Distributions of Annual Maximum Rainfall Series of North-East India

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Abstract: An attempt has been made to determine the best fitting distribution to describe the annual series of maximum daily rainfall data for the period 1966 to 2007 of nine distantly located stations in North East India. Five extreme value distributions viz. generalized extreme value distribution, generalized logistic distribution, generalized Pareto distribution, lognormal distribution and Pearson distribution are fitted for this purpose using the method of L-moment and LQ-moment. The performances of the distributions are evaluated using three goodness of fit tests namely relative root mean square error, relative mean absolute error and probability plot correlation coefficient. Further, L-moment ratio diagram is also used to confirm the goodness of fit for the above five distributions. Finally, goodness of fit test results are compared and generalized logistic distribution is empirically proved to be the most appropriate distribution for describing the annual maximum rainfall series for the majority of the stations in North East India.

Key Words: Extreme rainfall, L-moments, LQ-moments, Quantile function, North East India.

1. INTRODUCTION

Extreme rainfall events can have severe impacts on society. It afflicts the worst environmentally related tragedy, which contributes to loss of crops and valuable property and untold human misery. Stochastic models for extreme rainfall events over an area may be used for such disaster prevention purposes. Moreover, knowledge of spatial and temporal variability of extreme rainfall events is very much useful for the design of dam and hydrological planning. A detailed regionalized study is practically useful for the planners and other users. So there is a pressing need to know the magnitudes of the extreme rainfall events over different parts of the area under study. So far no rigorous work has been pursued in the North East India to study the annual maximum rainfall events. Considerable efforts have been made in this direction using the annual series of maximum daily rainfall data for the period of 42 years of nine stations in North East India. For this purpose, five three-parameter extreme value distributions viz. Generalized Extreme Value distribution (GEV), Generalized Logistic distribution (GLD), Generalized Pareto distribution (GPD), Lognormal distribution (LN3) and Pearson (P3) distribution are considered. The estimation of the parameters for each distribution has been done using the methods of L-Moment and LQ-Moment independently. Applications of extreme value distributions to rainfall data have been investigated by several authors from different region of the world. Rakhecha et al. (1994) analyzed the annual extreme rainfall series at 316 stations over the Indian region, covering 80-years of rainfall data for trend and persistence using standard statistical tests. For investigating more generalized issues regarding the adequacy of extreme value distributions for extreme rainfall analysis, Baloutsos et al. (2000) made the statistical analysis for the longest rainfall record available in Greece. In the same direction, Koutsoyiannis (2004) made an extensive empirical investigation of the longest available rainfall records worldwide, each having 100-154 years of data. Nadarajah et al. (2001) and Nadarajah (2005) provided the application of extreme value distributions to rainfall data over sixteen locations spread throughout New Zealand and fourteen locations in West Central Florida, respectively. Extreme value distributions have been also used by Aronica et al. (2002) to analyze the trend in the extreme rainfall series for a fixed return period by estimating the maximum rainfall...
depth in Palermo, Sicily, Italy. They estimated the parameters using L-moments. Zalina et al. (2002) discussed the comparative assessment of eight candidate distributions in providing accurate and reliable maximum rainfall estimates for Malaysia. Model parameters were estimated using the L-moment method. They concluded that the GEV distribution is the most appropriate distribution for describing the annual maximum rainfall series in Malaysia. On the other hand, Zin et al. (2008) found GLD as the most frequently selected best fitting distribution and LN3 as the least frequently selected distribution for extreme rainfall in Peninsular Malaysia. Those results differ from the results obtained by Zalina et al. (2002). Therefore, a regionalized study on the statistical modeling of extreme rainfall is very much essential as the statistical model may vary according to the geographical locations of the area considered. So an attempt has been made to study the annual maximum daily rainfall data in North East India and the findings of the same along with the methodology adopted are presented in this paper.

While Kotz et al. (2000) made an extensive study on the fitting of extreme value distribution, the detailed references on the statistical modeling of annual maximum rainfall based on L-moment and LQ-moment can be found in Zin et al. (2008). The most commonly used distributions for extreme rainfall data can be found from the references such as Hosking and Wallis (1997) and Rao and Hamed (2000). For the application of L-moments in flood frequency analysis we refer to Hussain and Pasha (2009).

2. DATA AND AREA OF STUDY

Series of annual maximum daily rainfall data of nine stations in North East India viz Imphal, Mohanbari, Guwahati, Cherrapunji, Pasighat, North Lakhimpur, Silchar, Shillong and Tezpur for a period of 42 years from 1966 to 2007 have been considered for this study. The geographical locations of the nine rain gauge stations are shown in Figure 1. The series of annual maximum daily rainfall is collected from Regional Meteorological Centre, Guwahati and the graphical representation of the data is shown in Figure 2.

