



Long-term Rainfall Data Analysis of the Major Stations of Brahmaputra Plain in Northeast Region of India

Ashok Singh^{1,*}, Samir Thakur¹, Nirab C. Adhikary²

¹Department of Applied Sciences, Gauhati University, 781014, Assam, India

²Physical Sciences Division, Institute of Advanced Study in Science and Technology, Paschim Boragaon, Garchuk, Guwahati 781035, Assam, India

Article Type: Article

Article Citation: Ashok Singh, Samir Thakur, Nirab C. Adhikary. Long-term rainfall data analysis of the major Stations of Brahmaputra plain in northeast region of India. *Indian Journal of Science and Technology*. 2020; 13(08),907-920.DOI:10.17485/ijst/2020/v013i08/149815

Received date: January 2, 2020

Accepted date: February 11, 2020

***Author for correspondence:**

Ashok Singh ✉ ashok11278@yahoo.com
Department of Applied Sciences, Gauhati University, 781014, Assam, India

Abstract

Objectives: This study explores the rainfall variability and long-term trend in the Brahmaputra plain of northeast region of India. The data analysis is mainly focused on estimating the amount, frequency, and trend of rainfall, using daily recorded data between the year 1950 and 2013. **Methods:** Linear Regression analysis was utilized to check the correlation relation between elevation and rainfall. The Mann Kendall test was used to detect a significant trend in rainfall series. Sen's slope method was used to measure the magnitude of trends in rainfall series. The correlation between time and rainfall was estimated by utilizing Kendall's tau. **Findings:** Data analysis reveals a heaviest-rainfall pockets zone at North Lakhimpur region, wherein annual average rainfall occurs about 3249.57 mm. Another rain shadow zone has detected at Guwahati, wherein annual average rainfall occurs is about 1706.27 mm. A high-low-high gradient in the spatial distribution of seasonal and yearly rainfall has observed from west to east. A similar spatial trend has also observed from south to north along latitudes. The Linear regression analysis reveals a positive relationship between elevation and annual average rainfall. The Mann Kendall test detected a significant rainfall trend on a monthly and seasonal scale whereas, on an annual scale, no significant trend was detected. Rainfall intensity over each station was observed uniform for most of the years. The frequency of light, heavy and very heavy rainfall over the entire Brahmaputra plain region shows a non-significant decreasing trend. Whereas, Dibrugarh and North Lakhimpur experience decreasing trends in the frequency of rainy day and light rainfall and heavy rainfall respectively with a 5% significance level. **Application:** The result that comes out from this study shall be useful for the study of soil erosion, water resources management, and agricultural activity and may be useful for adopting flood disaster management policies.

Keywords: Brahmaputra Plain Region, Rainy Day, Mann Kendall Test, Sen's Slope Method.

1. Introduction

In recent times, several research papers published on climate change reported that it is one among the biggest threats for the environment that the entire world facing today [1–3]. The potential impact of climate change is found to see in food production, forest, water resources, and biodiversity of many regions throughout the entire world. One of the major attributes of climate change can be understood by the study of rainfall over a certain period. The analysis of rainfall data allows us to understand the evolution of climate change with respect to time of a certain region. In addition to that, it also provides important information about temporal variations of climate within that region. Furthermore, change in rainfall amount and frequency over a particular region is directly influences the hydrologic cycle, soil moisture, agricultural activity, and groundwater reserves of that region [4–5]. In [6–9] view of this, several studies throughout India have conducted and reported relating to rainfall trends, its extreme events, and possible causes. Some of these studies reported significant rainfall trends (increasing/decreasing) on a monthly and seasonal scale. Whereas some others reported that extreme rainfall events over India are significantly influenced by El-Nino Southern Oscillation. Similarly, some studies reported on rainfall variability and its long-term trends over the North East region of India [10–14]. On the other hand, some studies also reported which are mainly focused on extreme rainfall events over the North East region. In [15] a study, reported that heavy rainfall events over the North East region, especially, in pre-monsoon are due to severe thunderstorm activity as well as pre-monsoon Nor'westers (tornadoes). In Ref. [16], Prokop and Walanus reported that extreme rainfall events over the Meghalaya plateau of the North East region, especially in the monsoon period have a significant link with Madden–Julian oscillation. In a recent study, relevant to receiving a different amount of rainfall over India, noted the increasing frequency of extreme rainfall and decreasing frequency of little and moderate rainfall over the North East region of India [17]. Further [18] in their study during the last decades over the Brahmaputra basin reported that the North East region is one of the most flood-prone areas in India it is a special interest to know the present scenario of spatial and temporal rainfall variability over the Brahmaputra plain region. The Brahmaputra plain is the largest plain region in the entire North East region. Simultaneously, this region is the larger producer of agricultural products like tea, rice, etc. Almost all crop areas of this region are under rainfed agriculture. The enormous water bodies over the region are water resources as well as courses disaster. The abundance rainfall during monsoon season, especially in the month of June and July over the plateau and mountainous region come down to the Brahmaputra River and its tributaries rivers which make them flooded as a result often cause several damages to infrastructure, agricultural product and human life in the lowland area of this plain region. In addition, last few decades due to urbanization, deforestation activity was carried out in some area of this region. Therefore, it is important to analyze the influence of climate change on rainfall variability over the study region and its attendant effect on the ecosystem. Furthermore, no previous study has found to analyze the frequency of different amount rainfall, i.e. light, heavy, very heavy and extremely and consecutive rainfall days using data period from 1950 to 2013. Therefore, in this work, we analyzed the spatial and temporal characteristics of rainfall between the period 1950 and

2013 using daily recorded rainfall data from selected 6 major weather stations from west to east of the Brahmaputra plain region.

