

# International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452

NAAS Rating (2026): 4.49

Maths 2026; 11(3): 111-117

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<https://www.mathsjournal.com>

Received: 03-12-2025

Accepted: 20-01-2026

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## Rainfall frequency analysis of Brahmaputra valley of Assam, India

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**DOI:** <https://www.doi.org/10.22271/math.2026.v11.i3b.2284>

### Abstract

In this work, the frequency analysis of season-wise regional rainfall has been conducted in the Brahmaputra Valley utilizing L-moments. To this end, the data collected in 11 rain stations per day over a period of 15-19 years from the IMD, Indian Meteorological Department (Guwahati), has been utilized. These daily rainfall records are then transformed into seasonal highest monthly rainfall, *e.g.*, the Pre-Monsoon, the Monsoon, and the Post-Monsoon". The measures of heterogeneity are computed, and the two goodness-of-fit trials, which are the L-moment ratio diagram and the Z-Statistic values, are employed to determine the best fitting distribution. "It uses the five most common probability distributions, including Pearson Type III (PE3), Generalized Extreme Value (GEV), Generalized Pareto (GPA), Generalized Normal (GNO), and Generalized Logistic (GLO). Seasonal rainfall frequency models in each of the three seasons are established, and the model performances have been assessed by using the Leave One Out Cross-Validation (LOOCV) technique.

**Keywords:** Regional rainfall frequency analysis, probability distribution, Z-statistic, ratio diagram of L-moment

### 1. Introduction

Rainfall is an atypical event that is both spatial and temporal. The distribution of rainfall is highly uneven and differs significantly not only across locations but also from one year to another. In any agricultural program, rainfall is crucial to the creation and execution of any given agricultural arrangement. Furthermore, the factor that causes the decrease in rice production throughout India is most significant because of the inadequate and improper supply of water in the lake (Panigrahi and Panda, 2006)<sup>[6]</sup>. There is stress on the rainfed food production system due to varying rainfall predictions and inadequate use of land and water utilization (Khan and Hanjra, 2009)<sup>[20]</sup>. Nevertheless, the most significant aspects in rainfed regions are the magnitude and spatial and temporal distribution of rainfall (Shetty *et al.* 2000)<sup>[4]</sup>. Once again, the premature cessation of rains affects production by several moisture stressors, particularly as Kharif crops are growing and producing grains (Dixit *et al.*, 2005)<sup>[2]</sup>. Bora *et al.* 2022, 2021<sup>[17, 18]</sup> focused on the rainfall frequency for crop planning.

There are various modes of rainfall frequency based on day, week, month, season, annual, and successive days of extensive downpour. Each of them is significant in predicting rainfall and assists farmers in making superior decisions in planting harvests. It is also beneficial in the design and building of both big and small bridges, dams, drainage networks, and other tasks involving hydrology. Numerous studies have been carried out on the analysis of regional flood and rain frequency. "Among them, Hosking and Wallis (1990 & 1997)<sup>[10-13]</sup> created the L-Moment, which has a major advantage over the Standard Moment, which is a product of a Probability-Weighted Moment (PWM) and a linear use of the data set". The inverse form of the various distributions had been explained by Greenwood *et al.* 1979<sup>[9]</sup> to provide the variables. In 1995, when Bobee and Rasmussen, 1995<sup>[5]</sup> used regional samples, less sampling unreliability was created by assembling data and less model unpredictability by allowing a superior distributional choice". In their research work, H. J. Fowler and C. G. Kilsby, 2003<sup>[7]</sup> resorted to using the regional rainfall analysis of the period from 1961 to 2000 and perceived that the

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significant rainfall has influenced the character of worldwide environmental transformation in the UK. In Iran, Hossein *et al.* [8] studied the L-Moment to determine the frequency of day-to-day rainfall for the development of techniques regarding rainfall estimation.

Frequency anatomization provides information that is used in the determination of the likelihood of a certain event taking place. It utilizes distributions of probability to accumulate data based on the frequency and magnitude of significant events (L.V. Noto and G. La Loggia, 2009) [14]. Deka *et al.* 2019 [19] determined the highest daily rainfall of forty-two years in the nine states of North-East India through L-Moment and LQ-Moment. Ahmad *et al.* 2016 [1] measured the maximum rainfall per day by employing various consequences in Pakistan and then decided that the probability that was fit was chosen by employing the goodness-of-fit assessment. Md. Ashraful Alam *et al.* 2018 [15] concluded that the L-Moment approach provides the most accurate distribution of probability for maximum rainfall in Bangladesh per-month amongst nine frequently utilized distributions. Bora *et al.* 2021 [16] analyzed successive days of maximum precipitation employing the L-Moment technique.

