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ORIGINAL ARTICLE

Rainfall Trends in six districts of Assam during the period 1950-2013

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ABSTRACT
This paper investigated rainfall trend over six district under Brahmaputra and Barak valleys of Assam, India, over a 63-year study period (1950 to 2013). Nonparametric Mann-Kendall test at 95% confidence level and Sen's estimator of slope were used to detect trend and the change per unit time in monthly, seasonal and annual rainfall. The resultant Man-Kendall statistic (S) indicates how strong the trend is and whether it is increasing or decreasing. The result highlighted a mix of positive (increasing) and negative (decreasing) statistically significant trends in monthly and seasonal rainfall. In April month, 4 district (Dhubri, Goalpara, Kamrup and Sonitpur) experience statistically significant increasing trend (mm/yr.) of rainfall measuring 1.45, 2.57, 1.16 and 1.13 respectively. A statistically significant increasing trend (1.24mm/yr.) is also observed in October month in Kamrup district and a statistically significant decreasing trend (-4.01 mm/yr.) in the May month in Goalpara district. In post-monsoon season, Kamrup district experience statistically significant increasing trend (1.14mm/yr.) while a statistically significant decreasing trend (-1.22mm/yr.) was observed in Dibrugarh district. The winter, pre-monsoon, monsoon and annual rainfall did not show any statistical significant trend.
***Keywords**: Brahmaputra valley, Barak valley, Mann-Kendall test, Sen's slope estimator.*

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INTRODUCTION

Rainfall is very pertinent for the economic growth and development any agro-based state because the amount of rainfall during the seasons determine the success or failure of seasonal crops. Assam is an agro-based state located in North Eastern Region (NER) of India, where rainfall receives both during the summer and winter months from the south-west monsoon and the north-east monsoon. It forms the basis for monsoon onset and its prevalence over other parts of India due to the synoptic features prevalent over the region [1].The region is characterized by high rainfall but analysis of long-term trends in the annual rainfall indicates a slight decline in the total rainfall received in the region. Some work has been reported on rainfall variability over NER [2, 3]. Studies of Deka *et al.* (2013), Jain *et al.* (2013), Das *et al.* (2011) and Das *et al.* (2003) have concluded that there is no significant trend in annual rainfall for NER [4-7]. Rupa Kumar *et al.* (1992) reported a significant increasing trend in monsoon rainfall along the west coast, central peninsula and northwest India, while a significant decreasing trend was observed over the northeast and northwest peninsula, and northeast India while Guhathakurta and Rajeevan (2006) reported decrease in winter rainfall in Nagaland-Manipur- Mizoram-Tripura region and a significant increase in annual rainfall in Assam-Meghalaya subdivision [8, 9]. Similarly few studies reported on rainfall variability over Brahmaputra and Barak basin of Assam [10, 11]. Mirza *et al.* (1998) studied the changes of rainfall over Ganges, Brahmaputra and Meghna basins and found that annual rainfall over the south Assam sub-division (part of Barak basin) showed a decreasing trend (39.8 mm/decade) especially evident from 1960 whereas north Assam subdivision (part of Brahmaputra basin) showed an increasing trend (4.32mm/decade) during the study period of 1901-1981[12]. Kale (2011) have reported insignificant decreasing trend of monsoon rainfall in Brahmaputra- Barak basin during his study period 1829-2006 [13]. Deka *et al.* [14] in their study in rainfall trend during period 1901-2010 on the Brahmaputra and Barak basins of Assam concluded that the annual as well as monsoon rainfall showed long-term decreasing in both basins with significant values for the Barak basin.

The Brahmaputra and Barak are two main river of Assam. The total geographical area of the state about 78,438 sq.km and out of which 56,194 sq.km and 22,244 sq.km fall under Brahmaputra and Barak valley [15]. The rain-fed agriculture is the main source of livelihood for majority people living in the areas through which these rivers flows in Assam. Due to ecological and climate difference from one place to another these valleys always experience, from time to time, both excessive as well as insufficient rainfall as result agricultural production are often been seriously affected. Therefore an elaborate study on district-wise or Block-wise of rainfall trend need to be meticulously done to predict such situation in well advance and formulate effective agricultural planning. Keeping in view the above facts, this study is aimed to assess the spatial variation of monthly, seasonal and annual rainfall pattern over the selected six districts (Dhubri, Goalpara, Kamrup, Cachar, Sonitpur and Dibrugarh) of Assam through which Brahmaputra and Barak river flow, taking data for a 63-year period (1950-2013) using non-parametric method.

MATERIAL AND METHODS

Study area

The study area Assam is located south of the eastern Himalayas, comprises Brahmaputra and Barak river valleys and it is situated 90° to 96° North latitude and 24° to 28° East longitude. The Dhubri, Goalpara, Kamrup, Sonitpur and Dibrugarh districts cover approximate 17712 sq. km under Brahmaputra valley and the Cachar district cover approximate 3,786 Sq. km under Barak valley. The Dhubri, Goalpara, Kamrup, Sonitpur, Cachar and Dibrugarh district are considered for this studies based on the longest period of data available. The study areas are shown in fig-1.