2. Study Area and Data Used

2.1. Study Area

The Brahmaputra plain is the largest plain area in the entire northeast region. This region is covering an area of 54,315 km² out of 255,036 km² of the entire northeast region. The geographic location of the station has depicted in Table 1. The entire area of Brahmaputra plain is encircled in north, east, and south side by hill and mountain range of Arunachal Himalaya, Patkai Bum-Arunachal hills, Nagahills, and Meghalaya-Karbi plateau. The western part of this plain is joined with Ganga plain. From west to north-east, its length about 720 km and from south to north, it breath about 90 km. Its latitude is varying from 28 m (at Dhubri) to 130 m (at Sadiya-Pasighat Plain). The Brahmaputra River is the main river in this plain which flowing in the middle along latitude. This river has more than 50 Tributaries Rivers, which also flowing in this plain. Yearly average rainfall in this plain is about 2300 mm. As being within South-East Asian monsoon zone, the climate of this plain is considered as tropical monsoon climate.

TABLE 1. Basic statistic of the stations corresponding to geographic location

Station	Lat. (°N)	Lon. (°E)	Elev. (m)	AAR (mm)	SD	CV (%)	Ck	Cs
DHB	26° 02'	89°58'	34	2460.28	657.96	27	-0.84	0.16
GLP	26°10'	90°37'	35	2584.70	498.15	19	-0.50	0.25
GHT	26°11'	91°35'	43	1706.27	284.84	17	1.04	0.01
TZP	26°37'	92°48'	48	1779.76	277.87	16	0.92	-0.25
DIB	27°48'	95°06'	108	2613.69	361.29	14	-0.87	0.15
NLP	27°48'	95°06'	147	3249.57	379.74	12	-0.02	0.11

Abbreviations: Lat, Latitude; Lon, Longitude; AAR, Average annual rainfall.

2.2. Data Used

A series of daily rainfall data of available rain-gauge stations of the northeast region of India has collected from the archives of the National Data Centre (IMD), Pune. After scanning the data of each year, we selected six-station: Dhubri (DHB), Goalpara (GLP), Tezpur (TZP), Guwahati (GHT), North Lakhimpur (NLP), and Dibrugarh (DIB), to represent from Brahmaputra plain region (BP). The data period 1950–2013 has selected for this study. The stations have selected for this study due to the availability of continuous data from the period 1950–2013. Few missing days in the series has calculated by Nonlinear Iterative Partial Least Squares (NIPALS) algorithm.

3. Methods

The daily-recorded rainfall data were used to calculate monthly, seasonal, and yearly for each station. To analyze the different amount of rainfall distribution over the each station,

the following parameters have calculated; total rainfall, Number of rainy days ($R \geq 2.5$ mm), heavy rainfall ($R \geq 64.5$ mm), very heavy rainfall ($124.5 \leq R \leq 244.5$ mm), and extremely heavy rainfall ($R > 244.5$ mm). To analyze rainfall intensity, we followed the method adopted by [19–20] to investigate rainfall intensity over the Sultanate of Oman [1]. Accordingly, we analyzed rainfall intensity over each station in three groups; light rainfall ($2.5 \leq R \leq 64.4$ mm), heavy rainfall ($64.5 \leq R \leq 124.4$ mm), and very heavy rainfall ($124.5 \leq R \leq 244.5$ mm). The wettest period is analyzed by calculating the numbers of rain days in a decade. During monsoon season, the numbers of consecutive rainfall days up to 4 days are common over all the stations understudy. However, we used following consecutive rainfall day per decade; 5–9 days, 10–14 days, and 15–19 days to estimate wettest periods. No adjustments were made of missing data for calculation of frequency of rainfall, the intensity of rainfall and wettest period. Apart from these, we also calculated some basic statistics like Standard deviation (SD), Coefficient of variation (CV), Coefficient of Kurtosis (Ck), Coefficient of Skewness (Cs) for each station to get the information of type of rainfall distribution. Furthermore, relation between rainfall and elevation over this region is estimated by the linear regression analysis. The trends in the time series were detected by using Mann–Kendall (M–K) test. Magnitudes of the trend in time series were estimated by using Sen Slope estimator [21].

In [2] M–K test, if p value (in two-sided test) is equal to or less than 0.05, then the trend is statistically significant. The correlation between rainfall and years can be obtained by calculating Kendall's tau τ (range between -1 and $+1$). The positive value of τ indicates ranks of both variables increase together, while the negative value τ indicates that as the rank of one variable increases, the other decreases. Autocorrelation in the rainfall series was minimized before running M–K test [22]. Mann–Kendall test was tested at 5% significance level (i.e. 95% confidence level).