The selection of the probability distribution is vital because a faulty selection may cause significant bias and inaccuracy in updated design flood prediction, mainly for extended return periods. This may lead to either an underestimation or an overestimation, which could have substantial significance for the daily operations. Again, A. S. Rahman *et al.* 2013 [3] provided a method to identify the best-fitting probability distributions of floods in Australia. The best-fit probability distribution in this research paper will help us to obtain an appropriate return period to analyze seasonal rainfall.

## 2. Study region and data collection

We have made use of rainfall records of a total of 11 sites in the Brahmaputra valley of Assam in this study, viz. Beki, Dibrugarh, Goalpara, Golaghat, Guwahati, Jorhat, Kokrajhar, North Lakhimpur, Sivsagar, Tezpur, and Kampur, which are based on IMD, Guwahati, and contain about 15 years of precipitation measurements.

## 3 Methodology

### 3.1 L-Moments

L-Moments has been described by Hosking and Wallis [12] as-

$$\lambda_{r+1} = (-1)^r \sum_{k=0}^r p_{r,k}^* \alpha_k = \sum_{k=0}^r p_{r,k}^* \beta_k, \quad r = 0, 1, \dots \quad (1)$$

$$\text{Where } p_{r,k}^* = \frac{(-1)^{r-k} (r+k)!}{(k!)^2 (r-k)!}$$

From Eq.(1), the initial four L-Moments will be as follows –

$$\lambda_1 = \beta_0 \quad (2)$$

$$\lambda_2 = 2\beta_1 - \beta_0 \quad (3)$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0 \quad (4)$$

$$\lambda_4 = 20\beta_3 - 30\beta_2 + 12\beta_1 - \beta_0 \quad (5)$$

According to Hosking and Wallis, 1997 [13], the L-Moments Ratio (LMRs) is -

$$LC_v, \tau = \frac{\lambda_2}{\lambda_1} \quad (6)$$

$$LC_s, \tau_3 = \frac{\lambda_3}{\lambda_2} \quad (7)$$

$$LC_k, \tau_4 = \frac{\lambda_4}{\lambda_2} \quad (8)$$

## 4. Results and Discussion

The models of the frequency of regional rainfall of all three seasons are constructed, and their validity is ensured by the Jackknife resampling technique, also called leave-one-out (LOO). The sections below contain all the required information.

### 4.1 Data screening through Discordancy Measure

Hosking and Wallis formula of discordancy measure [12, 13] took the sites of a group as follows-

Let  $u_i = [\hat{\tau}_3^{(i)}, \hat{\tau}_4^{(i)}]$  be a vector encompassing the LMRs,  $\hat{\tau}_3^{(i)}, \hat{\tau}_4^{(i)}$  for the  $(i)$  site, then the group average for NS sites will be the given equation-

$$\bar{u} = \frac{1}{NS} \sum_{i=1}^{NS} u_i \quad (9)$$

The sample equation for the Covariance Matrix is-

$$S = \sum_{i=1}^{NS} (u_i - \bar{u})(u_i - \bar{u})^T \quad (10)$$

The discordancy measure for the site  $(i)$  is shown by the equation-

$$D_i = \frac{1}{3} NS (u_i - \bar{u})^T S^{-1} (u_i - \bar{u}) \quad (11)$$

As suggested by Hosking and Wallis [13], if  $D_i$  is higher than the critical value, then the site  $i$  is considered to be discordant.