![Figure 1. Locations of rain gauge stations used in this study](image)
The brief description, especially hydroclimatoloy, of nine rain gauge stations used in this study is prescribed below:

**Guwahati:** Guwahati is the largest city in the North East Region of India and is located at 26° 11'N 91° 44'E. Guwahati's climate is mildly sub-tropical with warm, dry summers from April to late May, a strong monsoon from June to September and cool, dry winters from late October to March. The city experiences an annual rainfall of 180 cm (from May to September) with an average number of 77.3 rainy days. While summer temperatures range from 22 to 38°C, in winters the mercury ranges from 10 to 25°C.

**Shillong:** Shillong is the capital of Meghalaya, one of the smallest states in India. Shillong is located at 25°34'N 91°53'E / 25.57°N 91.88°E. It is on the Shillong Plateau, the only major pop-up structure in the northern Indian shield. Due to its latitude and high elevation Shillong has a sub-tropical climate with mild summers and chilly to cold winters. Shillong is subject to vagaries of the monsoon. The monsoons arrive in June and it rains almost until the end of August. In summers the temperature varies from 23 degree Celsius and in winters the temperature varies from 4 degree Celsius.

**Cherrapunji:** Cherrapunji is the world's wettest place and is just 56km from the capital Shillong of Meghalaya. Geographically it is located at 25°18'N 91°42'E / 25.30°N 91.70°E. Cherrapunji's yearly rainfall average stands at 11,430mm (450 in). This figure places it behind only nearby Mawsynram, Meghalaya, whose average is 11,873 mm (467 in) and Mount Waialeale (USA) on the Hawaiian island of Kauai, whose average is 11,684 mm (460 in). The orography of the hills with many deep valleys channels the low flying (150-300 m) moisture laden clouds from a wide area to converge over Cherrapunjee which falls in the middle of the path of this stream. The winds push the rain clouds through these gorges and up the steep slopes. The rapid ascendance of the clouds into the upper atmosphere hastens the cooling and helps vapours to condense. Most of Cherrapunjee's rain is the consequence of air being lifted as a large body of water vapour. Extremely large amount of rainfall at Cherrapunjee is perhaps the most well known feature of orographic rain in northeast India.

**Imphal:** Imphal is the capital of Manipur, located at 24°49'N 93°57'E / 24.82°N 93.95°E. It has an average elevation of 786 metres (2578 feet). It is located in the extreme east of India. The Imphal Valley is drained by several small rivers originating from the hills surrounding it. Imphal has a subtropical climate with cool, dry winters, a warm summer and a moderate monsoon season. July is the hottest month with temperatures averaging around 25°C (78°F), while January is the coldest with average lows near 4°C (40°F). The city gets about 1320 mm (52 inches) of rain with June being the wettest month.

**Mohanbari:** Mohanbari is located 15 km from the city center Dibrugarh of district Dibrugarh, Assam, India. Being located 27° 26' 60N 95° 1' 60E and with its unique physiographic elements, the area experiences subtropical monsoon climate with mild winter, warm and humid summer. Rainfall decreases from south to north and east to west in the area. The average annual rainfall of the Dibrugarh city in the north is 276 cm with a total number of 193 rainy days, while at Naharkatia in the south, it is 163 cm with 147 rainy days.

**North Lakhimpur:** North Lakhimpur is situated in the eastern parts of India in the state of Assam. The district of Lakhimpur lies on north bank of the mighty river Brahmaputra. It is situated at 27° 13' 60 N and 94° 7' 0 E.

**Pasighat:** Pasighat is the headquarters of East Siang district in the Indian state of Arunachal Pradesh and located at 28.07°N 95.33°E . It has an average elevation of 153 metres (501 ft). The area
experience tropical humid climate during summer and dry mild winter. The place is known for receiving highest rainfall in a single year. In fact Pasighat and area around it receive heavy rainfall every year during monsoon season starting from May till September.

**Silchar**: Silchar is the headquarters of Cachar district in the state of Assam in India. Silchar is located at the southern part of Assam, situated on the Barak River near the Bangladesh border. It has an average elevation of 22 metres (72 feet).

**Tezpur**: Tezpur is situated in the eastern parts of India in the state of Assam and located at 26.63°N 92.8°E. It has an average elevation of 157 ft. The climate in this part of Assam is usually pleasant apart from the high humidity factor. In summer the temperature rises up to 38.6°C and during winters the temperatures may drop to 12°C.

3. METHODOLOGY

In order to describe the behavior of extreme rainfall at a particular area, it is necessary to identify the distribution(s), which best fit the data. In this study, five three-parameter extreme value distributions namely Generalized Extreme Value, Generalized Logistic, Generalized Pareto, Lognormal and Pearson distribution are considered to find the best fitting probability distribution function to extreme rainfall data.

The probability density functions of the above distributions along with their quantile functions are exhibited below.