Mathematical equation of M–K statistic (S), Kendall's tau (τ), and Sen's slop estimator (Q_k) are as follows:

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

$$\tau = \frac{S}{d} \quad (2)$$

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

$$Q_k = \begin{cases} \frac{T_{n+1}}{2} & \text{nis odd} \\ \frac{1}{2} \left(\frac{T_n}{2} + \frac{T_{n+2}}{2} \right) & \text{nis even} \end{cases} \quad (3)$$

$$\text{Where, } X_k = \frac{T_j - T_i}{j - i} \text{ For } k = 1, 2, 3, \dots, n,$$

where T_j and T_i are observed value at time j and i (where $i = 1, 2, 3, \dots, n-1$; $j = 2, 3, \dots, n$; $j > i$), n is the length of the data set, and Q_k is the median of n values of X_k .

All the computational part in this study were done by using software R, version 3.5.1

4. Results and Discussion

4.1. Yearly, Seasonal, and Monthly Rainfall

Annual rainfall over the Brahmaputra plain is quite variable and is dependent upon the geographical location as represented in Figure 1. Basic statistic of the stations corresponding to geographic location has depicted in Table 1. The average yearly rainfall over the Brahmaputra plain of period 1950–2013 is 2399 mm. Among all the stations' understudy, North Lakhimpur experienced the highest average yearly of 3249 mm rainfall and the lowest average yearly of 1706 mm rainfall was recorded at Guwahati. The yearly average rainfall shows a small variation (CV = 27%). The Coefficient of Kurtosis (Ck) varies from 0.12 to 0.27 and Coefficient of Skewness (Cs) from -0.02 to 1.04 , indicate that annual rainfall has not normally distributed over Brahmaputra plain. For a normal distribution, Ck and Cs should be equal to 3 and 0, respectively. Furthermore, average yearly rainfall shows a positive relationship (correlation coefficient, $R = 0.714$) with elevation (Figure 2). The different amount of rainfall distribution over the region is attributed by topographic elements, locally generated low-pressure gradient over this region, severe thunderstorm activity and location of monsoon trough. Furthermore, the lowest rainfall in Guwahati is due to the rain-shadow effect of Meghalaya-Karbi plateau.

The average monthly rainfall distribution between 1950 and 2015 has depicted in Figure 3. It can be observed that monthly average rainfall attains its maximum magnitude in June or July and afterward decreases gradually to the rich it lowest value in December or January. Of six stations, North Lakhimpur recorded the highest of 270.80 mm of rainfall and the lowest recorded of 142.19 mm was recorded at Guwahati. For seasonal

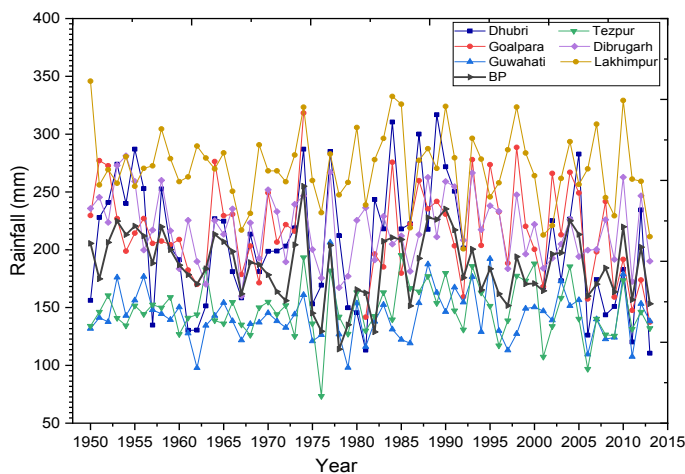


FIGURE 1. Yearly average rainfall in Brahmaputra plain (1950–2013).

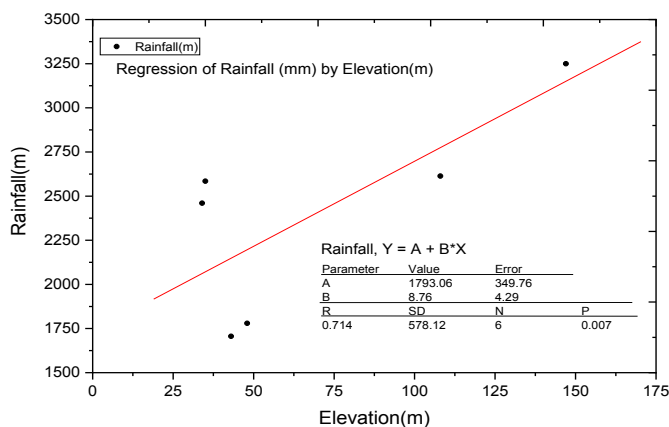


FIGURE 2. Relation between average annual rainfall and elevations.

