Journal of Energy Research and Environmental Technology (JERET)
p-ISSN: 2394-1561; e-ISSN: 2394-157X; Volume 6, Issue 2; April-June, 2019, pp. 96-100

http://www.krishisanskriti.org/Publication.html

Analysis and Estimation of the Rainfall Trend in the North-East India

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Abstract—*Meteorological trend detection in the climate change studies has become essential nowadays. In this paper, trend analysis is done for the annual and seasonal rainfall (P)in the Barak River Basin located in the north-eastern part of India. A total of thirty five number of rain gauge stations are considered taking observed data during 1911-2012. The Mann-Kendall test is applied to detect the trend and Sen's slope estimator is used to determine trend magnitude. It is found that most of the stations in the river basin are showing insignificant decreasing trends on the annual time series. Decreasing trend are significant at Golaghat, Lohitpur, Mon, Lakhimpur, Tuensang and West Kameng with 0.05 level of significance. Significant decreasing trend are detected in the monsoon P series. Most of the stations in the winter are not showing any trend. The study outcome may be used for the weather forecasting in this region.*

1. INTRODUCTION

The Barak River is flowing parallel to the River Brahmaputra in north-eastern part of India. The climatic scenario of the Barak River basin is different from that of the Brahmaputra basin. This basin is surrounded by hills with the downstream side towards the Bay of Bengal. The basin receives mostly or graphic and cyclonic precipitation with an average annual rainfall of about 300 cm. The Barak River basin is considered as one of the large basin, covering an area of 41000 square kilometer, in India. From the literature, it is found that there is no study regarding the climate change or meteorological change were done in this area. Moreover, it is noticed that most of the studies conducted are on the change of precipitation and temperature only. But there are also some other factors which may influence the climatic condition. The study area under consideration is sub-tropical in nature and its land pattern and geomorphology alter rapidly from one area to another. The number of gauging sites and time-span considered for the trend analysis in some previous studies may not reflect the actual climatic trend. So it is intended to carry out a trend analysis study for the Barak River basin. Here, we have taken Precipitation data for thirty five of gauging stations distributed all over the basin with a long data set ranging from 1911-2012. The main objective of this study is to analyze the trend of precipitation using Mann-Kendall test and Sen's slope estimator and to identify the possible changes in the data series. As trend analysis is one of the key feature for climate change/weather study, therefore, this type of study will help further to carry out research in respect of climate change or weather prediction for this large basin. Also, this will help the hydrologist for river/flood modeling for this basin.

2. STUDY AREA AND DATA

In the present work, the study area considered is the Barak River basin as shown in figure 1. This basin is situated in northeastern region of India covering an area of about 41157 sq. km. The basin lies between east longitudes 90º10' to 95º7' and north latitudes 21º58' to 26º24'. The Barak River Basin is surrounded by hills in its three sides and at the downstream direction it goes through Bangladesh and reaches to the Bay of Bengal. The major hills are Barail hills, Meghalaya hills, Mizoram hills and Naga Hills which are in the North and West sides. In the South and East sides, it is covered by Tripura, some part of Mizoram and Bangladesh. The plain area of this river starts soon after it reaches Assam and flows through Bangladesh with relatively flat slope varies from 1:10,000 in upper reach to 1:20,000 in lower reach. Major part of the basin area is covered with forest which is about 72.58% of the total area and only 1.92% of the basin area is covered by the water bodies. The weather of the study area is somewhat humid and temperate with four seasons viz winter, pre-monsoon, monsoon and post-monsoon.

The weather datasets were collected from 35 meteorological stations which are located within the basin for the period 1911 – 2012. These datasets are obtained from the India water portal, Pune (http://www.indiawaterportal.org/). The weather dataset contained daily values of precipitation which are averaged as per the season. It is considered that the selected data are of good quality having adequate record length and is reliable as the data is recorded by India water portal. The mean values for P are summarized in table 1with their standard deviations. Mean annual P in this area is found to vary between 254.54 to 288.35 mm. In this basin, the winter begins from December and ends in February followed by pre-monsoon with cyclone and thunderstorm. The monsoon starts from June and continues till the month of August when the basin receives maximum rainfall. But, the rain continues to occur with less intensity till November. From the rainfall data it is observed that rain occurs almost 9 month in a calendar year.