**Table 1:** Pre-Monsoon Rainfall

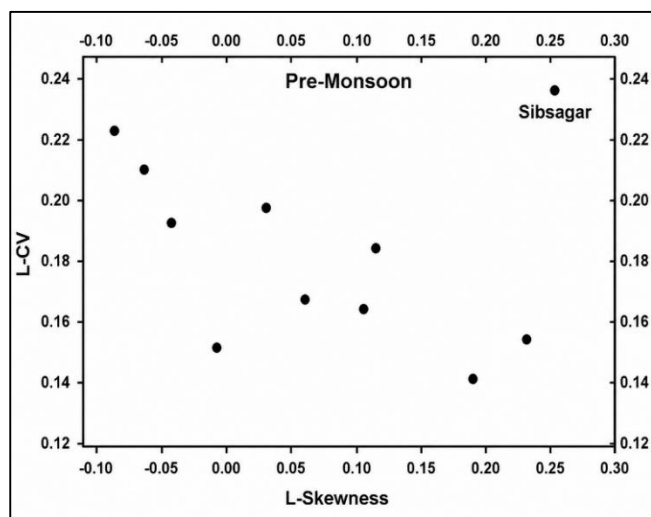
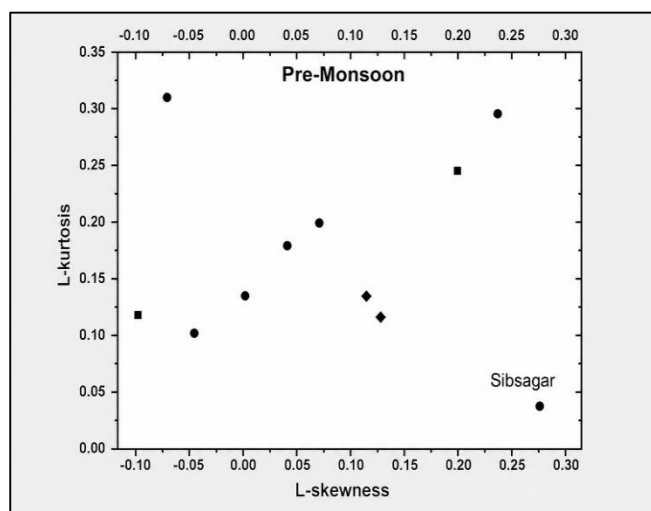
| Site            | Record (yr) | 1 <sup>st</sup> L-Moment | L-CV   | L-Skewness | L-Kurtosis | Discordancy |
|-----------------|-------------|--------------------------|--------|------------|------------|-------------|
| Beki            | 15          | 351.78                   | 0.2031 | -0.0717    | 0.3080     | 2.23        |
| Dibrugarh       | 15          | 348.45                   | 0.1856 | -0.0466    | 0.0984     | 0.67        |
| Goalpara        | 15          | 411.04                   | 0.1618 | 0.0667     | 0.1964     | 0.13        |
| Golaghat        | 15          | 231.77                   | 0.1477 | 0.0001     | 0.1309     | 1.07        |
| Guwahati        | 15          | 265.40                   | 0.1933 | 0.0378     | 0.1753     | 0.12        |
| Jorhat          | 23          | 284.17                   | 0.1800 | 0.1239     | 0.1118     | 0.23        |
| Kokrajhar       | 15          | 466.74                   | 0.1588 | 0.1103     | 0.1304     | 0.39        |
| North Lakhimpur | 15          | 382.32                   | 0.1376 | 0.1914     | 0.2412     | 0.90        |
| Sivsagar        | 15          | 265.16                   | 0.2353 | 0.2623     | 0.0347     | 2.77 *      |
| Tezpur          | 15          | 275.41                   | 0.1515 | 0.2288     | 0.2926     | 1.42        |
| Kampur (Nagaon) | 14          | 158.69                   | 0.2169 | -0.0986    | 0.1156     | 1.06        |

**Table 2:** Monsoon Rainfall

| Site            | Record (yr) | 1 <sup>st</sup> L-Moment | L-CV   | L-Skewness | L-Kurtosis | Discordancy |
|-----------------|-------------|--------------------------|--------|------------|------------|-------------|
| Beki            | 15          | 716.50                   | 0.1893 | 0.3148     | 0.2113     | 0.40        |
| Dibrugarh       | 15          | 542.65                   | 0.0968 | 0.0622     | 0.1920     | 1.15        |
| Goalpara        | 15          | 606.60                   | 0.1890 | 0.3332     | 0.2164     | 0.40        |
| Golaghat        | 15          | 358.70                   | 0.1606 | 0.1557     | 0.2384     | 1.42        |
| Guwahati        | 15          | 386.98                   | 0.1803 | 0.4147     | 0.3746     | 1.59        |
| Jorhat          | 23          | 396.17                   | 0.1277 | 0.1835     | 0.3506     | 1.09        |
| Kokrajhar       | 15          | 904.37                   | 0.1762 | 0.2939     | 0.0624     | 1.26        |
| North Lakhimpur | 15          | 839.07                   | 0.1158 | 0.0051     | 0.0819     | 1.20        |
| Sivsagar        | 15          | 397.45                   | 0.1542 | 0.1802     | 0.0761     | 0.39        |
| Tezpur          | 15          | 391.08                   | 0.1287 | 0.2003     | 0.1797     | 0.85        |
| Kampur (Nagaon) | 14          | 339.28                   | 0.1954 | 0.2321     | 0.0507     | 1.25        |

**Table 3:** Post-Monsoon Rainfall

| Site            | Record (yr) | 1 <sup>st</sup> L-Moment | L-CV   | L-Skewness | L-Kurtosis | Discordancy |
|-----------------|-------------|--------------------------|--------|------------|------------|-------------|
| Beki            | 15          | 106.49                   | 0.3861 | 0.0464     | -0.0114    | 0.42        |
| Dibrugarh       | 15          | 108.25                   | 0.3271 | 0.1871     | 0.0012     | 1.16        |
| Goalpara        | 15          | 126.46                   | 0.3801 | 0.2470     | 0.3180     | 1.26        |
| Golaghat        | 15          | 91.87                    | 0.3272 | -0.0318    | -0.0465    | 0.66        |
| Guwahati        | 15          | 108.58                   | 0.2941 | -0.0109    | 0.2493     | 1.13        |
| Jorhat          | 23          | 108.25                   | 0.3868 | 0.3015     | 0.0962     | 0.74        |
| Kokrajhar       | 15          | 166.03                   | 0.4495 | 0.1454     | 0.0801     | 1.29        |
| North Lakhimpur | 15          | 144.28                   | 0.3872 | 0.2159     | 0.2006     | 0.42        |
| Sivsagar        | 15          | 90.62                    | 0.3243 | 0.2814     | 0.1589     | 1.02        |
| Tezpur          | 15          | 85.29                    | 0.2434 | -0.0901    | 0.1710     | 1.59        |
| Kampur (Nagaon) | 14          | 85.16                    | 0.3686 | -0.1209    | -0.0766    | 1.30        |