**Generalized Extreme Value (GEV) Distribution:**

\[
 f(x) = \frac{1}{\alpha} \left\{ 1 - k \left( \frac{x - \xi}{\alpha} \right) \right\}^{-\frac{1}{k}} \left[ -\left( 1 - k \left( \frac{x - \xi}{\alpha} \right) \right) \right]^{-\frac{1}{k}} 
\]

where \(-\infty < x \leq \xi + \frac{\alpha}{k}\) for \(k > 0\) and \(\xi + \frac{\alpha}{k} \leq x < \infty\) for \(k < 0\).

![Figure 2. Representation of annual maximum rainfall data.](image-url)
Quantile function of GEV:

\[ Q(F) = \xi + \alpha Q_o(F) \]  

(3.2)

where

\[ Q_o(F) = [1 - (-\log F)^k] / k. \]  

(3.3)

Generalized Logistic Distribution (GLD):

\[ f(x) = \frac{1}{\alpha} \left \{ 1 - k \left( \frac{x - \xi}{\alpha} \right) \right \}^{1-k} \left [ 1 + \left \{ 1 - k \left( \frac{x - \xi}{\alpha} \right) \right \} \right ]^{-2} \]  

(3.4)

where \( -\infty < x \leq \xi + \frac{\alpha}{k} \) for \( k > 0 \) and \( \xi + \frac{\alpha}{k} \leq x < \infty \) for \( k < 0 \).

Quantile function of GLD:

\[ Q(F) = \xi + \alpha Q_o(F) \]  

(3.5)

where

\[ Q_o(F) = [1 - \{(1 - F)^k / F\}^k] / k. \]  

(3.6)

Generalized Pareto Distribution (GPD):

\[ f(x) = \frac{1}{\alpha} \left \{ 1 - k \left( \frac{x - \xi}{\alpha} \right) \right \}^{1-k} \]  

(3.7)

where \( \xi < x \leq \xi + \frac{\alpha}{k} \) for \( k > 0 \) and \( \xi \leq x < \infty \) for \( k \leq 0 \).

Quantile function of GPD:

\[ Q(F) = \xi + \alpha Q_o(F) \]  

(3.8)

where

\[ Q_o(F) = [1 - (1 - F)^k] / k. \]  

(3.9)

Lognormal Distribution (LN3):
\[
f(x) = \frac{1}{\alpha \sqrt{2\pi}} e^{-\frac{\left(1 - k \frac{x - \xi}{a} \right)^2}{2}} \left(1 - \frac{1}{k} \log \left(1 - k \frac{x - \xi}{a} \right) \right)^	au
\]  
(3.10)

where \(-\infty < x \leq \xi + \frac{\alpha}{k}\) for \(k > 0\) and \(\xi + \frac{\alpha}{k} \leq x < \infty\) for \(k < 0\).

Quantile function of LN3:

\[
Q(F) = \zeta + \exp(\mu)Q_0(F)
\]  
(3.11)

where

\[Q_0(F) = \exp[\sigma \Phi^{-1}(F)]\] and \(\Phi^{-1}(\cdot)\) has a standard normal distribution with mean zero and unit variance. Parameters \(\zeta, \mu\) and \(\sigma\) are the standard parameterizations which can be obtained by setting

\[k = -\sigma, \quad \alpha = \sigma e^\mu, \quad \xi = \zeta + e^\mu.\]  
(3.12)

Pearson Distribution (P3):

\[
f(x) = \frac{1}{\beta \Gamma(\alpha)} \left(\frac{x - \xi}{\beta} \right)^{a-1} \exp \left(-\frac{x - \xi}{\beta} \right)
\]  
(3.13)

where \(-\infty < x < \infty\).

The quantile function of P3:

\[
Q(F) = \mu + \sigma Q_0(F)
\]  
(3.14)

where

\[Q_0(F) = \frac{2}{\gamma} \left[1 + \gamma \Phi^{-1}(F) - \frac{\gamma^2}{36} - \frac{2}{\gamma} \right] - \frac{2}{\gamma} \] and \(\Phi^{-1}(\cdot)\) has a standard normal distribution with mean zero and unit variance. Parameters \(\gamma, \mu\) and \(\sigma\) are the standard parameterizations which can be obtained by setting

\[\alpha = \frac{4}{\gamma^2}, \quad \beta = \frac{1}{2} \sigma |\gamma|, \quad \xi = \mu - \frac{2\sigma}{\gamma}\]  
(3.15)

To estimate the parameters for each of the aforesaid distributions, methods of L-Moment and LQ-Moment are used independently.
3.1 Method of L-moment

The L-moments (LMOM) were introduced by Sillitto (1951) and comprehensively reviewed by Hosking (1986, 1990) for estimating the parameters of certain statistical distributions. The L-moments are linear functions of the expectations of order statistics and they can be viewed as an alternative system of describing the shapes of probability distributions. The main advantages of using the method of LMOM are that the parameter estimates are more reliable (i.e. smaller mean-squared error of estimation) and are more robust, and are usually computationally more tractable than the conventional moments and maximum likelihood.

