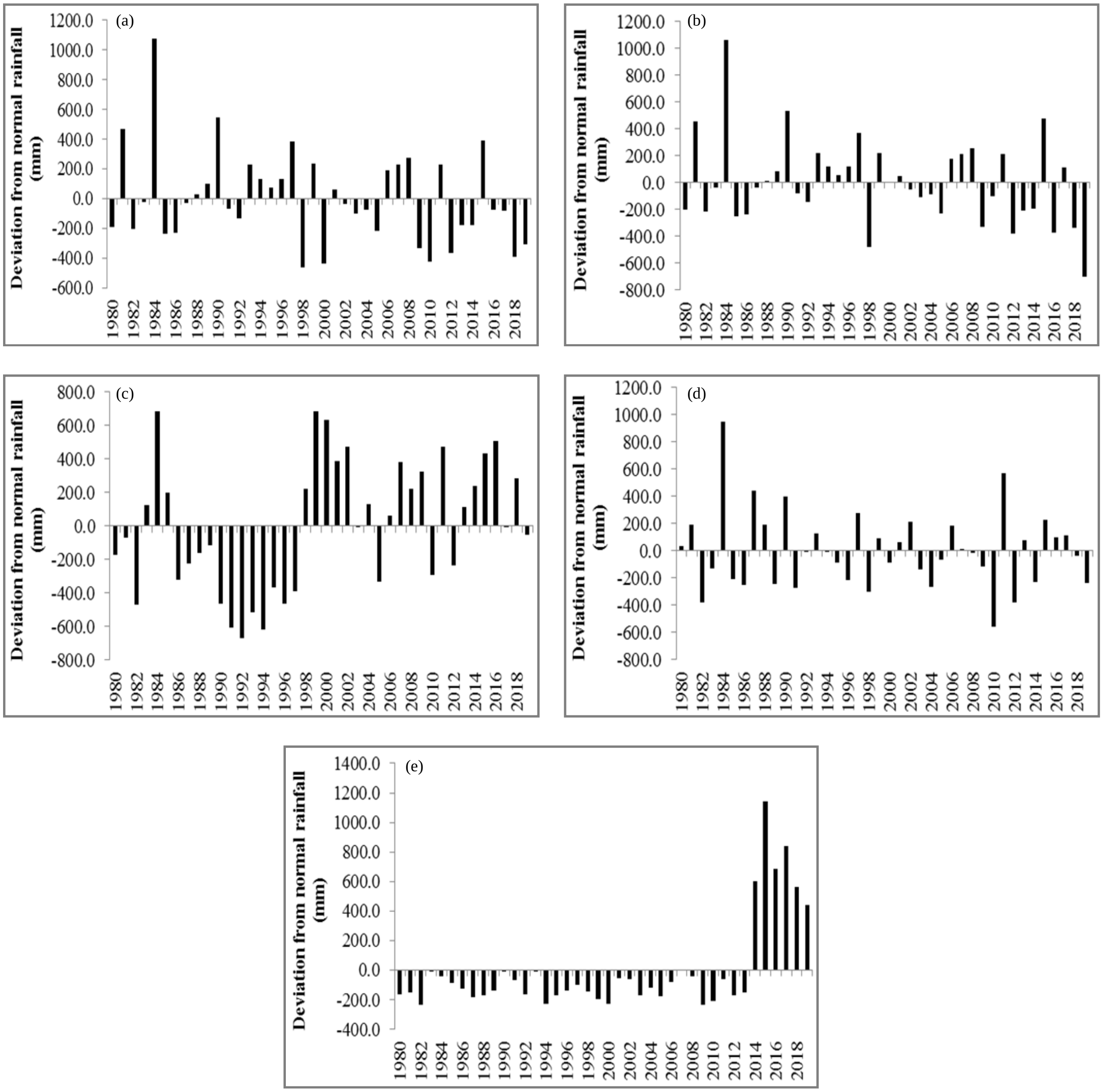
Trend analysis reflects that among the various nonparametric methods, M-K test is one of the best methods and is highly preferred by various researchers (Jain and Kumar, 2012). Initially the results give an insight on how temperature and rainfall is varying during the jute growing period in various districts. The observed data were analysed for the period of 1980-2019 and from the figure, it becomes clear that the maximum temperature is low during monsoon seasons and are comparatively high during pre-monsoon months (Fig. 2). As compared to Hooghly and Howrah, rainfall was more during all the growth stages in Nadia, North 24 Parganas (N24 Parganas) and Burdwan. Higher maximum temperature was noted for Nadia during initial stages. Since data from 1980-2019 shows that rainfall is less during initial 7-8 weeks in Hooghly and Howrah as compared to other districts, so intermittent irrigation is necessary during early stage.