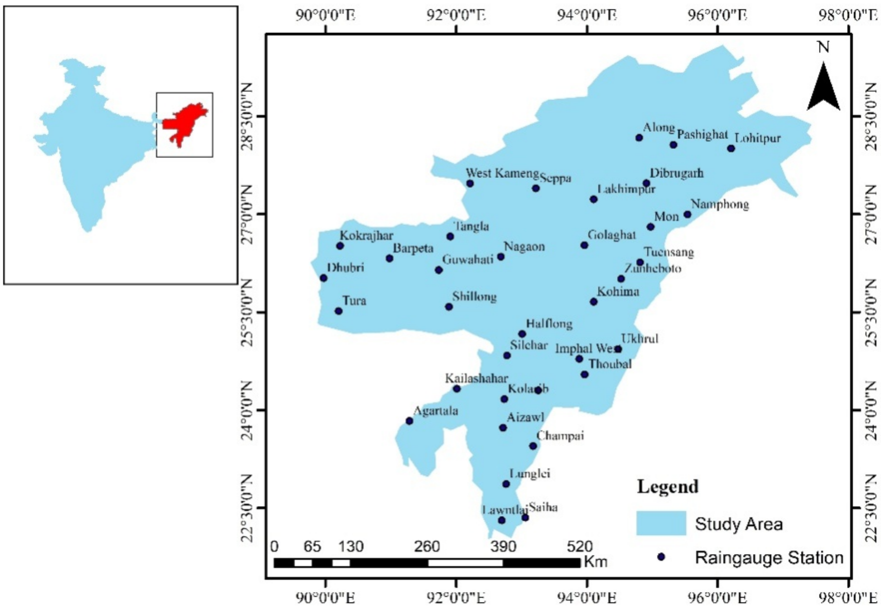

Fig. 1: Location of the stations in the Barak River Basin.

3. METHODOLOGY

3.1 Trend analysis methods

The Mann-Kendall statistical test has been widely used by the researches to compute the trends in hydro-meteorological time series as it is a robust technique.

A brief description of the Mann-Kendall test is summaries as follows:-

The Mann-Kendall test statistic (S) is computed as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \quad (1)$$

Where n is the quantity of records, $x_i$and x_j are the data values in time series i and j (where $j > i$), respectively and $sgn(x_j - x_i)$ is the sign function as:

$$sgn(x_j - x_i) = \begin{cases} +1, & if\ (x_j - x_i) > 0 & 2(a) \\ 0, & if\ (x_j - x_i) = 0 & 2(b) \\ -1, & if\ (x_j - x_i) < 0 & 2(c) \end{cases}$$

The variance is calculated as

$$Var\ (S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18} \quad (3)$$

Where$n$ is the amount of data points, t_i denotes the number of ties of extent i and m represents number of coupled groups. Here, coupled groups mean a set of similar type of data points. When the number of data is more than 10 (n>10), the standard normal test statistic Z_s is computed using equation 4:

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \; when\, S > 0 & 4(a) \\ 0 \qquad when\, S = 1 & 4(b) \\ \frac{S+1}{\sqrt{Var(S)}} \; when\, S < 0 & 4(c) \end{cases}$$

When the value of, Z_s is greater than zero, it denotes that there is a increasing trend and it is decreasing when Z_s is less than zero. Here, the null hypothesis (H_0) is taken as there is no trend while the alternative hypothesis (H_1) is taken as there is a positive or negative trend in the variable. A significant trend is found to be exists in the data series when $|Z_s| > Z_{1-\alpha/2}$, and null hypothesis is rejected. The value of $Z_{1-\alpha/2}$ can be obtained from the standard normal distribution table. At the 5% significance level, the null hypothesis of no trend is rejected if $|Z_s| > 1.96$at the 5% significance level obtained from standard normal cumulative distribution chart[22,24]. In this study, significance level (α) = 0.05 is used.