**Fig 1:** L-Skewness vs L-CV diagram**Fig 2:** L-Skewness vs L-Kurtosis diagram

Based on Table 1 to Table 3, it is evident that the values of  $D_i$  are lower than the critical value (Hosking and Wallis, 1997) <sup>[13]</sup> in all sites and in all three seasons, except one site, Sivsagar, specifically in the pre-monsoon season. Thus, the discordancy measure indicates that only Sivsagar is discordant in this regard. However, as Figures 1 and 2 have shown, the L-CV is bigger, in contrast to the smaller L-Kurtosis in Sivsagar. As such, we have found once again that with the help of heterogeneity measures (Table 5), our study region is homogeneous, including this site. Consequently, we apply all 11 sites to the development of a regional rainfall frequency model in our region.

#### 4.2 Heterogeneity measures

The three levels of variability of Hosking and Wallis, 1997 <sup>[13]</sup> propose the heterogeneity measure of a group of sites that would be supposed to be homogeneous. The heterogeneity test is then expressed in the form of the following-

$$H_i = \frac{V_i - \mu V_i}{\sigma V_i}, i = 1, 2, 3 \quad (12)$$

For  $V_1$ ,  $V_2$  and  $V_3$ , We use the following equations

$$V_1 = \sum_{i=1}^{NS} N_i (\hat{\tau}^{(i)} - \hat{\tau}^R)^2 / \sum_{i=1}^{NS} N_i \quad (13)$$

$$V_2 = \sum_{i=1}^{NS} N_i \sqrt{(\hat{\tau}^{(i)} - \hat{\tau}^R)^2 + (\hat{\tau}_3^{(i)} - \hat{\tau}_3^R)^2} / \sum_{i=1}^{NS} N_i \quad (14)$$

$$V_3 = \sum_{i=1}^{NS} N_i \sqrt{(\hat{\tau}_3^{(i)} - \hat{\tau}_3^R)^2 + (\hat{\tau}_4^{(i)} - \hat{\tau}_4^R)^2} / \sum_{i=1}^{NS} N_i \quad (15)$$

where  $NS$  indicates the site's number,  $N_i$  indicates each side's record length and  $\hat{\tau}^{(R)}$ ,  $\hat{\tau}_3^R$  and  $\hat{\tau}_4^R$  is the regional average L – Moments, which can be achieved through the below given formulations.

$$\hat{\tau}^R = \frac{\sum_{i=1}^{NS} N_i \hat{\tau}^{(i)}}{\sum_{i=1}^{NS} N_i} \quad (16)$$

$$\hat{\tau}_3^R = \frac{\sum_{i=1}^{NS} N_i \hat{\tau}_3^{(i)}}{\sum_{i=1}^{NS} N_i} \quad (17)$$

$$\hat{\tau}_4^R = \frac{\sum_{i=1}^{NS} N_i \hat{\tau}_4^{(i)}}{\sum_{i=1}^{NS} N_i} \quad (18)$$

Also,  $\mu_{V_i}$  and  $\sigma_{V_i}$  gives the Standard Deviation of  $V_i$  for  $i = 1, 2, 3$ .

According to Hosking and Wallis [13], an area is considered properly homogeneous if  $H_i < 1$ , likely heterogeneous if  $1 \leq H_i < 2$ , and clearly heterogeneous if  $H_i \geq 2$ .

**Table 4:** Different sites' Heterogeneity Measures

| Heterogeneity Measures | Values      |         |              |
|------------------------|-------------|---------|--------------|
|                        | Pre-Monsoon | Monsoon | Post-Monsoon |
| $H_1$                  | -0.70       | -0.05   | -0.56        |
| $H_2$                  | -0.54       | -0.93   | 1.84         |
| $H_3$                  | -1.02       | -0.66   | 2.19         |

Table 4 indicates that the values of  $H_1$  are -0.70, -0.04, and -0.56 for maximum rainfall occurring every month during the three monsoon periods, reflecting that all the values are less than 1. Consequently, our study area can be classified as a homogeneous zone.

**Table 5:** Study areas' |Z|-Statistics measures

| Distributions | Z -statistics values |             |              |
|---------------|----------------------|-------------|--------------|
|               | Pre-monsoon          | Monsoon     | Post-monsoon |
| GLO           | <b>0.11</b>          | <b>0.03</b> | 2.68         |
| GEV           | 1.46                 | 0.89        | 1.04         |
| GNO           | 1.25                 | 1.18        | 1.11         |
| PE3           | 1.35                 | 1.74        | <b>0.87</b>  |
| GPA           | 4.53                 | 3.08        | 2.31         |

Table 5 indicates that during the pre-monsoon period, GLO (0.11), for the monsoon period, GLO (0.03), and for the post-monsoon period, PE3 (0.87) are the most effective distributions for our study region, relative to the critical value of 1.64.