3.2. *Descriptive statistical analysis of rainfall*

The descriptive statistics of month wise rainfall such as the mean, SD, kurtosis and skewness are discussed in Tables 1(a-e). During the pre-monsoon period, rainfall recorded decreasing value which is reverse during post monsoon. As a result of an overall inspection, it has been detected that districts are showing a very fluctuating trend which is significant during certain months at 5% level of significance (α = 0.05). For Hooghly and Howrah, the CV varied between 35 to 99%. An overall decreasing trend was noted as supported by Sen's slope estimator which was statistically significant during August in Hooghly and May, August in Howrah, *i.e*., number of excess and deficient rainfall years were more or less the same. Significant decrease in rainfall trend was recorded in months of August for both the districts which was statistically significant at 95% confidence limit during the period of 1980-2019. From this, it can be interpreted that the decrease in rainfall has potential negative impact on rainfed agriculture specially jute growing belts. April and June months reported high skewness and heavy tailed values due to asymmetrical nature of the data. The CV was found to vary between 74-103%, 33-79% and 113-170% for Nadia, N24 Parganas and Burdwan district. Slope coefficient was positive for all months in Nadia and Burdwan with significant slope values in August and May, July, respectively while N24 Parganas showed no significant pattern of trend. Although no significant trend was noted for N24 Parganas district, Man Kendall test showed negative trend to higher side during initial months. Increasing trend of rainfall in Nadia and Burdwan were recorded from June onwards. Though these districts, showed a fluctuating trend which is insignificant at 95% level, still these districts display positive trend as per Kendall's S value and Sen's slope. Kurtosis was higher in the month of April in Nadia while



Figs. 3(a-e). Variability of rainfall in the districts under study for the month of (a) April (% CV), (b) May (% CV), (c) June (% CV), (d) July (% CV) and (e) August (% CV)