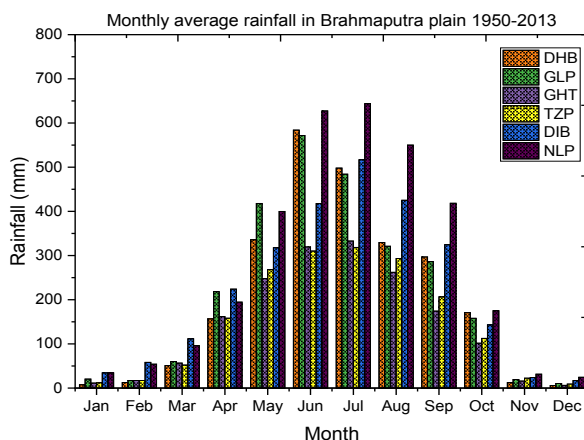


FIGURE 3. Monthly average rainfall (1950–2013).

analysis, we divided each year into four seasons starting from January of each year namely: January–February (winter), March–May (pre-monsoon), June–September (monsoon), and October–December (post-monsoon). It was observed that each station received high rainfall in monsoon followed by pre-monsoon season. In the post-monsoon and winter season, all the stations received relatively low rainfall. In the monsoon season, North Lakhimpur receiving 2239.66 mm of rainfall and the lowest 1088.30 mm was measured at Guwahati. The rainfall in the period June–September in Brahmaputra plain accounts for 66.08% of total annual rainfall. Generally, a high-low-high gradient in seasonal and yearly from east to west in Brahmaputra plain was observed.

4.2. Rainy Days, Rainfall Intensity, and Wettest Period

The average yearly rainy days of all geographic locations of Brahmaputra plain were represented in Figure 4. Indian Meteorological Department (IMD) defined rain day, rainy day, heavy, very heavy, and extremely heavy rainfall as, if the rainfall (R) of that day is

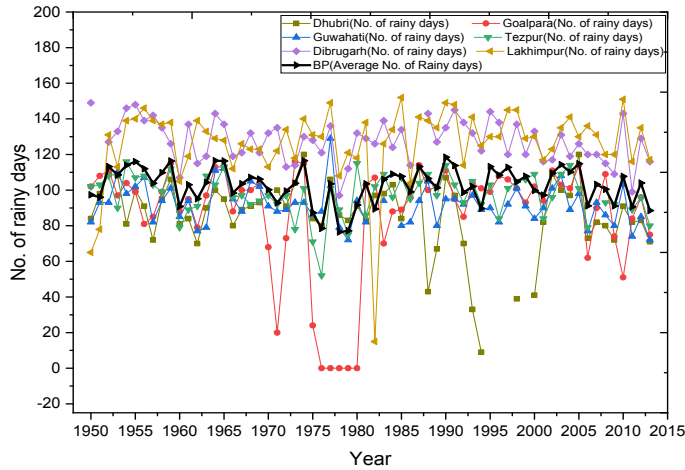


FIGURE 4. No. of rainy days of all six stations and average no. of rainy days in Brahmaputra plain (1950–2013).

$R \geq 0.1$ mm, $R \geq 2.5$ mm, $R \geq 64.5$ mm, $124.5 \leq R \leq 244.5$ mm, and $R > 244.5$ mm, respectively [23]. Throughout the study period, the height average numbers of rainy days ($R \geq 2.5$ mm) were observed in Dibrugarh, whereas the lowest was observed in Dhubri (Table 2). The height average number of heavy rainfall ($R \geq 64.5$ mm) throughout 64 years was observed in North Lakhimpur and the lowest was observed in Tezpur. Furthermore, the highest average number of very heavy rainfall ($124.5 \leq R \leq 244.5$ mm) and extremely heavy rainfall ($R > 244.5$ mm) was observed at Dhubri.

The rainfall intensity has calculated in two ways. First, we construct a time series for each station, where total rainfall in a year is divided by the total number of rainy days of that year (Figure 5). Secondly, rainfall was analyzed in three groups, consisting light rainfall ($2.5 \leq R \leq 64.4$ mm), heavy rainfall ($64.5 \leq R \leq 124.4$ mm), and very heavy rainfall ($124.5 \leq R \leq 244.5$ mm) (Figure 6). The extremely heavy rainfall ($R > 244.5$ mm) was excluded from this study, as it has seen rarest events for most of the stations over the study period. It is seen from Figure 5 that, rainfall intensity over the stations' understudy is uniform for most of the years. The high rainfall intensity was observed in North Lakhimpur in 1950 followed by Dhubri in 1988, 1989 and Goalpara in 2010. The light and heavy rainfall

TABLE 2. Number of average rain day, rainy days, light rainfall, heavy rainfall, very heavy rainfall, and extremely heavy rainfall 1950–2013

Rainfall amount	DHB	GLP	GHT	TZP	DIB	NLP
$R \geq 0.1$	110.86	118.22	135.77	139.16	175.03	167.45
$R \geq 2.5$	86.29	86.44	91.82	97.43	127.52	126.39
$2.5 \leq R \leq 64.4$	78.47	79.45	88.47	94.30	122.00	116.89
$R \geq 64.5$	8.29	6.98	3.24	3.02	5.55	9.50
$64.5 \leq R \leq 124.4$	6.46	5.72	3.02	2.65	5.13	8.66
$124.5 \leq R \leq 244.5$	1.46	1.17	0.28	0.24	0.42	0.83
$R > 244.5$	0.17	0.09	0.00	0.00	0.00	0.02