**LMRD:** Hosking, 1991 [11] defined the LMRD as a curve that exemplifies the L-Skewness and L-Kurtosis of several distributions of candidates that have theoretical links." When summarising regional results, LMRDs have been considered as a method for identifying amongst candidate distributions.

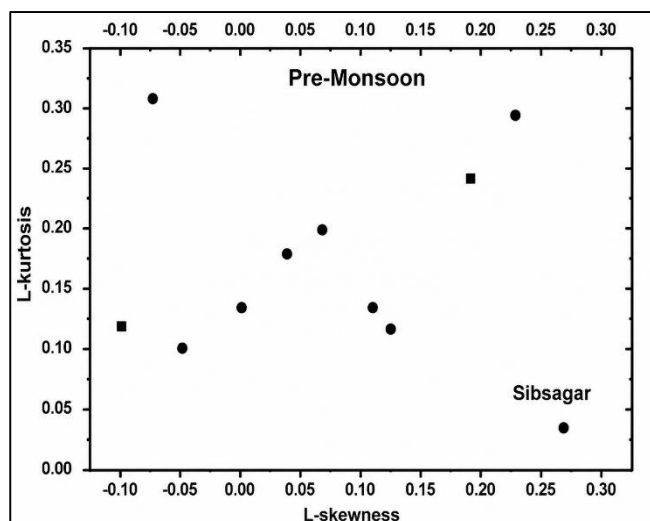


**Fig 3:** LMRD (pre-monsoon)

**4.3 Goodness of Fit-Tests:** Two goodness-of-fit tests, specifically the Z-Statistic criterion and the L-Moment Ratio Diagram (LMRD) proposed by Hosking and Wallis [13], are employed to bring out the most suitable probability distributions for the three seasons of our research region.

**Z- Test Criteria:** The primary benefit of this test is its direct application to the regional average, as presented by Hosking and Wallis [13]. The equation for this is forwarded below-

$$Z^{\text{Dist}} = (\tau_4^{\text{Dist}} - \hat{\tau}_4^R + B_4) / \sigma_4 \quad (19)$$

where  $\hat{\tau}_4^R$  indicates the Regional Average of  $\hat{\tau}_4$  and  $B_4, \sigma_4$  states the bias and standard deviation of  $\hat{\tau}_4$  respectively.

And these can be presented as

$$B_4 = \frac{1}{N_{\text{sim}}} \sum_{m=1}^{N_{\text{sim}}} (\tau_4^m - \hat{\tau}_4^R) \quad (20)$$

$$\sigma_4 = \sqrt{\left[ \frac{1}{(N_{\text{sim}}-1)} \left\{ \sum_{m=1}^{N_{\text{sim}}} (\tau_4^m - \hat{\tau}_4^R)^2 - N_{\text{sim}} B_4^2 \right\} \right]} \quad (21)$$

$N_{\text{sim}}$  denotes the simulated data quantity sets and  $m$  is the  $m^{\text{th}}$  region of simulation resulting from the Kappa Distribution.

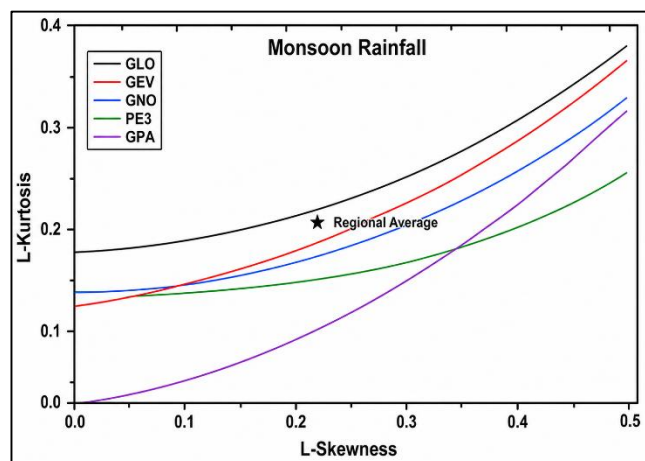


**Fig 4:** LMRD (Monsoon)

**Table 6:** Regional Average L-Moments:

| L-Moments (Regional) | Pre-Monsoon | Monsoon | Post-Monsoon |
|----------------------|-------------|---------|--------------|
| L-CV                 | 0.1791      | 0.1543  | 0.3537       |
| L-Skewness           | 0.0765      | 0.2187  | 0.1168       |
| L-kurtosis           | 0.1646      | 0.1934  | 0.1044       |

Again, from LMRD (Figures 3 to 5), it has been observed that the GLO distribution is found to be most suitable during the Pre-Monsoon and the Monsoon seasons, while for the post-monsoon period, the PE3 distribution is the best. Table 6 gives the regional average of L-moments.