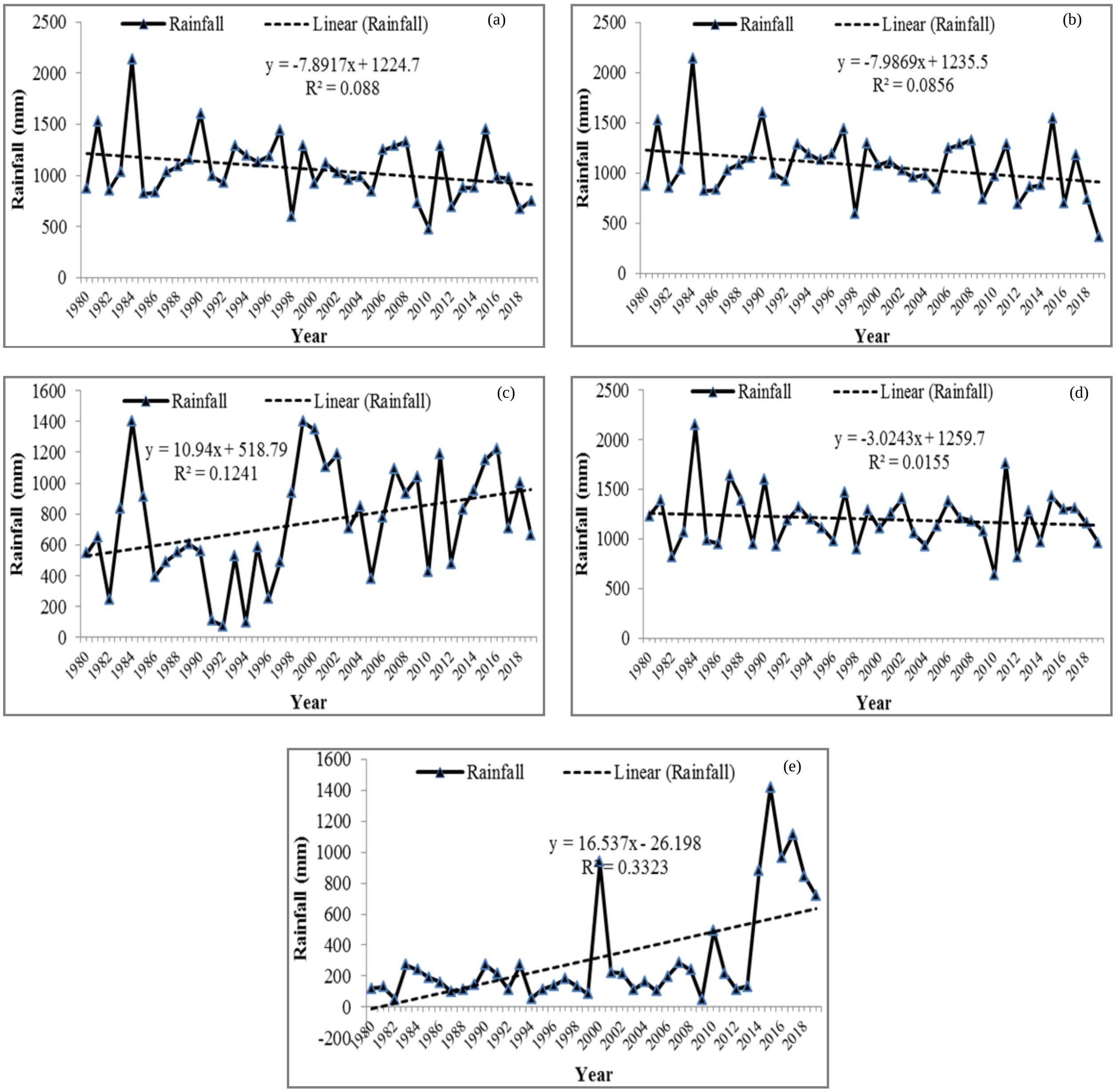


Figs. 4(a-e). Rainfall deviation during jute season from average in (a) Hooghly, (b) Howrah, (c) Nadia, (d) N24 Parganas and (e) Burdwan

light tailed values and low skewness were observed in June, July and August months. April and June month resulted in higher kurtosis value and skewness for N24 Parganas. Both skewness and kurtosis values were high for Burdwan district during all the months which shows asymmetrical pattern of the trend. From the descriptive statistical analysis, it is quite clear that April and June months showed maximum variation in rainfall value as depicted by kurtosis value. The monthwise variation of rainfall for the various districts has been depicted in Figs. 3(a-e).

3.3. *Deviation of rainfall from average monthly rainfall*

The deviation of rainfall was recorded for the five districts by calculating deviation from the average monthly rainfall of the jute growing season during 39 years [Figs. 4(a-e)]. There was no abrupt variation in rainfall during the growth period except 1984 for Hooghly, Howrah and N24 Parganas. Deviation was high for Nadia with negative value from 1986 to 1997 followed by positive value for the next 6 years. For Burdwan,