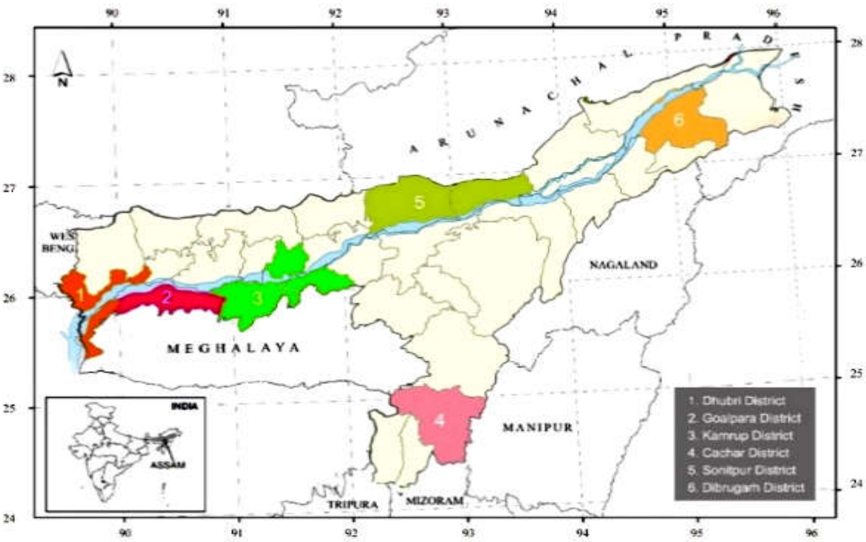

Fig-1 Colours blocks show study districts

Data used:

Series of daily rainfall data for a 63-year period (1950-2013) of the selected districts was collected from the archives of National Data Centre (India Meteorological Department), Pune. The station having longest period of data within the district is consider for this studies. The missing data of the selected station is fill up from the nearby station within the district so as to get a continuous series of data set. The station Rupsi, Goalpara, Guwahati, Tezpur, Mohanbari and Silchar are represents on behalf of the district Dhubri, Goapara, Kamrup, Sonitpur, Dibrugarh and Cachar district respectively. The daily recorded data of each station is used to compute the monthly, seasonal and annual rainfall of respective stations. For seasonal analysis, each year is divided into four climate season viz. winter (January to February), pre-monsoon (March to May), monsoon (June to September) and post-monsoon (October to November). All the observations are measured in millimetre (mm).

Trend analysis:

In this studies trend analysis was estimated by using Mann- Kendall test and Sen Slope estimator. Their definitions and brief mathematical concept are given in this section.

Mann-Kendall Test:

The Mann-Kendall test is widely acceptable non-parametric statistical test use to analysis trend hydro-meteorological data [16, 17]. It searches for a trend in a time series without specifying whether the trend is linear or nonlinear [18]. In this test the Mann-Kendall Statistic (S) indicate trend in time series. The positive value of S indicate upward and negative value of S indicate downward trend. The presence of statistical significant trend of statistic S is checked using standardized test statistic (Z).

This test checks the null hypothesis H_o of no trend (i.e. data is independent and randomly ordered) versus the alternative hypothesis H_1 of the existence of increasing or decreasing trend [19]. The mathematical equation of Mann-Kendall statistic (S), variance(σ^2) and standardized test statistic (Z) are as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sign}(T_j - T_i) \qquad (1)$$

$$\mathrm{Sign}(T_j - T_i) = \begin{cases} 1 & \text{if } T_j - T_i > 0 \\ 0 & \text{if } T_j - T_i = 0 \\ -1 & \text{if } T_j - T_i < 0 \end{cases} \qquad (2)$$

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum_{q=1}^{p} t_q(t_q-1)(2t_q+5)}{18} \qquad (3)$$

$$Z = \begin{cases} \frac{S-1}{\sigma} & \text{for } S > 0 \\ 0 & \text{for } S = 0 \\ \frac{S+1}{\sigma} & \text{for } S < 0 \end{cases} \qquad (4)$$

In these equation, T_j and T_i are observed value at time j and i (where $i = 1,2,3,\ldots,n-1$;$j = 2,3,\ldots\ldots,n$; $j > i)$, n is the length of the data set , p is the number of tied group and t_q is the number of data value in the q^{th}(tied) group [20, 21] . If the calculated value of$|Z| > Z_{\frac{\alpha}{2}}$, the null hypothesis $H_o$is rejected at α level of significance in a two-sided test, where α depicts significance level 0.05 (e.g.: 5% with $Z_{0.025} = 1.96$) [22].