The application of non-parametric method, Sen's slope estimator, is used in hydro-climatic time series analysis and can be found in the work of various researchers. It approximates the slope of trend in the sample of N sets of data. The slope of trend Q_i is calculated as:

$$Q_i = \frac{x_j - x_k}{j - k} [i = 1,2, \dots, N] \qquad (5)$$

Where, $x_j$and x_k are the data points at interval *j* and *k* (*k*> *j*).

When a single data exists in every time series, in that case $N=\frac{n(n-1)}{2}$; here *n* denotes number of observations. If there are numerous data points in more than one time periods, in that case, $N<\frac{n(n-1)}{2}$. The total number of *n* values of Q_i is placed descending order and the median slope or Sen's slope estimate is calculated as:

$$Q_{med} = \begin{cases} Q_{[(N+1)/2]} & \text{, if } N \text{ is odd} \qquad 6(a) \\ \frac{Q_{[N/2]} + Q_{[(N+2)/2]}}{2} & \text{, if } N \text{ is even} \qquad 6(b) \end{cases}$$

Q_{med}indicates the slope and gradient of the data trend. To avoid zero median slope, level of significance of Q_{med}should be chosen specifically. Confidence interval about the time slope (C_α), can be calculated using the following equation:

$$C_\alpha = Z_{1-\alpha/2}\sqrt{Var(S)} \qquad (7)$$

Where $Var(S)$ is described in equation 3, and $Z_{1-\alpha/2}$ is derived from the standard normal distribution table. The lower and upper limits of the confidence interval,Q_{min} and Q_{max}, are the M_1^{th} largest and the $(M_2+1)^{th}$ largest of the N ordered slope estimates[9] and given by:

$$M_1 = (N - C_\alpha)/2 \text{and}$$
$$M_2 = (N + C_\alpha)/2$$

4. RESULT AND DISCUSSION

The atmospheric unpredictability has not been studied to a great extent in northeast India. For that reason, the focal aim of this research is to carry out an investigation of the precipitation trend in the Barak River basin from 1911 to 2012. The magnitude and direction are worked out by Sen's slope test and the statistical significance of trends is shown in their respective tables with bold numbers. The level of significance for two sided test is selected as 0.05. Normalized Z_s Statistic values larger than 0 or lesser than 0 respectively, indicates upward or downward trend based on this level of significance.

4.1 Annual Precipitation trend:

The results of Mann Kendall statistics and Sen's slope test for the annual P trends are illustrated in Table 1whereboth increasing and decreasing trends are observed. Though, the trends are mostly insignificant at 0.05 level of significance. The analysis revealed that sixstations are having significant decreasing trends. Significant decreasing trends rangedfrom 0.245 mm/yearto 2.597 (mm/year). The result shows that the overall annual Pis decreasing during 1911–2012. It can be clearly seen from table 1 that the annual P trend distribution is positive in the northern part of the basin. However, negative trend is determined in other parts of the basin. This can be explained through various micro climatic issues and local weather factors. One of them might be due to the fact that the northern part of the basin is hilly with high altitude and low temperature, hence the precipitation variation isgreater than the rest of the area.

4.2 Seasonal Precipitation trend:

Seasonal trends of P are given in table 1. According to these results, decreasing trend in seasonal P series is found in almost all the stations.On the seasonal scale, there are decreasing trends in monsoon precipitation series. No trends are detected in winter precipitation series for all the stations except insignificant decreasing trend in three stations. Almost all the stations are found to be decreasing trend. Majority of the stations shows decreasing trend in post monsoon season also. No trends are detected in the winter season.