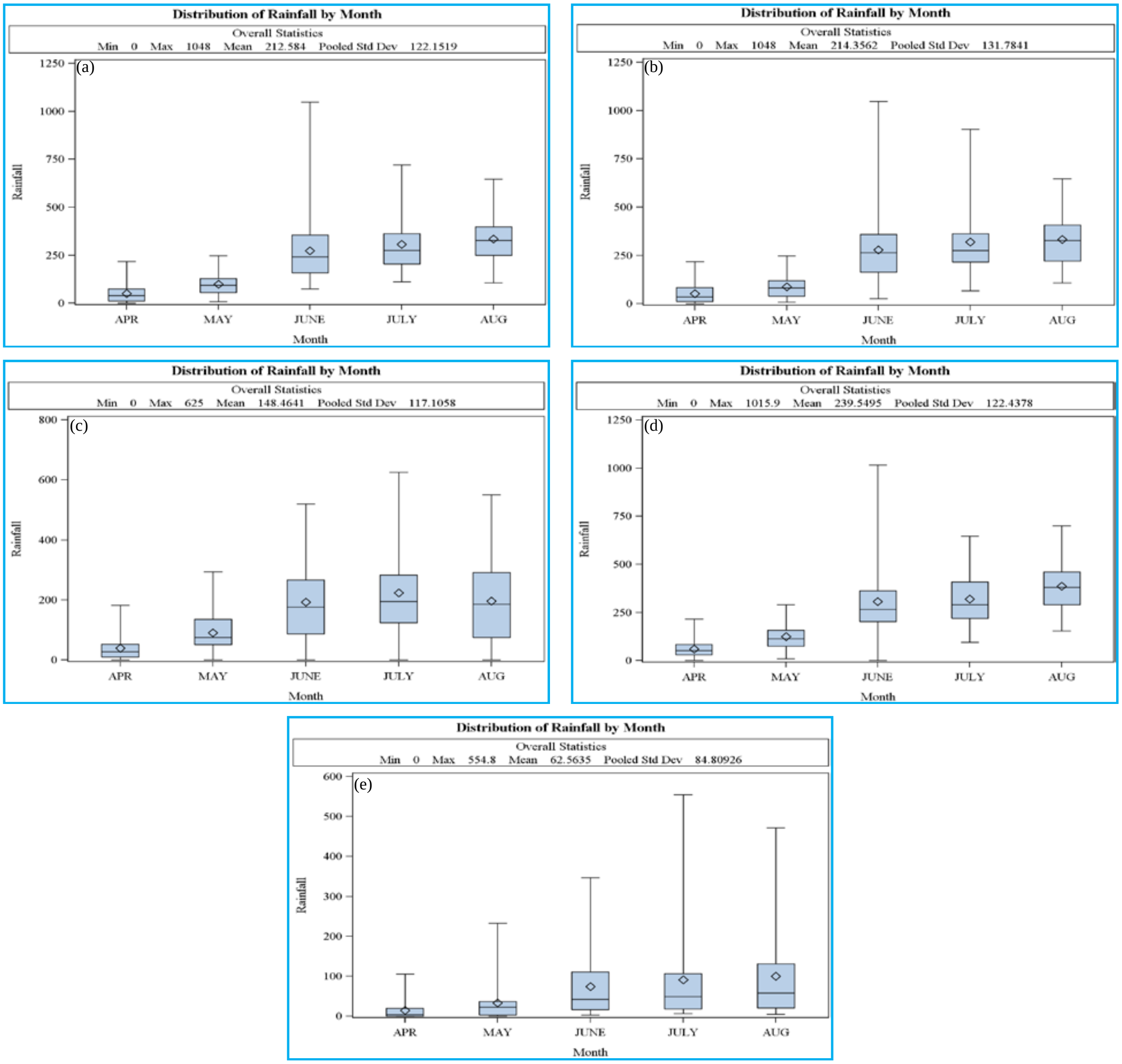


Figs. 5(a-e). Linear regression analysis for rainfall in (a) Hooghly, (b) Howrah, (c) Nadia, (d) N24 Parganas and (e) Burdwan

negative values were recorded with high positive deviation values during 2014 to 2019.

3.4. *Rainfall trend based on linear regression analysis*

The rainfall trends based on the linear regression analysis for different districts are shown in Figs. 5(a-e) which shows a definite pattern of rainfall for the studied districts. Linear regression equation was calculated for different districts which clearly demonstrates decreasing trend for Hooghly, Howrah and increasing trend for Nadia and Burdwan, as shown by negative and positive slope value (5% level of significance). The R^2 value, *i.e.*, coefficient of determination for Burdwan was highest (0.33) which means 33% variability of rainfall can be justified by this equation of linear regression model. Rainfall data over the years has been presented by box and whisker plot [Figs. 6(a-e)] which shows wide range of values in monsoon as compared to pre monsoon period. In case of Burdwan, the values of monsoon months are skewed to the right since the median is close to the lower quartile and the top whisker is much longer than the lower one.



Figs. 6(a-e). Box and whisker plot of rainfall for (a) Hooghly (1980-2019), (b) Howrah (1980-2019), (c) Nadia (1980-2019), (d) N24 Parganas (1980-2019) and (e) Burdwan (1980-2019)

3.5. *Number of years having weekly rainfall >100 mm*

From the rainfall data of 1980-2019, the number of years having weekly rainfall >100 mm (Table 2) was studied to find out the effect of water logging, if any on the initial growth stages. It was observed that among the five districts, Howrah and N24 Parganas are more prone to water logging condition, particularly from the 25^{th} to 33^{rd} meteorological week, reason being they are situated mostly near to the Bay of Bengal. However, occurrence of cyclone during initial growth stages accompanied by heavy rainfall may cause lodging and anaerobic condition hindering proper growth. Burdwan district was found to be less prone for such situation.

3.6. *Descriptive statistics of maximum and minimum temperature*

A preparatory examination of the descriptive statistics (mean, coefficient of variation, skewness, standard deviation and kurtosis) of the temperature series (1980-2019) have been calculated in every station (Tables 3&4). The trend magnitudes are also presented in the form of Sen's slope estimator, during the whole period. Regarding minimum and maximum temperature, the CV was low but skewness and kurtosis showed variation. The temperature was low during monsoon and higher during pre-monsoon. For Howrah and Hooghly, SD of maximum temperature varied between 1.5 and 2.2 whereas CV