Kendall's Tau

Kendall's tau (τ) is the measure of correlation, and so measures the strength of the relationship between two variables. The Kendall's tau [17] is closely related to statistic S in equation (1) and is defined [23] as:

$$\tau = \frac{S}{d} \qquad (5)$$

$$\text{Where, } d = \sqrt{\left[\frac{1}{2}\, n(\, n-1) - \frac{1}{2}\sum_{j=1}^{q} t_j\,(t_j-1)\right]}\sqrt{\left[\frac{1}{2}\, n(n-1)\right]} \qquad (6)$$

$$\tau = \frac{S}{\frac{1}{2}n(\,n-1)} = \frac{S}{\binom{n}{2}} \qquad (7)$$

If there are no ties in the data, the summation term equation (6) is vanished and equation (6) reduced to equation (7). Kendall's tau has a range between -1 to +1. The positive correlation indicates that the ranks of both variables increase together while the negative correlation indicates that as the rank of one variable increases, other decreases [21].

Modified Mann-Kendall test:

In time series analysis, it is essential to consider autocorrelation or serial correlation prior to testing for trends. Autocorrelation increases the chances of detecting significant trends even if they are absent and vice versa [21]. Thus the trend for autocorrelation series has been estimated by Modified Mann-Kendall test as proposed by Hamed and Rao [24] and corrected variance is calculated as:

$$Var\,[S] = \frac{1}{18}[\, n(n-1)(2n+5)]\frac{n}{N_S{}^*} \qquad (8)$$

$$\text{Where } \frac{n}{N_S{}^*} = 1 + \frac{2}{n(n-1)(n-2)}\sum_{i=1}^{p}(n-i)(n-i-1)(n-i-2)p_s(i)$$

In this equation, n is the number of observations in the sample, $N_S{}^*$ is the effective number of observations to account for autocorrelation in the data, $p_s(i)$ is the autocorrelation between ranks of the observation for lag i and p is the maximum time lag under consideration [20, 21].

The null hypothesis of the Mann-Kendall test is tested at 95% confidence level.

Sen's slop estimator:

The magnitude of trend in time series data has been estimated by using Sen's nonparametric method [25] which is computed as:

$$T_i = \frac{x_j - x_k}{j-k} \qquad \text{For } i = 1,2,3, \ldots \ldots . N \qquad (9)$$

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases} \qquad (10)$$

In these equation, x_j and $x_k$are data value at time j and k ($j > k$) respectively and Q_i is the median of N values of T_i . The positive (negative) value of Q_i indicate upward (downward) tend in the time series.

RESULTS AND DISCUSSION

Preliminary Analysis:

The preliminary analysis for this study included computing the Mean(M), Standard deviation (SD), Median (Me), Co-efficient variation (Cv), Co-efficient of kurtosis (Ck) and Coefficient of skewness (Cs) in seasonal and annual rainfall of each station.

Table -1: The geographical details and corresponding basic statistics of seasonal and annual rainfall of six stations during period 1950-2013

Station	Latitude(^{0}N)/ Longitude(^{0}E)/ Elevation(m)	Seasons	M (mm)	SD (mm)	CV	Me (mm)	Ck	Cs
		Annual	2482.55	666.49	0.26	2472.4	-0.62	0.37
	26° 02'N/	Winter	19.48	21.20	1.08	13	6.04	2.11
Rupsi	89° 58'E/	Pre-	571.72	229.39	0.40	570.7	0.05	0.27
	34	monsoon	1711.13	529.50	0.30	1770.6	-0.69	0.33
		Monsoon	180.218	139.08	0.77	156.7	0.13	0.87
		Post-						
		monsoon						
		Annual	2553.94	600.05	0.23	2478	1.38	-
	26°10'/	Winter	35.20	62.82	1.78	22.15	36.26	0.62
Goalpara	90° 37'/	Pre-	680.20	213.32	0.31	658.83	1.62	5.53
	35	monsoon	1660.12	572.78	0.34	1599.95	6.73	-
		Monsoon	178.40	114.68	0.64	143.65	-0.29	0.07
		Post-						1.70
		monsoon						0.67
		Annual	1706.27	284.83	0.16	1705.95	1.04	0.01
	26°11'/	Winter	28.46	24.47	0.85	22.8	6.05	1.93
Guwahati	91°35'/	Pre-	465.93	144.33	0.30	455.1	-0.06	0.44
	54	monsoon	1088.30	241.53	0.22	1080.4	2.97	-
		Monsoon	123.56	78.71	0.63	123.25	0.59	0.57
		Post-						0.84
		monsoon						
		Annual	1779.76	277.87	0.15	1754.4	0.92	-
	26°37'/	Winter	29.13	26.48	0.90	25.5	15.24	0.25
Tezpur	92°48'/	Pre-	478.58	120.96	0.25	479.6	0.47	3.10
	79	monsoon	1128.21	234.98	0.20	1122.1	0.61	0.67
		Monsoon	143.82	73.69	0.51	135	0.19	0.04
		Post-						0.85
		monsoon						
		Annual	2613.69	361.29	0.13	2606.65	-0.87	0.15
	27°48'/	Winter	92.47	44.85	0.48	95.55	-	0.17
Mohanbari	95°06'/	Pre-	653.09	197.55	0.30	642.15	0.0002	0.59
	106	monsoon	1684.48	273.44	0.16	1655.05	0.32	0.37
		Monsoon	183.69	88.20	0.48	167.5	-0.74	1.05
		Post-					1.29	
		monsoon						
		Annual	3008	551.45	0.18	3042.3	0.79	0.11
	24°83'/	Winter	57.18	59.82	1.04	43.95	7.03	2.13
Silchar	92°77'/	Pre-	860.74	275.01	0.319	838.95	-0.11	0.50
	29	monsoon	1850.37	369.51	0.19	1856.4	1.77	0.06
		Monsoon	240.15	114.93	0.47	227.85	0.66	0.85
		Post-						
		monsoon						