5. CONCLUDING REMARKS

Trend analysis of the climatic variables are important to estimate and forecast the probable meteorological conditions so as to take necessary management steps. There are no study found in respect of climate variability in the selected study area. Hence, it is intended to carryout a trend analysis study of precipitation for the seasonal and annual variability in the basin using meteorological data of twenty stations which are distributed throughout the basin.From the analysis it is found that there is a significant decreasing trend in annual as well as seasonal P series is found in majority of the stations. The magnitude of trends in mean annual P varied from 0.245 (mm/year) at the Badarpur station and 2.597 (mm/year) at the Serchip station.Therefore, it may be concluded that bulk of the area in the Barak River Basin isdecreasing precipitation trends on both annually and seasonally for the period 1911-2012 and if this decreasing trend continues, it is expected to have scarcity of water in the area in near future. So, various other factors on watershed such as urbanization rate and population growth

Table 1: Mann-kendall and Sen's slope test results for Rainfall trend

Station	Trends				
	Winter	Pre Monsoon	Monsoon	Post Monsoon	Annual
Agartala	0.20	-0.58▼	-1.67▼	-1.14▼	-0.74▼
Aizawl	0.30	-0.12▼	-0.48▼	-1.30▼	-1.04▼
Along	0.50	0.70	-2.56▼	-0.66▼	-2.36▼
Barpeta	0.05	0.14	-1.97▼	-0.86▼	-0.98▼
Champhai	0.36	0.14	-0.36▼	-1.57▼	-1.02▼
Churachandpur	0.30	0.38	-0.63▼	-0.63▼	-0.89▼
Dhubri	0.12	1.64	0.73	0.51	0.70
Dibrugarh	0.34	-0.22▼	1.73	0.58	1.76
Golaghat	0.63	-0.24▼	**-2.25**▼	-0.94▼	**-2.06**▼
Guwahati	0.78	-0.15▼	-0.10▼	-0.89▼	-0.22▼
Halflong	0.50	-0.40▼	-1.02▼	-0.95▼	-1.15▼
Imphal	0.19	-0.77▼	-0.86▼	-1.24▼	-1.09▼
Kailashahar	0.56	-0.04▼	-0.66▼	-0.86▼	-0.91▼
Kohima	0.37	-0.132▼	-1.14▼	-0.95▼	-1.85▼
Kokrajhar	0.88	-0.24▼	-0.62▼	-1.08▼	-0.54▼
Kolasib	0.23	-0.66▼	-0.65▼	-1.31▼	-0.90▼
Lawntlai	0.33	-0.19▼	-0.16▼	-1.28▼	-0.82▼
Lohitpur	0.17	-0.21▼	**-3.04**▼	-0.86▼	**-2.66**▼
Lunglei	0.32	-0.10▼	-3.04▼	-1.37▼	-0.78▼
Mon	0.11	-0.41▼	**-2.89**▼	-0.82▼	**-2.91**▼
Nagaon	0.77	-0.52▼	-0.37▼	-0.61▼	-1.20▼
Namphong	0.89	-0.15▼	-1.23▼	-0.39▼	-1.741▼
Lakhimpur	0.11	-0.22▼	-1.90▼	-0.24▼	**-2.08**▼
Pashighat	0.10	-0.45▼	-2.16▼	-1.34▼	-0.41▼
Saiha	0.38	-0.55▼	-0.66▼	-1.69▼	-0.93▼
Seppa	0.12	-0.57▼	-0.05▼	-0.86▼	-0.45▼
Shillong	0.71	-0.81▼	-0.10▼	-1.10	-0.48▼
Silchar	0.24	-0.27▼	-1.17▼	-1.58▼	-1.08▼
Tangla	0.70	-0.23▼	0.87	1.37	-0.31▼

Thoubal	0.25	-0.26▼	-0.28▼	-0.73▼	-0.97▼
Tuensang	0.08	-0.74▼	**-2.30**▼	-0.61▼	**-2.30**▼
Tura	0.30	0.19	-2.30▼	-0.95▼	-0.87▼
Ukhrul	0.17	-0.23▼	-1.75▼	-3.07▼	-1.53▼
West Kameng	0.12	-1.14▼	-1.02▼	-0.82▼	**-3.02**▼
Zunheboto	0.12	-0.54▼	**-2.22**▼	-1.03▼	-2.06▼

□□: Standard normal test statistics; Q_{med}: Sen's slope estimator.
▲: increasing trend; ▼: decreasing trend; ●: no trend.

rate ought to be considered for water resources management and planning strategies. Mann-Kendall statistical test and Sen's slope estimator has shown that clear insights in the trend detection for the area. In addition further study to compare the results with another trend detection method is recommended.

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