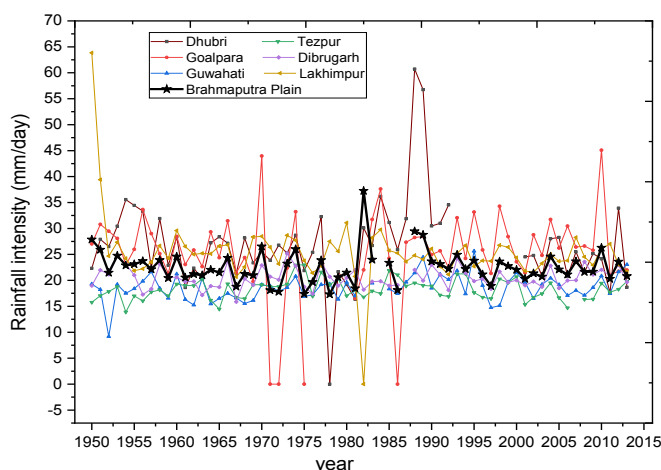
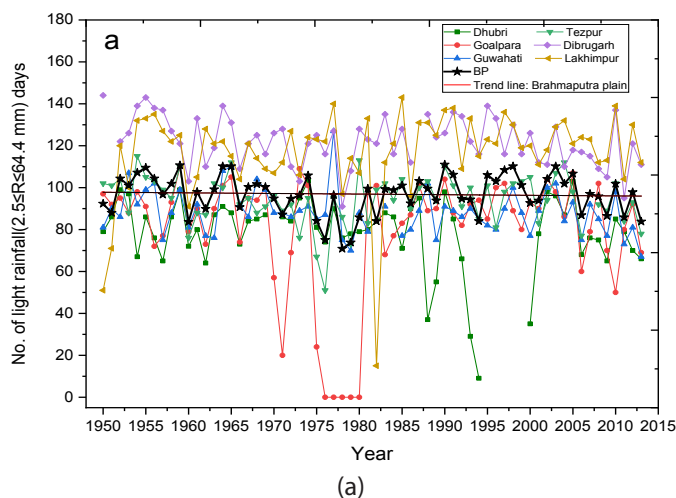


FIGURE 5. Rainfall intensity in Brahmaputra plain (1950–2013).

occurrence is very common events for most of the stations (Figure 6). From Table 2, it can be observed that the highest numbers of light rainfall occurred in North Lakhimpur and Dibrugarh whereas the lowest occurred at Dhubri. At the same time, the lowest numbers of heavy rainfall and very heavy rainfall occurred at Tezpur whereas; highest numbers of heavy and very heavy rainfall were recorded at North Lakhimpur and Dhubri, respectively. The wettest period was estimated by the number of consecutive rainfall days in a decade (Figure 7). The consecutive rainfall >30 days were seen rarest event for most of the stations. The days with the highest number of consecutive rainfall 5–9 days and 10–14 days per decade were observed at Dibrugarh and North Lakhimpur. Overall, no significant change was observed in the numbers of consecutive rainfall days over the stations' understudy.

4.3. Rainfall Trends

The results of the Mann–Kendall (M–K) test and Sen's slope estimator was represented in Tables 3 & 4. All the stations in Brahmaputra plain shown non-significant trends annual



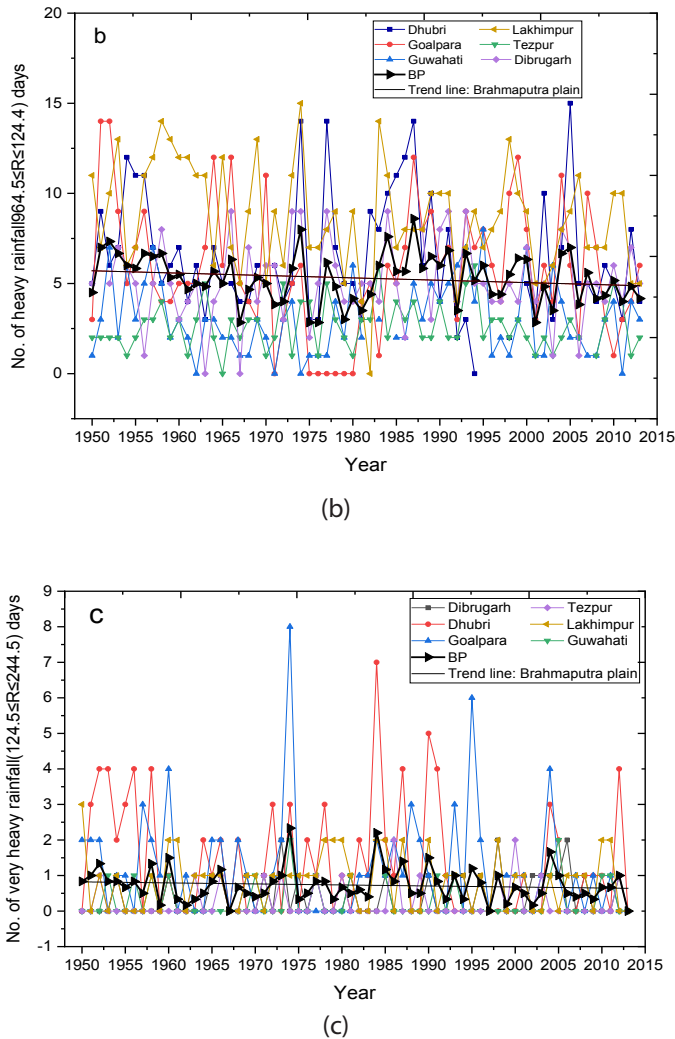


FIGURE 6. Distribution of (a) light, (b) heavy (c) very heavy rainfall in Brahmaputra plain (1950–2013).