M-Mean, SD-Standard deviation, CV-Coefficient of variation, Me-Median, Ck-Kurtosis, Cs-Skewness

Table-1 presents these statistical parameters for the 63 years studies period (1950-2013). The long-term (1950-2013) mean annual maximum rainfall received by Silchar (3008 mm) with standard deviation 551.45 mm. The Guwahati receives minimum mean annual rainfall (1706.27 mm) with a standard deviation of 284.83 mm. It is seen that the rainfall in the study area increases from January onward, attains a peak during June in Silchar and during July in Mohanbari and then falls, reaching the lowest value generally in December (Fig-2 a). The winter total rainfall is more in station Mohanbari (5854.78mm) compared to other five stations while Silchar received more rainfall in pre-monsoon (51863.23 mm), monsoon (111102.57 mm) and post-monsoon (14475.60 mm) as compared to other five stations (Fig-2b). The coefficient of variation of annual rainfall is highest in Rupsi (26%) and lowest in Tezpur (13%). The percentage contribution of monsoon rainfall to annual total rainfall was highest in Rupsi (68%) and lowest in Silchar (61%). As the table-1 shows, the coefficient of skewness in annual rainfall varied from -0.619 to 0.374, coefficient kurtosis in annual rainfall varied from -0.870 to 1.379. For time series data to be considered normally distributed, the coefficient skewness and kurtosis must be equal to 0 and 3 respectively. Table 1 therefore, indicates that annual and seasonal rainfall data are positively (negatively) skewed and not normally distributed.

Trend Analysis:

The changing pattern and trends both significantly depend on the data period [26]. Burn and Elnur (2002) suggested that data record of 25 years is long enough for finding trends, if any exists in climate change research [27]. In this study, Mann-Kendall (MK) test is performed for rainfall trend with 63 years of data. Table-2(a, b) is depicting the result of MK test. If the p value is less than the significance level α (alpha) = 0.05, H_0 is rejected. Rejecting H_0 indicate that there is trend in the time series, while accepting H_0 indicates no trend was detected. On rejecting the null hypothesis, the result is said to be statistically significant. For this test, the null hypothesis was rejected in 4 station (Rupsi, Goalpara, Guwahati and Tezpur) in April month, 1 station (Goalpara) in May month and 1 station (Guwahati) in October month while it was accepted in all station for remaining months. For seasonal trend analysis, the null hypothesis was accepted for all the stations in winter, pre-monsoon and monsoon season but it is rejected in 2 station (Guwahati and Mohanbari) in post-monsoon season. For annual trend analysis, the null hypothesis was accepted for all station. The result obtained from MK and Sen's slope estimator test in annual and monsoon rainfall trend is in agreement with previous findings of the authors [4-7]. Table 2(a) shown the value of Q_i and τ obtained from Sen's slope estimator and MK test. From this result, it is observed that over Guwahati, a significant monotonically increasing trend (1.14 mm/yr.) of rainfall has been detected in post-monsoon season. For this season, a relatively high τ value (0.1798) also implies strong positive correlation between precipitation and time i.e. rainfall increases considerably as the year progresses starting from 1950. In the same season (i.e. Post-monsoon), Mohanbari experience a significant decreasing trend (-1.22 mm/yr.) with relatively less τ value (-0.1856). Das *et al.* (2015) reported similar result i.e. significant increasing trend (1.68 mm/yr.) at Guwahati in post-monsoon season [28]. Table 2(b) depicting τ and Q_i values for monthly rainfall. From this tables, it has been observed that in the particular month of April, 4 station (Rupsi, Goalpara, Guwahati and Tezpur) experience significant increasing trend (mm/yr.) of rainfall measuring 1.45, 2.57, 1.16 and 1.13 respectively. A significant increasing trend (1.24mm/yr.) is also observed in October month in Guwahati while Goalpara experience a significant decreasing trend (-4.01 mm/yr.) in May month. The other months did not show any statistically significant trend.