TABLE 2

No. of years having weekly rainfall >100 mm

Week No.	Hooghly	Howrah	Nadia	N 24 Parganas	Burdwan
13	1	1	0	0	0
14	0	0	0	0	0
15	1	1	0	0	0
16	0	0	0	1	0
17	1	1	0	1	0
18	0	0	2	1	0
19	0	0	1	0	0
20	2	2	0	2	0
21	1	1	4	3	0
22	2	2	0	3	0
23	3	3	2	2	0
24	5	5	1	6	1
25	10	11	6	9	1
26	12	12	6	11	3
27	13	15	8	13	1
28	8	10	7	11	2
29	13	14	9	12	3
30	8	7	6	11	4
31	13	12	3	12	2
32	10	10	5	9	2
33	9	8	6	8	1
34	4	4	4	10	1
35	4	5	2	11	0
36	8	9	2	7	0

between 4.8 and 6.4% [Tables 3(a-e)]. The temperature trend distribution did not show very busy pattern, *i.e.*, trends reflected a harmony with district average temperature. Lowest CV of maximum temperature was noted for N24 Parganas (2.3 to 3.8%) followed by Nadia district (6.9 to 9.9%) whereas maximum variation was seen for Burdwan (24 to 25%). Significant positive trend was computed as per Sen's slope for Nadia and N24 Parganas whereas non-significant positive trend was found for Hooghly and Burdwan. For Hooghly, Howrah, Nadia, N24 Parganas district, kurtosis values were mostly negative and skewness value was <0.5 which shows symmetry in the data. Descriptive statistical analysis value shows high kurtosis value of maximum temperature for Burdwan, *i.e.*, asymmetrical nature of data which are skewed to the left since the values are negative. As compared to other districts, CV value of temperature (24-25%) of Burdwan district showed moderate variability. The preliminary analysis indicates that the zones of higher temperatures (Howrah, Hooghly, N24 Parganas) have the least variability and the zone of lowest temperatures (Burdwan, Nadia) has the highest variability.

Significant positive trend of minimum temperature was computed for Nadia, N24 Parganas, whereas trend was negative but non-significant for Howrah [Tables 4(a-e)]. Kurtosis value was positive (heavy tailed) whereas skewness was negative (skewed to left) for Burdwan, Hooghly and Howrah which indicates the presence of outliers. Both kurtosis and skewness was negative for Nadia. Similar to maximum temperature, CV was low for Hooghly, Howrah and N24 Parganas with moderate variation in Burdwan (24%).

3.7. *Deviation of temperature from optimum (34 °C)*

Temperature deviation was recorded from Feb-July with respect to optimum value 34 °C [Figs. 7(a-e)]. During April-June temperature was higher than optimum with February having maximum negative deviation from optimum temperature. In Nadia and N24 Parganas, temperature deviation from optimum was more in March-June as compared to the other two districts. In Burdwan, temperature was lower than optimum during entire growth period.

TABLE 3(a)

Descriptive statistics of maximum temperature during jute growing season in Hooghly

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	30.09	38.19	34.02	2.17	6.37	-0.020	NO	-0.122	-1.023
May	30.34	38.53	34.55	1.98	5.73	0.032	NO	-0.248	-0.373
June	30.02	37.51	33.66	1.88	5.58	0.019	NO	0.0114	-0.684
July	29.3	34.96	32.03	1.56	4.87	0.008	NO	-0.028	-0.724
August	30.38	36.17	33.24	1.65	4.96	0.020	NO	-0.414	-1.033

TABLE 3(b)

Descriptive statistics of maximum temperature during jute growing season in Howrah

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	31.67	39.34	36.04	1.93	5.35	-0.095	YES	-0.29	-0.67
May	32.95	40.99	36.71	1.92	5.23	-0.076	YES	-0.07	-0.69
June	31.76	40.07	35.53	1.96	5.51	-0.064	YES	0.34	-0.46
July	29.74	39.21	33.07	1.80	5.44	0.004	YES	1.24	4.02
August	29.40	38.99	32.88	1.76	5.35	0.005	YES	0.98	3.14

TABLE 3(c)

Descriptive statistics of maximum temperature during jute growing season in Nadia

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	18.8	25.9	22.6	1.69	7.48	0.073	Yes	-0.217	-0.53
May	20.8	26.8	23.9	1.67	6.98	0.10	Yes	-0.072	-1.05
June	20.1	27.9	24.6	2.05	8.33	0.11	Yes	-0.692	-0.62
July	18.5	27.8	24.2	2.37	9.79	0.12	Yes	-0.856	-0.29
August	17.6	27.5	24.2	2.40	9.91	0.09	Yes	-1.05	0.106

TABLE 3(d)

Descriptive statistics of maximum temperature during jute growing season in N24 Parganas

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	32.86	38.6	35.6	1.33	3.74	0.03	NO	-0.23	0.14
May	33.34	37.7	35.9	0.996	2.77	0.05	YES	-0.13	-0.01
June	32.41	37.0	34.7	1.056	3.04	0.05	YES	0.21	-0.09
July	31.40	35.2	33.0	0.794	2.41	0.02	NO	0.43	0.51
August	29.4	33.7	32.7	0.752	2.3	0.02	YES	-2.22	9.36