rainfall. Dhubri, Goalpara, Guwahati, and Tezpur depicted a significant increasing trend in April month. The relatively high Kendall's tau value over these stations indicate rainfall increases considerably as the year progresses. In May and October, North Lakhimpur shows a significant decreasing rainfall trend. Other two station, Goalpara and Guwahati shows decreasing trend in May and increasing trend in October respectively with 95% confidence level. In post-monsoon, Dibrugarh and North Lakhimpur show statistically significant decreasing trend whereas, Guwahati shows an increasing trend with 95% confidence level. In the event of frequency of different amount of rainfall, Dibrugarh shows declining trend in rainy day ($p = 0.02$) and light rainfall ($p = 0.01$). Further another significant decreasing trend in the event of heavy rainfall ($p = 0.02$) at North Lakhimpur. Other station shows non-significant trends in the frequency of different rainfall amount.

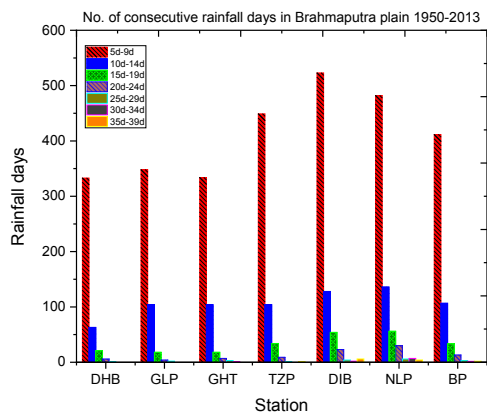


FIGURE 7. Number of consecutive rainfall days in Brahmaputra plain (1950–2013).

TABLE 3. Result of Mann Kendall test and Sen’s slope on monthly of Brahmaputra plain 1950–2013

		Station name					
Month	Parameters	DHB	GLP	GHT	TZP	DIB	NLP
JAN	τ	−0.021	−0.058	−0.022	−0.107	−0.134	−0.096
	Q_k	0.000	0.000	0.000	−0.067	−0.252	−0.187
FEB	τ	0.091	0.032	0.105	0.108	−0.066	−0.012
	Q_k	0.003	0.014	0.087	0.105	−0.197	−0.027
MAR	τ	0.009	0.057	−0.016	0.002	0.066	0.056
	Q_k	0.080	0.002	−0.059	0.014	0.425	0.208
APR	τ	0.178	0.235	0.166	0.187	0.107	0.125
	Q_k	1.538*	2.344*	1.163*	1.129*	0.729	0.763
MAY	τ	−0.161	−0.302	−0.090	−0.026	−0.101	−0.184
	Q_k	−1.846	−0.490*	−0.820	−0.177	−1.194	−2.417*
JUN	τ	−0.086	−0.129	−0.096	−0.011	−0.108	0.009
	Q_k	−2.305	−2.526	−1.136	−0.112	−1.067	0.148
JUL	τ	−0.133	−0.029	−0.110	−0.056	−0.032	0.003
	Q_k	−3.315	−1.041	−1.006	−0.491	−0.240	0.019
AUG	τ	−0.048	0.069	−0.072	0.065	−0.069	0.137
	Q_k	−0.504	0.833	−0.615	0.677	−0.635	1.553
SEP	τ	0.057	−0.083	0.103	0.079	0.020	−0.022
	Q_k	0.785	−0.792	0.705	0.634	0.151	−0.225
OCT	τ	0.005	−0.027	0.196	−0.023	−0.129	−0.169
	Q_k	0.187	0.244	1.239*	−0.138	−0.752	−1.229*
NOV	τ	−0.085	−0.124	0.060	−0.063	−0.081	−0.093
	Q_k	0.000	0.000	−0.008	−0.047	−0.080	−0.122
DEC	τ	0.131	−0.058	−0.045	−0.034	−0.133	−0.115
	Q_k	0.000	0.000	0.000	0.000	−0.113	−0.118

Significance level = 0.05, * = p value equal to or less than 0.05; Kendall Tau = τ , Sen’s slope = Q_k .

The result of trends analysis in this study is in agreement with previous findings except in some cases (Table 5) [11–13].

TABLE 4. Result of Mann Kendall and Sen's slope of station of Brahmaputra plain 1950–2013

Station	Annual		Pre-monsoon		Monsoon		Post-monsoon		Winter	
	T	Q_k	τ	Q_k	τ	Q_k	τ	Q_k	τ	Q_k
DHB	-0.1013	-5.0222	-0.0049	-0.1027	-0.0929	-5.1048	0.0161	0.217	0.0609	0.0889
GLP	-0.1421	-7.2266	-0.0916	-1.5714	-0.1071	-3.9199	-0.0047	-0.03	-0.0007	0
GHT	0.0206	0.4692	0.1042	1.2846	-0.1259	-2.0515	0.1798	1.14*	0.0811	0.1333
TZP	0.0108	0.3889	0.0722	0.7865	0.0333	0.5585	-343	-0.228	0.0205	0.0455
DIB	-0.0931	-3.425	-0.0201	-0.3057	-0.0502	-1.407	-0.1856	-1.22*	-0.1306	-0.4689
NLP	-0.0543	-1.7103	-0.1096	-1.6979	0.0548	1.5231	-0.23	-2.021*	-0.0384	-0.1531

Significance level = 0.05, * = p value equal to or less than 0.05; Kendall Tau = τ , Sen's slope = Q_k .