For the interest of comparative study, linear fitting is applied in annual, seasonal and monthly rainfall. Fig-3 represent linear fitting in annual rainfall of six stations. From this result, it is observed that annual rainfall trend is decreasing in 4 station (Rupsi, Goalpara, Silchar and Mohanbari), increasing in 1 station (Guwahati) and 1 station (Tezpur) has apparently no trend. The slope of annual trend of rainfall (mm/yr.) is around -5.25, -4.50, -3.12, -2.87, 1.18 and 0.35 for Rupsi, Goalpara, Silchar, Mohanbari, Guwahati and Tezpur respectively. In seasonal and monthly analysis, linear fitting is applied only for those seasons (months) which are shown statistically significant by MK test. Fig-4 depict linear fitting in Guwahati and Mohanbari in post-monsoon season. The slope of post-monsoon rainfall trend (mm/yr.) in Guwahati and Mohanbari is around 1.05 and -1.31 respectively. Fig-5 (a) depict linear fitting in April month in Rupsi, Goalpara, Guwahati and Tezpur. The slope of April month rainfall trend (mm/yr.) is around 1.43, 2.0, 1.37 and 1.00 in Rupsi, Goalpara, Guwahati and Tezpur respectively. Fig-5 (b, c) shows the linear fitting in May and October month in Goalpara and Guwahati. The slope of the rainfall trend (mm/yr.) of the respective stations are around -3.620 and 1.18.

In general, there was conformity in the result obtained from the MK test and linear trend line for the selected districts over the studies period.

Table-2(a): Modified Mann Kendall test and Sen's slope estimator test result for seasonal and annual rainfall in six stations during period1950-2013

Season	Station	Mann- Kendall Statistics (S)	Kendall's Tau (τ)	Var (S)	p-value (Two tailed test)	alpha	Test interpretation	Sen's slope estimator (Q_i)
Annual	Rupsi	-155.00	-0.1044	18975.00	0.263	0.05	Accepted H_o	-6.70
	Goalpara	-194.00	-0.1260	20020.00	0.172	0.05	Accepted H_o	-7.03
	Guwahati	39.00	0.0206	27104.33	0.817	0.05	Accepted H_o	0.46
	Tezpur	21.00	0.0108	28427.00	0.900	0.05	Accepted H_o	0.38
	Mohanbari	-176.00	-0.0931	27103.33	0.285	0.05	Accepted H_o	-3.42
	Silchar	-142.00	-0.0802	24583.33	0.365	0.05	Accepted H_o	-3.89
Winter	Rupsi	67.000	0.0453	18957.33	0.631	0.05	Accepted H_o	0.07
	Goalpara	-53.00	-0.0346	19991.66	0.713	0.05	Accepted H_o	-0.02
	Guwahati	153.00	0.0811	27091.66	0.355	0.05	Accepted H_o	0.13
	Tezpur	40.00	0.0205	28424.00	0.812	0.05	Accepted H_o	0.04
	Mohanbari	-247.00	0.1306	27104.33	0.133	0.05	Accepted H_o	-0.46
	Silchar	-91.00	-0.0515	24580.33	0.561	0.05	Accepted H_o	-0.18
Per-monsoon	Rupsi	-13.00	-0.0088	18975.00	0.930	0.05	Accepted H_o	-0.15
	Goalpara	-23.00	0.0149	20019.00	0.876	0.05	Accepted H_o	-0.29
	Guwahati	197.00	0.1042	27104.33	0.231	0.05	Accepted H_o	1.29
	Tezpur	141.00	0.0722	28427.00	0.403	0.05	Accepted H_o	0.78
	Mohanbari	-38.00	-0.0201	27103.33	0.817	0.05	Accepted H_o	0.30
	Silchar	-66.00	-0.0373	24583.33	0.673	0.05	Accepted H_o	-0.78
Monsoon	Rupsi	-153.00	-0.1030	18975.00	0.269	0.05	Accepted H_o	-5.47
	Goalpara	-154.00	-0.1000	20020.00	0.279	0.05	Accepted H_o	-4.0
	Guwahati	-238.00	-0.1259	27103.00	0.148	0.05	Accepted H_o	-2.05
	Tezpur	65.00	0.0333	28427.00	0.699	0.05	Accepted H_o	0.55
	Mohanbari	-95.00	-0.0502	27104.33	0.563	0.05	Accepted H_o	-1.40
	Silchar	-76.00	-0.0429	24583.33	0.627	0.05	Accepted H_o	-1.19
Post-monsoon	Rupsi	7.000	0.0047	18975	0.965	0.05	Accepted H_o	0.07
	Goalpara	-50.00	0.0325	20020.00	0.729	0.05	Accepted H_o	-0.25
	Guwahati	340.00	**0.1798**	27103.33	0.038	0.05	**Rejected H_o**	**1.14**
	Tezpur	-67.00	-0.0343	28427.00	0.691	0.05	Accepted H_o	-0.22
	Mohanbari	-351.00	**-0.1856**	27104.33	0.033	0.05	**Rejected H_o**	**-1.22**
	Silchar	-288.00	-0.1627	24583.33	0.066	0.05	Accepted H_o	-1.68