TABLE 3(e)

Descriptive statistics of maximum temperature during jute growing season in Burdwan

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	22	38.9	32.2	8.27	25.7	0.04	NO	-3.29	11.39
May	26	38.5	32.6	8.15	25	0.06	NO	-3.54	12.89
June	26	37.6	31.87	7.79	24.4	0.03	NO	-3.64	13.57
July	25	35	30.09	7.43	24.7	0.004	NO	-3.59	13.04
August	30	34.4	30.37	7.29	24	-0.004	NO	-4.01	15.72

TABLE 4(a)

Descriptive statistics of minimum temperature during jute growing season in Hooghly

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	20.5	26.6	23.7	1.27	5.34	-0.005	NO	-0.53	0.99
May	20.7	27.1	24.9	1.34	5.38	0.021	NO	-1.06	1.56
June	22.5	27.7	25.8	1.13	4.38	0.005	NO	-1.25	2.10
July	22.7	27.3	25.8	0.99	3.83	0.003	NO	-1.54	2.35
August	22.7	26.9	25.9	0.85	3.28	-0.008	NO	-2.05	4.76

TABLE 4(b)

Descriptive statistics of minimum temperature during jute growing season in Howrah

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	19.9	26.6	23.5	1.39	5.91	-0.013	NO	-0.83	0.83
May	20.7	27.8	24.9	1.38	5.54	0.011	NO	-0.76	1.27
June	22.5	27.2	25.6	1.00	3.90	-0.013	NO	-1.66	3.01
July	22.7	27.3	25.7	1.12	4.36	-0.015	NO	-1.17	0.85
August	20.6	27	25.6	1.28	5.00	-0.185	NO	-2.38	6.23

TABLE 4(c)

Descriptive statistics of minimum temperature during jute growing season in Nadia

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	18.9	25.9	22.6	1.69	7.47	0.073	YES	-0.22	-0.539
May	20.7	26.8	23.9	1.68	7.03	0.104	YES	-0.073	-1.053
June	20.1	27.9	24.6	2.04	8.29	0.107	YES	-0.695	-0.623
July	18.5	27.79	24.2	2.37	9.79	0.118	YES	-0.856	-0.296
August	17.6	27.6	24.2	2.41	9.95	0.087	YES	-1.056	0.094

TABLE 4(d)

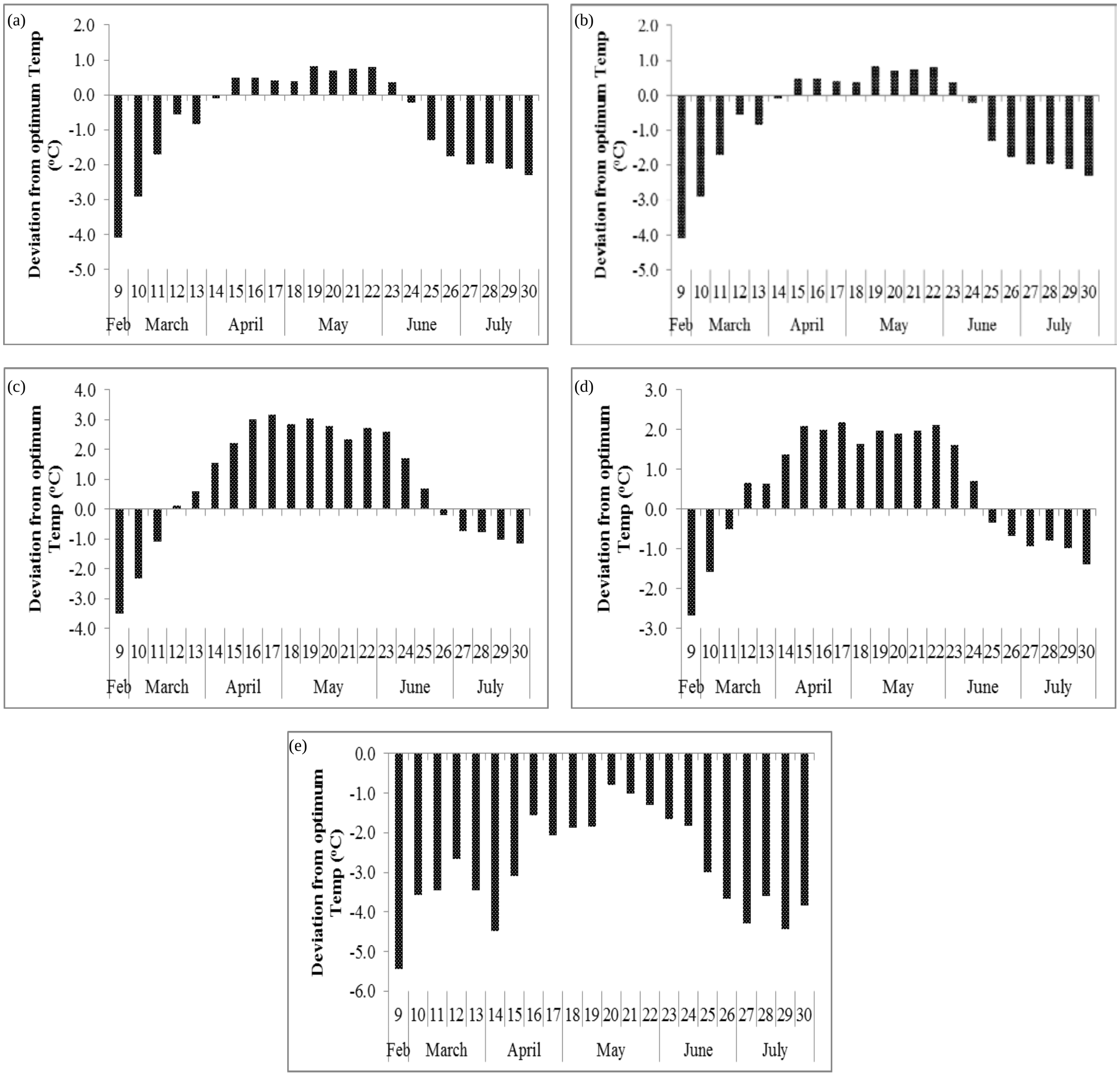
Descriptive statistics of minimum temperature during jute growing season in N24 Parganas