TABLE 5. Comparison of Sen's slope estimator

Month/ season	Period	Station/region	Sen's slope estimator (Q_k)	Journal name and year
APR	1951–2008	Assam and Meghalaya	1.28*	Int. J. Climatol, 2012 Ref. [11]
	1951–1980	Brahmaputra Basin	10.50	Theor. Appl. Climatol, 2013 Ref. [12]
	1981–2010	Brahmaputra Basin	-0.11	Theor. Appl. Climatol, 2013 Ref. [12]
	1961–2010	TZP; GHT; DIB; NLP	1.59*; 1.54; 0.63; 0.47	Int. J. Earth Sci, 2015 Ref. [13]
	1950–2013	TZP ; GHT; DIB; NLP; BP	1.12*; 1.16*; 0.729; 0.763; 1.05*	Present study
MAY	1951–2008	Assam and Meghalaya	-2.03*	Int. J. Climatol, 2012 Ref. [11]
	1951–1980	Brahmaputra Basin	-34.33	Theor. Appl. Climatol, 2013 Ref. [12]
	1981–2010	Brahmaputra Basin	-4.78	Theor. Appl. Climatol, 2013 Ref. [12]
	1961–2010	GHT; DIB; NLP	-0.60; 0.72; -1.39	Int. J. Earth Sci, 2015 Ref. [13]
	1950–2013	GHT; DIB; NLP; BP	-0.820; -1.194; -2.417*; -1.6*	Present study
OCT	1951–2008	Assam and Meghalaya	-0.51	Int. J. Climatol, 2012 Ref. [11]
	1961–2010	GHT; NLP	1.83*; -0.28	Int. J. Earth Sci, 2015 Ref. [13]
	1950–2013	GHT; NLP;BP	1.23*; -1.22*; -0.09	Present study
PM	1951–2008	Assam and Meghalaya	-0.08	Int. J. Climatol, 2012 Ref. [11]
	1961–2010	GHT; DIB; NLP	1.68*; -0.12; -0.68	Int. J. Earth Sci, 2015 Ref. [13]
	1950–2013	GHT; DIB; NLP;BP	1.14*; -1.22*; -2.02*; -0.4	Present study

Significance level = 0.05, * = p value equal to or less than 0.05; Sen's slope = Q_k ; PM = Post-monsoon.

5. CONCLUSION

In this study, an attempt was made to analyze rainfall characteristics in the Brahmaputra plain region using daily recorded data of period 64 years. Data analysis revealed three different rainfall-zones from west to east along longitude, where the high-low-high gradient of annual and seasonal rainfall was observed. The highest annual and seasonal rainfall was observed in North Lakhimpur and Dibrugarh followed by Dhubri whereas, the lowest was observed at Guwahati. The Linear regression analysis reveals a positive relationship between elevation and annual average rainfall. Furthermore, the Mann Kendall test detected a significant rainfall trend on a monthly and seasonal scale whereas, on an annual scale, no significant trend was detected. Rainfall intensity over each station was observed uniform for most of the years. In addition, no significant change throughout the study period was observed in the numbers of consecutive rainfall days per decade over the stations' understudy. The frequency of light, heavy, and very heavy rainfall over the entire Brahmaputra plain region shows a non-significant decreasing trend. On the other hand, Dibrugarh and North Lakhimpur experience decreasing trends in the frequency of rainy day and light rainfall and heavy rainfall respectively with a 5% significance level. Overall, the trend analysis of rainfall volume in this study is a good agreement with previous studies in most events.

The topographic elements of the region and global climatological factors may play a crucial role in the formation of different rainfall patterns over the study regions. Simultaneously, the adverse impact of climate change in the distribution of rainfall was revealed in North Lakhimpur, Guwahati, and Dibrugarh. To ascertain the detail rainfall dynamics over these stations, further research is needed. The result that comes out from this study shall be useful for the study of soil erosion, water resources management, and agricultural activity and may be useful for adopting flood disaster management policies over the study region.

Acknowledgments

The author would like to acknowledge the Indian Institute of Meteorology (IMD), Pune for providing data. The author would also like to acknowledge the Department of Applied Sciences, Gauhati University and Physical Sciences Division, Institute of Advanced Study in Science and Technology, Guwahati.