Table-2(b): Modified Mann-Kendall and Sen's slope estimator test result for Monthly rainfall in six stations during period 1950-2013

Month	Station											
	Rupsi		Goalpara		Guwahati		Tezpur		Silchar		Mohanbari	
	Q_i	τ	Q_i	τ	Q_i	τ	Q_i	τ	Q_i	τ	Q_i	τ
Jan	0	-0.020	0	-0.058	0	-0.021	0.06	-0.106	-0.05	-0.155	-0.25	-0.134
Feb	0.02	0.090	0	0.031	0.08	0.104	0.1	0.107	-0.04	-0.026	-0.19	-0.066
March	0.01	0.009	0.28	0.056	0.06	-0.015	0.01	0.001	0.86	0.092	0.42	0.066
April	**1.45***	**0.177**	**2.57***	**0.235**	**1.16***	**0.165**	**1.13***	**0.186**	0.08	0.009	0.72	0.107
May	-2.26	-0.160	**-4.01***	**-0.294**	-0.82	-0.090	-0.17	-0.025	-0.75	-0.049	-1.19	-0.101
June	-2.03	-0.085	-2.58	-0.128	-1.13	-0.095	-0.11	-0.010	-0.62	-0.041	-1.06	-0.108
July	-3.33	-0.132	-0.44	-0.028	-1.00	-0.110	-0.49	-0.055	-0.77	-0.074	-0.24	-0.032
Aug	-0.89	-0.047	0.97	0.068	0.61	-0.072	-0.67	0.065	0.03	0.003	-0.63	-0.069
Sept	0.81	0.057	-1.6	-0.083	0.70	0.102	0.63	0.079	0.3	0.033	0.15	0.020
Oct	0.05	0.004	-0.18	-0.026	**1.24***	**0.195**	-0.14	-0.023	-1.05	-0.119	-0.75	-0.128
Nov	0	-0.084	0	-0.124	-0.01	0.059	-0.04	-0.063	-0.03	-0.048	-0.08	-0.080
Dec	0	0.131	0	-0.024	0	-0.044	0	-0.033	0	0.081	-0.11	-0.133

Q_i – Sen's Slope estimator , τ- Mann-Kendall Tau, *- Statistically Significant (**Rejected H_o**)