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	21.4	27.3	24.5	0.92	3.75	0.0	NO	-0.42	3.48
May	24.1	27.5	25.9	0.83	3.20	0.048	YES	-0.29	-0.54
June	25.8	28.0	26.7	0.61	2.28	0.029	YES	0.53	-0.77
July	25.5	27.5	26.5	0.44	1.66	0.024	YES	-0.11	-0.22
August	25	27.1	26.3	0.41	1.56	0.011	YES	-1.05	2.54

TABLE 4(e)

Descriptive statistics of minimum temperature during jute growing season in Burdwan

Meteorological week	Min.	Max.	Mean	SD	CV	Sen's Slope	Trend	Skewness	Kurtosis
April	19.9	25.6	22.2	5.42	24.4	0.015	NO	-3.16	10.0
May	19.4	26.5	23.2	5.76	24.8	0.00	NO	-3.59	13.10
June	21	27.5	24.3	5.88	24.2	-0.005	NO	-3.84	14.61
July	22.4	27.3	24.4	5.84	23.9	-0.022	YES	-4.07	16.03
Aug	22.5	27.1	24.4	5.87	24.1	-0.009	NO	-4.01	15.61



Figs. 7(a-e). Temperature deviation from optimum during jute growth in (a) Hooghly, (b) Howrah, (c) Nadia, (d) N24 Parganas and (e) Burdwan

4. Discussion

Rainfall and temperature are the most critical climate determinants in jute growing districts of West Bengal since jute cultivation is reliant on rain. In the light of climate change, a variability analysis of climate parameters is of paramount importance for researchers and policy makers in understanding the challenges of hydrology and determining the water use in the areas. The analysis of the temporal trend and variability in rainfall and temperature at five locations was carried out using nonparametric M-K test and Sen's slope estimator which is frequently used tests for conducting trend analysis. West Bengal is susceptible to climate variability and fluctuation in climatic parameter is a recurring phenomenon in the studied districts. The consequences of climate variability exacerbate existing social conditions since people are mainly reliant on resources that are sensitive to climate variability. In addition to the aforementioned drought and flood consequences, climate change has great impacts on the changes in temperature and incidence of new pests, weeds and disease. Rainfall has been found to be favourable for proliferation of grey weevil (*Myllocerus discolor*) in a study made by Rahman and Khan, 2012. Pre-monsoon rain followed by drought condition are congenial for the outbreak of semi looper which may lead to 50% crop loss as reported by Sadat and Chakraborty, 2015. Water logging may increase the incidence of diseases like seedling blight and damping off. Consequently, adaptation measures and enhanced ability to cope with future climate vulnerabilities can abate the extent of social, economic and human loss.