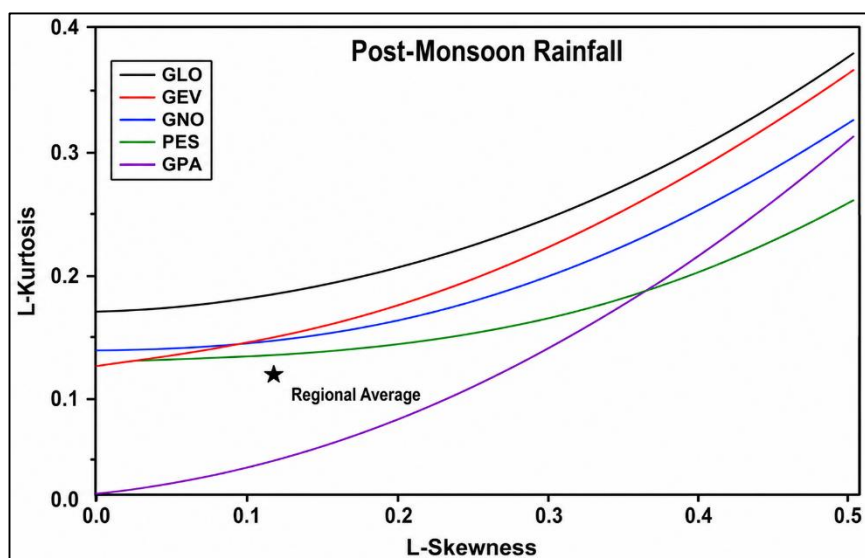


Fig 5: LMRD (post-monsoon)

**4.4 Development of regional relationship:** Here, we construct the models of the frequency of rainfall in the region of our study in all three seasons. To this end, the regional parameters have been computed in all the candidate distributions of each

of the three seasons, and they are provided in Table 7. Regional growth factors of each of the candidate distributions in the various return periods are calculated as well, in each of the three seasons, and presented in Tables 7 to 9.

Table 7: Regional statistics for maximum monthly precipitation during the pre-monsoon, periods:

| Distribution | Return Period (Years) |       |       |       |       |       |       |       |       |       |
|--------------|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|              | 1                     | 2     | 5     | 10    | 20    | 50    | 75    | 100   | 500   | 1000  |
| GLO          | 0.619                 | 0.978 | 1.237 | 1.402 | 1.563 | 1.781 | 1.888 | 1.954 | 2.388 | 2.591 |
| GEV          | 0.611                 | 0.974 | 1.262 | 1.427 | 1.568 | 1.730 | 1.798 | 1.837 | 2.046 | 2.121 |
| GNO          | 0.611                 | 0.975 | 1.258 | 1.421 | 1.565 | 1.736 | 1.812 | 1.857 | 2.118 | 2.224 |
| PE3          | 0.610                 | 0.975 | 1.259 | 1.422 | 1.565 | 1.733 | 1.807 | 1.851 | 2.102 | 2.203 |

Table 8: Regional statistics for maximum monthly precipitation during the Monsoon, periods:

| Distribution | Return Period (Years) |       |       |       |       |       |       |       |       |       |
|--------------|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|              | 1                     | 2     | 5     | 10    | 20    | 50    | 75    | 100   | 500   | 1000  |
| GLO          | 0.696                 | 0.947 | 1.177 | 1.348 | 1.533 | 1.815 | 1.966 | 2.065 | 2.805 | 3.210 |
| GEV          | 0.696                 | 0.942 | 1.194 | 1.371 | 1.550 | 1.795 | 1.915 | 1.989 | 2.475 | 2.700 |
| GNO          | 0.695                 | 0.941 | 1.198 | 1.376 | 1.551 | 1.786 | 1.898 | 1.967 | 2.409 | 2.610 |

Table 9: Regional statistics for maximum monthly precipitation during the Post-Monsoon, periods:

| Distribution | Return Period (Years) |       |       |       |       |       |       |       |       |       |
|--------------|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|              | 1                     | 2     | 5     | 10    | 20    | 50    | 75    | 100   | 500   | 1000  |
| GEV          | 0.252                 | 0.924 | 1.499 | 1.850 | 2.167 | 2.550 | 2.718 | 2.817 | 3.379 | 3.597 |
| GNO          | 0.250                 | 0.926 | 1.496 | 1.844 | 2.160 | 2.550 | 2.727 | 2.832 | 3.463 | 3.729 |
| PE3          | 0.248                 | 0.925 | 1.502 | 1.849 | 2.160 | 2.537 | 2.705 | 2.804 | 3.386 | 3.624 |

The regional rainfall frequency for each of the three seasons is developed for our study region and is given below.