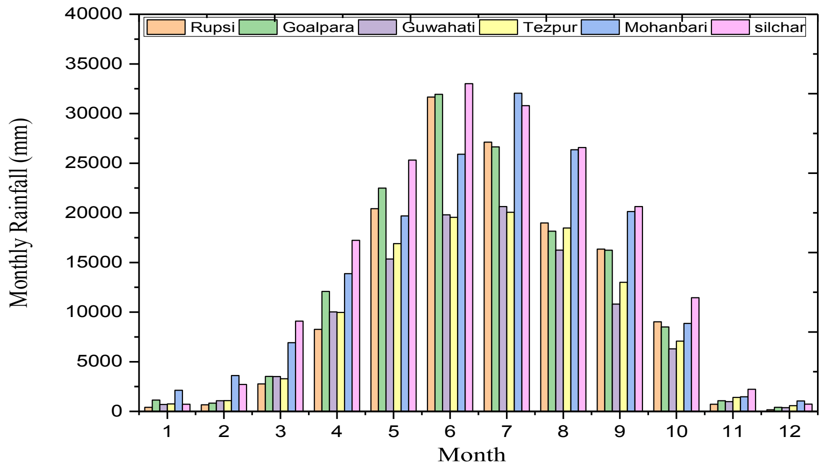

Fig-2(a) Monthly total rainfall distribution during period 1950 to 2013

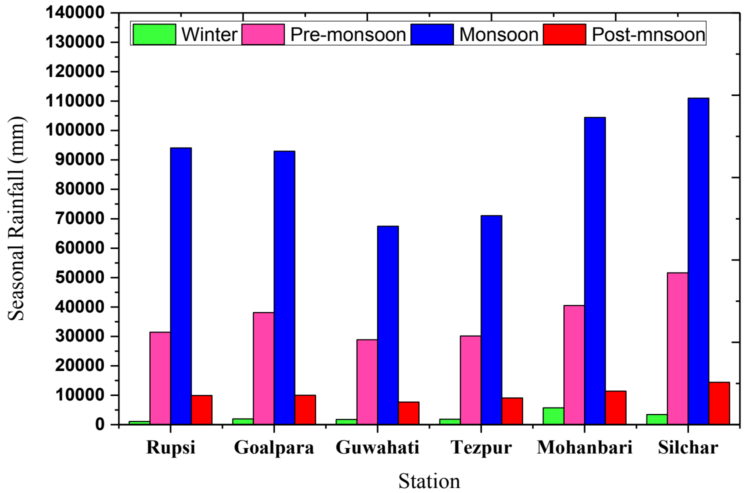

Fig 2(b) Seasonal total Rainfall of period 1950 to 2013

Equation	y = a + b*x					
Plot	Rupsi	Goalpara	Guwahati	Silchar	Tezpur	Dibrugarh
Slope	-5.25018	-4.50018	1.18755	-3.12509	0.35939	-2.87509

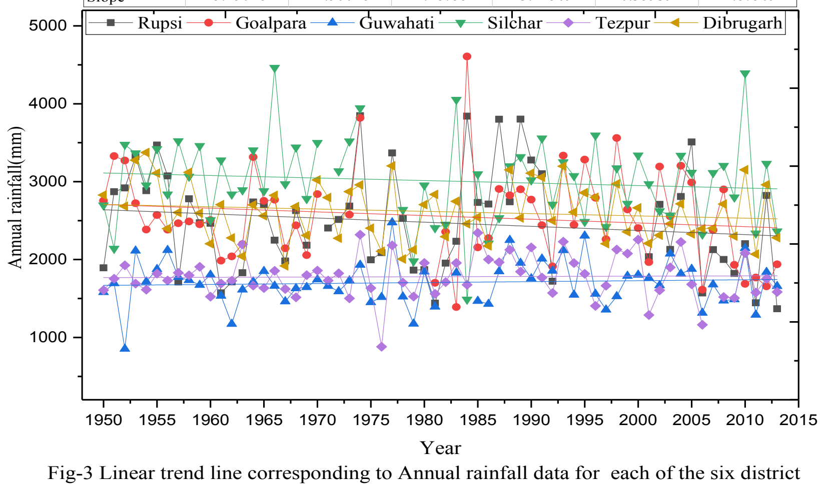

Fig-3 Linear trend line corresponding to Annual rainfall data for each of the six district

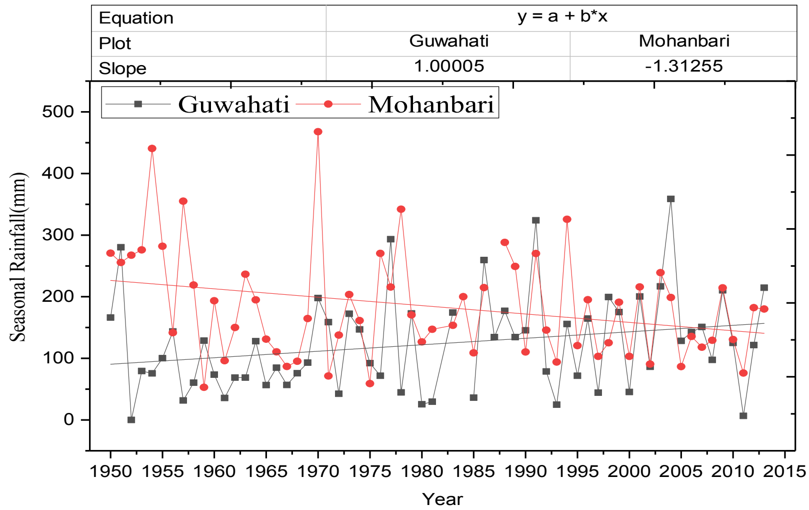

Fig- 4 : Seasonal Rainfall trend at Guwahati and Mohanbari in post-monsoon season

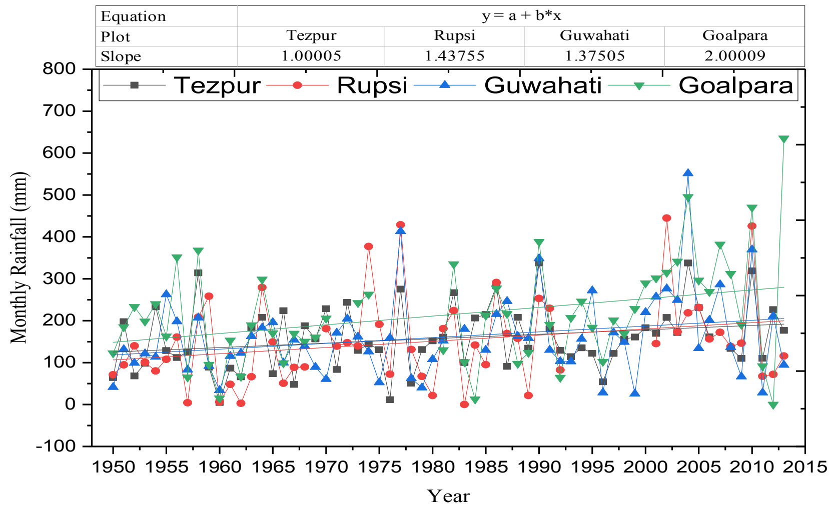

Fig 5(a) April Month rainfall trend at Tezpur, Rupsi,Guwahati and Goalpara during 1950 to 2013