The variability analysis of rainfall has been presented using a box and whisker plot which assists to visually summarize and compare data groups. These plots graphically describe the statistical distribution in a way that is easy to understand for a wide range of users. Box plot uses median, quartile values, lowest and highest data point to convey symmetry and spread of data values. The box represents middle 50% of the data and gives an indication of sample variability. Lack of symmetry entails one tail longer than the other. From the following box plots, it can be clearly understood that box plot as well as whiskers are longer in case on monsoon months, especially June.

From the observed data, it can be considered that rainfall was maximum in the month of June and the CV for the districts under study varied between 35-170%, highlighting the precipitation variability over the area. Then, if the kurtosis values are analysed, then it can be established that during May, July, August the kurtosis values are less and also the skewness value which elucidates that the dataset are light tailed during these months. Alternatively stated, rainfall in the study area follows a symmetric pattern during the above months for most of the districts. Contrary to this, in pre-monsoon months (April) and June, the dataset exhibit high kurtosis value and skewness in Hooghly, Howrah and N24 Parganas, for which it can be stated that rainfall follows a heavy tailed nature, *i.e.*, the presence of extreme values are there. For Burdwan, data showed high skewness and kurtosis value throughout the jute growing season.

The present study highlights the results of the trend analysis using monthly rainfall data for 39 years (1980-2019) of the 5 districts falling under Gangetic West Bengal at seasonal scale (jute growing period) because more than 75% of rainfall is received during the monsoon season. Both positive and negative trend in the rainfall pattern have been recorded in the five districts which show mixed scenario in rainfall trend over the West Bengal state. Out of 5 districts, Nadia and Burdwan recorded increasing trend whereas the other three districts showed decreasing pattern to higher side which is clear from the linear regression analysis. The coefficient of determination varied from 0.015 (N24 parganas) to 0.33 (Burdwan) which shows rainfall to be inconsistent in the former. The districts of West Bengal which are suffering from decreasing trend and hence drought conditions must think about alternative measures and timing of irrigation. Similarly, increasing trend in the monsoon rainfall (>100 mm) has become a concern for flood probability and crop loss due to water logging which rises awareness about drainage through ditches.

Temperature and its behaviour are important for understanding of climate variability which can vary spatially and temporally at different local, regional and global scales (Ghasemi, 2015). Regardless of the overwhelming evidence of escalating temperature trend all across the globe, accurate appraisal of the time trends is still an unresolved issue (Gil-Alana, 2018). Temperature deviation from optimum plays a critical role mainly during the initial germination stages and can further result in changes in the physiology of the plant. From the above observation, February planting should be discouraged to avoid the short day condition. Moreover, Burdwan district recorded lower temperature from optimum throughout the crop duration.

It is observed that coefficient of variation (CV) for maximum and minimum temperature in all the district varies from 1.5 to 9.9%, which means stability of the temperature over time. Less variability is examined in case of four districts except Burdwan which shows moderate variation (24-25%). Unlike other districts, in Nadia and N24 Parganas a significant increasing trend of temperature was ascertained in all the jute growing weeks, as denoted by Sen's slope.

5. Conclusions

It may be inferred that the jute growing farmers should be alert and prepared for any kind of climate aberrations such as drought and water logging condition due to erratic rainfall distribution and temperature deviation from optimum. A number of noticeable impacts of climate change have been recently observed in West Bengal state such that heavy rainfall in short period due to cyclone sometimes causes water logging as opposed to scarce rainfall in dry season which causes drought. In view of the above findings, farmers are challenged to cope with the sharply decreasing rainfall and adapt appropriate strategies to keep themselves less vulnerable. Besides, it may cause other potential socio-economic and ecological threats to farmers. The analysis shows that the variability is more or less the same for all months for temperature as compared to rainfall. The districts under study are susceptible to the rainfall variability and hence its extreme occurrence during monsoon and also during post and pre-monsoon months may hamper growth. Time of sowing should be given due importance since deviation of temperature during Feb and March (upto second week) may result in premature flowering. District wise it may be concluded that Howrah and Hooghly shows decreasing rainfall trend whereas Burdwan and Nadia shows increasing trend. N24 Parganas recorded negative rainfall trend to higher side. Temperature variability was less for all the districts except Burdwan. Moreover, positive Sen's Slope exhibited by Nadia and N24 Parganas shows an increasing temperature trend. March end-April may be considered to be the best sowing window to reap the benefits of optimum temperature and rainfall. Thus, the stakeholders should consider the rainfall variability in particular and temperature variability in general of these areas into their climate change adaptation strategy. In a nutshell, by this analysis we aimed to support the decision-making processes of agricultural and irrigation managers and also advise the farmers to cope up with the adversities for a secure future.

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