*For Pre-Monsoon rainfall:*

$$Q_T^j = \left[ -1.351 + 2.329 \times \left( \frac{1}{T-1} \right)^{-0.076} \right] \times 1^{\text{st}} \text{ L - moment of site } j \quad (22)$$

**For Monsoon rainfall**

$$Q_T^j = \left[ 0.279 + 0.668 \times \left( \frac{1}{T-1} \right)^{-0.214} \right] \times 1^{\text{st}} \text{ L - moment of site } j \quad (23)$$

$Q_T^j$  stands for the quantile determines for the period  $T$  of site  $j$ . For Post-Monsoon rainfall, the best-fitting distribution is the PE3 distribution. As no explicit formula of the quantile function exists, so to estimate the quantiles for each study site

of the region, we can proliferate the regional growth factors given in Table 9 for the PE3 distribution, by the 1st L-Moments of the site.

#### 4.5 Validity of the Model

In this part, the validity of the formulated models for different seasons within our study areas is verified through the LOOCV method. To this end, we shall omit one side and use the regional flood frequency procedure for the other ten locations. The regional factors are determined of identified best fitting distributions of 2 to 1000 years return period. This process is done on all 11 sites, and the Root Mean Square Error (RMSE) and the BIAS of each of the return periods are determined and are provided in Tables 10 to 13.

**Table 10:** Development of a model for the Pre-Monsoon (RMSE and BIAS)

| Measures | Return Period |       |       |       |       |       |       |       |       |
|----------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|
|          | 2             | 5     | 10    | 20    | 50    | 75    | 100   | 500   | 1000  |
| RMSE     | 0.010         | 0.005 | 0.006 | 0.009 | 0.016 | 0.020 | 0.023 | 0.046 | 0.059 |
| BIAS     | -0.009        | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |

**Table 11:** Development of a model for the Monsoon (RMSE and BIAS)

| Measures | Return Period |       |       |       |       |       |       |       |       |
|----------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|
|          | 2             | 5     | 10    | 20    | 50    | 75    | 100   | 500   | 1000  |
| RMSE     | 0.003         | 0.002 | 0.007 | 0.014 | 0.027 | 0.035 | 0.040 | 0.090 | 0.123 |
| BIAS     | 0.000         | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.002 | 0.004 |

**Table 12:** Development of a model for the Post-Monsoon (RMSE and BIAS)

| Measures | Return Period |       |       |       |       |        |       |       |       |
|----------|---------------|-------|-------|-------|-------|--------|-------|-------|-------|
|          | 2             | 5     | 10    | 20    | 50    | 75     | 100   | 500   | 1000  |
| RMSE     | 0.011         | 0.006 | 0.016 | 0.030 | 0.049 | 0.059  | 0.065 | 0.103 | 0.120 |
| BIAS     | 0.000         | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 | 0.000 |

## 5. Conclusions

We have conducted an analysis on the frequency of rainfall for the three Monsoon seasons in the Brahmaputra Valley region, utilizing data from 11 gauging stations. Based on discordancy measures, we obtained that there is only the Sibsagar site discordant. However, the site may be taken into consideration because L-Cv is more significant, and there is lower L-Kurtosis. Moreover, when testing regional heterogeneity, we make all the sites homogeneous. Using the Z-statistic method, it is seen that during the three Monsoon stages, the most appropriate distribution with the least critical value than the standard critical value is determined by the GLO, GLO, and PE3, respectively. The L-Moment Ratio Diagram also reflects the same result. Lastly, we built a regional relationship of the maximum monthly rainfall per season using the L-moment on the optimum probability distributions. The development model is tested with the evaluation of validity with the help of the LOOCV method and estimation of RMSE and BIAS. As observed in the RMSE and the BIAS values, the values are relatively low in all three cases; the models developed can be used to estimate the growth factors of various periods of returns that can be used for any planning purpose in the region.

## 6. Acknowledgment

The Indian Meteorological Department (IMD), Guwahati (Assam), recognizes us for immediately supplying data relating to rainfall for the study.