References

1. Kwarteng AY, Dorvlo AS, Vijaya Kumar GT. Analysis of a 27-year rainfall data (1977-2003) in the Sultanate of Oman. *International Journal of Climatology*. 2009, 29(4), 605–617. <https://doi.org/10.1002/joc.1727>
2. Karmeshu N. Trend detection in annual temperature & precipitation using the Mann-Kendall Test- a case study to assess climate change on select states in the Northeastern United States. *Scholarly Commons*. 2012; 1–33. <https://pdfs.semanticscholar.org/f2c3/519bb7f5d1c16667fa40318cbc3c1e8817be.pdf>

3. Dawadi DB, Chhetri PDTB, Dhital DYP. Detection of a Tornado event on March-31(2019) and its effects on the Eastern part of Nepal. *Indian Journal of Science and Technology*. 2019, 12(38), 1–5. <https://doi.org/10.17485/ijst/2019/v12i38/146311>
4. Nor Bazilah B, Ahmad F I, Suriza AZ, Mohammad KH. Development of a rainfall rate monitoring system for Malaysia. *Indian Journal of Science and Technology*. 2016, 9(28). DOI: 10.17485/ijst/2016/v9i28/97959.
5. Dore MHI. Climate change and changes in global precipitation patterns: what do we know? *Environment International*. 2005, 31(8), 1167–1181. <https://doi.org/10.1016/j.envint.2005.03.004>
6. Meena PK, Khare D, Shukla R, Mishra PK. Long term trend analysis of mega cities in Northern India using rainfall data. *Indian Journal of Science and Technology*. 2015, 8(3), 247–253. DOI: 10.17485/ijst/2015/v8i3/59580.
7. Bhuvaneswari K, Gethalakshmi V, Lakshmanan A. Rainfall Scenario in Future over Cauvery Basin in India. *Indian Journal of Science and Technology*. 2013;6(7), 4966–4970. https://www.researchgate.net/publication/256334734_Rainfall_Scenario_in_Future_over_Cauvery_Basin_in_India
8. Guhathakurta P, Rajeevan M. Trends in the rainfall pattern over India. *International Journal of Climatology*. 2008, 28(11), 1453–1469. <https://doi.org/10.1002/joc.1640>
9. Kumar V, Jain S K, Singh Y. Analysis of long-term rainfall trends in India. *Hydrological Sciences*. 2010, 55(4), 484–496. <https://doi.org/10.1080/02626667.2010.481373>
10. Das P J, Goswami D C. Long-term variability of rainfall over northeast India. *Indian Journal of Landscape System and Ecological Study*. 2003, 26(1), 1–20.
11. Jain SK, Kumar V, Saharia M. Analysis of rainfall and temperature trends in northeast India. *International Journal of Climatology*. 2012, 33(4), 968–978. <https://doi.org/10.1002/joc.3483>
12. Deka RL, Mahanta C, Pathak H, Nath KK, Das S., Trends and fluctuations of rainfall regime in the Brahmaputra and Barak basins of Assam, India. *Theoretical and Applied Climatology*. 2013, 114(1–2), 61–71. <https://doi.org/10.1007/s00704-012-0820-x>
13. Das S, Tomar C S, Saha D, Shaw S O, Singh C. Trend in rainfall patterns over North-East India during 1961–2010. *International Journal of Earth Sciences*. 2015, 2(2), 37–48.
14. Gharphalia B J, Deka R L , Islam A N , Dutta P, Medhi K. Variability and trends of rainfall events in the Brahmaputra Valley of Assam, India. *International Journal of Current Microbiology and Applied Sciences*. 2018, 7(11), 1902–1912. <https://www.ijcmas.com/7-11-2018/Bikash%20Jyoti%20Gharphalia,%20et%20al.pdf>
15. Mahanta R, Sarma D, Choudhury A. Heavy rainfall occurrences in northeast India. *International Journal of Climatology*. 2012, 33(6), 1456–1469. <https://doi.org/10.1002/joc.3526>
16. Prokop P, Walanus A. Variation in the orographic extreme rain events over the Meghalaya Hills in northeast of India in the two halves of the twentieth century. *Theoretical and Applied Climatology*. 2014, 121(1–2), 389–399. <https://doi.org/10.1007/s00704-014-1224-x>
17. Kumar PV, Naidu CV, Prasanna K. Inconsistency in the frequency of rainfall events in the Indian summer monsoon season. *International Journal of Climatology*. 2019, 39(13), 4907–4923. <https://doi.org/10.1002/joc.6113>
18. Dhar ON, Nandargi S. A study of floods in the Brahmaputra basin in India. *International Journal of Climatology*. 2000, 20(7), 771–781. [https://doi.org/10.1002/1097-0088\(20000615\)20:7<771::AID-JOC518>3.0.CO;2-Z](https://doi.org/10.1002/1097-0088(20000615)20:7<771::AID-JOC518>3.0.CO;2-Z)
19. Mann HM. Nonparametric tests against trend. *Econometrica*. 1945, (13), 245–259. <http://dx.doi.org/10.2307/1907187>
20. Kendall MG. Rank correlation methods, Griffin, London, UK. 1975. [https://www.scirp.org/\(S\(351jmbntvnsjt1aadkposzje\)\)/reference/ReferencesPapers.aspx?ReferenceID=2099295](https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=2099295)

21. Sen PK. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association*. 1968, (63), 1379–1389. <http://dx.doi.org/10.1080/01621459.1968.10480934>.
22. Hamed HK, Rao AR. Modified Mann-Kendall trend test for auto correlated data. *Journal of Hydrology*. 1998, (204), 182–196. [https://doi.org/10.1016/S0022-1694\(97\)00125-X](https://doi.org/10.1016/S0022-1694(97)00125-X)
23. Guahathakurta P, Sreejith OP, Menon PA. Impact of climate change on extreme rainfall events and flood risk in India. *Journal of Earth System Science*. 2011, 120(3), 359–373. <https://doi.org/10.1007/s12040-011-0082-5>