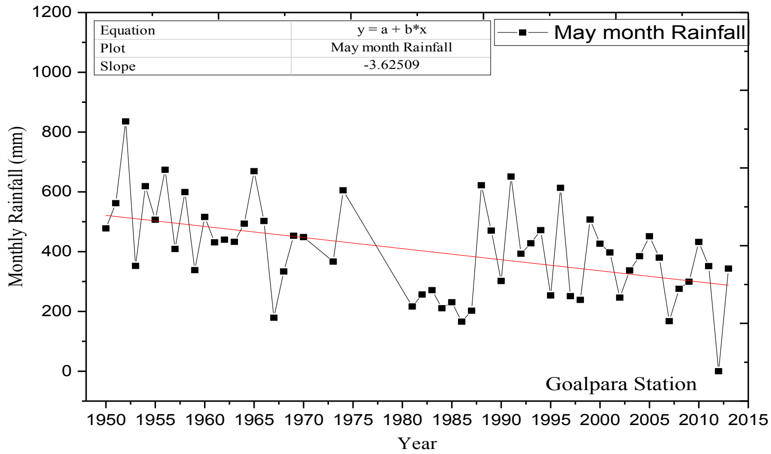

Fig 5(b) Monthly Rainfall trend at Goalpara Station during period 1950 to 2013

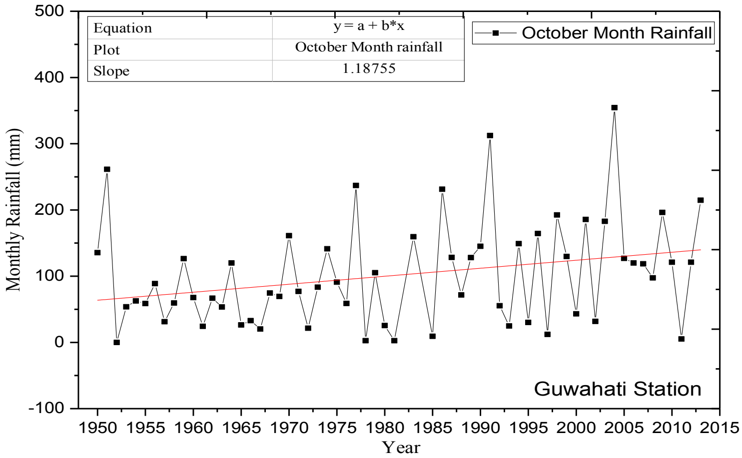

Fig 5(c) Monthly Rainfall Trend at Guwahati during period 1950 to 2013

CONCLUSION

This paper analysed trends in monthly, seasonal and annual rainfall in the six districts of Assam under Brahmaputra and Barak valleys over the 63-year study period (1950 to 2013). The district-wise trend of rainfall volume in many cases, is not same as reported by some authors on their studies over entire Brahmaputra and Barak valleys. As an instant, the Cachar district (under Barak valley) experience insignificant decreasing trend in annual as well as in monsoon rainfall but it was reported by some author that Barak valley experience significant decreasing trends in annual as well in monsoon. Similarly, the Sonitpur district (under Brahmaputra Valley) does not experience any decreasing trend in annual as well as in monsoon rainfall instead in was experience insignificant increasing trend but it was reported by some author that Brahmaputra and Brahmaputra-Barak valley experience decreasing trends in annual and monsoon rainfall. Thus the importance of trend analysis, in the scale of smaller region i.e. district in this case, is justified. The level of precision can be improved, if the analysis would be done in block level covering all the districts of Assam under Brahmaputra and Barak valley. An interesting result, in the present study, revealed that in the month of April, 4 out of 5 districts under Brahmaputra valley experience statistically significant increasing trend of rainfall during the study period 1950-2013. This can lead to draw an inference i.e. rising in amount of rainfall before monsoon season at least in those district over the period. Another result obtained from present study is that Kamrup district experience statistically significant increasing trend of rainfall in post-monsoon season. It produces stagnation of water in agriculture field, which leads to significant loss of the pre-harvested crops. The excessive rainfall during the post-monsoon season which is the peak harvesting time for Kharif crops also produces several yield loss. On the other side, decreasing trend of post-monsoon rainfall in Dibrugarh district, can cause drought situation and hamper agricultural activities. Timely measures and institutional changes can certainly help in reducing the irreparable damages in seasonal crops that can be caused by rainfall.

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