## References

1. Abbas A, Fawad M, Ahmed I. Finding probability distributions for annual daily maximum rainfall in Pakistan using linear moments and variants. *Pol J Environ Stud.* 2016;25(3):925-937. DOI:10.15244/pjoes/61715.
2. Dixit AJ, Yadav ST, Kokate KD. The variability of rainfall in Konkan region. *J Agrometeorology.* 2005;7:322-324. Available from: <https://www.agrimetassociation.org/journal/fullpage/fullpage-202001221616289137.pdf>.
3. Rahman AS, Rahmana A, Zaman MA, Haddad K, Ahsan A, Imteaz M. A study on selection of probability distributions for at-site flood frequency analysis in Australia. *Nat Hazards.* 2013;69:1803-1813. DOI:10.1007/s11069-013-0775-y.
4. Shetty AV, Soni B, Chandrakumar S. Planning of crop and water management practices using weekly rainfall. Roorkee: National Institute of Hydrology; 2000. Report No.: NIH/1999-2000. Available from: [https://nihroorkee.gov.in/sites/default/files/Planning%20of%20Crop%20and%20Water%20Management%20Practices%20Using%20Weekly%20Rainfall%20Data\\_NIH\\_1999-2000.pdf](https://nihroorkee.gov.in/sites/default/files/Planning%20of%20Crop%20and%20Water%20Management%20Practices%20Using%20Weekly%20Rainfall%20Data_NIH_1999-2000.pdf).
5. Bobee B, Rasmussen PF. Recent advances in flood frequency analysis. *Rev Geophys.* 1995;33(S1):1111-1116. DOI:10.1029/95RG00287.
6. Panigrahi B, Panda SN. Dry spell probability by Markov chain model and its application to crop planning in Kharagpur. *Indian J Soil Cons.* 2002;30(1):95-100. Available from: [https://www.researchgate.net/publication/341192606\\_Dry\\_Spell\\_probability\\_by\\_Markov\\_Chain\\_model\\_and\\_its\\_application\\_to\\_crop\\_planning\\_in\\_Kharagpur](https://www.researchgate.net/publication/341192606_Dry_Spell_probability_by_Markov_Chain_model_and_its_application_to_crop_planning_in_Kharagpur).
7. Fowler HJ, Kilsby CG. A regional frequency analysis of United Kingdom extreme rainfall from 1961 to 2000. *Int J Climatol.* 2003;23:1313-1334. DOI:10.1002/joc.943.
8. Malekinezhad H, Garizi AZ. Regional frequency analysis of daily rainfall extremes using L-moments approach. *Atmosfera.* 2014;27(4):411-427. Available from: <https://www.scielo.org.mx/pdf/atm/v27n4/v27n4a7.pdf>.
9. Greenwood JA, Landwehr JM, Matlas NC, Wallis JR. Probability weighted moments: definition and relation to parameters of several distributions expressible in inverse form. *Water Resour Res.* 1979;15(5):1049-1054. DOI:10.1029/WR015i005p01049.
10. Hosking JRM. L-moments: analysis and estimation of distributions using linear combinations of order statistics. *J R Stat Soc Series B Methodol.* 1990;52(1):105-124. DOI:10.1111/j.2517-6161.1990.tb01775.x.
11. Hosking JRM. Approximation for use in constructing L-moment ratio diagrams. Yorktown Heights: IBM Research Division, T. J. Watson Research Centre; 1991. Research Report No.: RC16635. Available from: [https://researcher.watson.ibm.com/researcher/view\\_group.php?id=2639](https://researcher.watson.ibm.com/researcher/view_group.php?id=2639).
12. Hosking JRM, Wallis JR. Some statistics useful in regional frequency analysis. *Water Resour Res.* 1993;29(2):271-281. DOI:10.1029/92WR01980.
13. Hosking JRM, Wallis JR. Regional frequency analysis: an approach based on L-moments. New York: Cambridge University Press; 1997. DOI:10.1017/cbo9780511529443.
14. Noto LV, La Loggia G. Use of L-moments approach for regional flood frequency analysis in Sicily, Italy. *Water Resour Manag.* 2009;23(11):2207-2229. DOI:10.1007/s11269-008-9378-x.

15. Alam MA, Emura K, Farnham C, Yuan J. Best-fit probability distribution and return periods for maximum monthly rainfall in Bangladesh. *Climate*. 2018;6(1):9. DOI:10.3390/cli6010009.
16. Bora R, Bhuyan A, Dutta B. Analysis of consecutive days maximum rainfall together with dry, wet spell rainfall for crop planning at Jorhat (Assam), India. *Commun Math Appl*. 2021;12(4):835-851. DOI:10.26713/cma.v12i4.1620.
17. Bora R, Bhuyan A, Dutta B. Regional analysis of consecutive days maximum rainfall using L-moments: a case study for Brahmaputra valley region of Assam, India. *Commun Math Appl*. 2022;13(2):671-689. DOI:10.26713/cma.v13i2.1786.
18. Bora R, Bhuyan A, Dutta B. Analysis of dry and wet weeks of rainfall by using Markov chain - a case study at Jorhat (Assam), India. *Mausam*. 2021;73(4):869-876. DOI:10.54302/mausam.v73i4.6018.
19. Deka S, Borah M, Kakaty SC. Distribution of maximum rainfall series of North-East India. *European Water*. 2009;27(28):3-14. Available from: [http://www.ewra.net/ew/pdf/EW\\_2009\\_27-28\\_01.pdf](http://www.ewra.net/ew/pdf/EW_2009_27-28_01.pdf).
20. Khan S, Hanjra MA. Footprints of water and energy input in food production - global perspectives. *Food Policy*. 2009;34:130-140. DOI:10.1016/j.foodpol.2008.09.001.