Let \( X_1, X_2, \ldots, X_n \) be a sample from a continuous distribution function \( F(.) \) with quantile function \( Q(F) \) and let \( X_{1n} \leq X_{2n} \leq \ldots \leq X_{xn} \) denotes the order statistics. Then the \( r \)th L-moment \( \lambda_r \) is given by

\[
\lambda_r = r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} E(X_{r-k:n}), \quad r = 1, 2, \ldots
\]  

(3.1.1)

The details on the estimation of parameters for each of the aforesaid distributions can be found in Hosking and Wallis (1997).

3.2 Method of LQ-moment

Mudholkar and Hutson (1998) extended LMOM to a new moment called LQ-moments (LQM) by introducing some quick estimators such as median, trimean or Gastwirth in places of expectations in LMOM. They found that LQM always exists, are often easier to compute and estimate than LMOM, and in general behave similarly to the LMOM. In fact, in some recent literature such as Shabri et al. (2007) it has found that LQM gives better performance in high quantile estimation as compared to the conventional LMOM.

Analogous to \( \lambda_r \), the \( r \)th LQ-moments \( \zeta_r \) of \( X \) is defined as

\[
\zeta_r = r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} \tau_{\alpha,p}(X_{r-k:n}), \quad r = 1, 2, \ldots
\]  

(3.2.1)

where \( 0 \leq \alpha \leq 1/2, \ 0 \leq p \leq 1/2 \), and

\[
\tau_{\alpha,p}(X_{r-k:n}) = pQ_{X_{r-k:n}}(\alpha) + (1-2p)Q_{X_{r-k:n}}(1/2) + pQ_{X_{r-k:n}}(1-\alpha)
\]  

(3.2.2)

and \( Q_X(.) \) is the quantile function. \( \tau_{\alpha,p} \) is called the median for \( p=0, \alpha=1 \), trimean for \( p=1/4, \alpha=1/4 \) and Gastwirth for \( p=1/3, \alpha=1/3 \). In this study trimean based estimator is considered.

The LQ moment can be estimated from the sample by estimating the quick estimator

\[
\hat{\tau}_{\alpha,p}(X_{r-k:n}) = p\hat{Q}_{X_{r-k:n}}(\alpha) + (1-2p)\hat{Q}_{X_{r-k:n}}(1/2) + p\hat{Q}_{X_{r-k:n}}(1-\alpha)
\]  

(3.2.3)

of the location of the order statistic \( X_{r-k:n} \) and \( \hat{Q}_X(.) \) denotes the linear interpolation estimator given by
\[
\hat{Q}_X(u) = (1-\varepsilon) X_{[n'/u]n} + \varepsilon X_{[n'/u]+1n}
\]  
(3.2.4)

where \( \varepsilon = n' u - [n' u] \) and \( n' = n + 1 \). Details procedure for parameter estimations of different distributions using LQM for extreme events can be found in the existing references such as Mudholkar and Hutson (1998), Shabri and Jemain (2007), Zin et al. (2008).

### 3.3 Goodness of fit

The tests applied for judging the goodness of fit for the fitted distributions for annual maximum rainfall series are relative root mean squared error (RRMSE), relative mean absolute error (RMAE) and probability plot correlation coefficient (PPCC). While the first two tests involve the assessment on the difference between the observed values and expected values of the assumed distributions, the last one measures the correlation between the ordered values and the corresponding expected values. The formulae for the tests are

\[
\text{RRMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{x_{i:n} - \hat{Q}(F_i)}{x_{i:n}} \right)^2}
\]  
(3.3.1)

\[
\text{RMAE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{x_{i:n} - \hat{Q}(F_i)}{x_{i:n}} \right|
\]  
(3.3.2)

\[
\text{PPCC} = \frac{\sum_{i=1}^{n} (x_{i:n} - \bar{x}) \{\hat{Q}(F_i) - \overline{Q}(F)\}}{\sqrt{\sum_{i=1}^{n} (x_{i:n} - \bar{x})^2} \sqrt{\sum_{i=1}^{n} \{\hat{Q}(F_i) - \overline{Q}(F)\}^2}}
\]  
(3.3.3)

where \( x_{i:n} \) is the observed values of the ith order statistics of a random sample of size n, \( \hat{Q}(F_i) \) is the estimated quantile values associated with the ith Gringorten plotting position, \( F_i = \frac{i - .44}{n + .12} \) and \( \overline{Q}(F) = \frac{1}{n} \sum_{i=1}^{n} \hat{Q}(F_i) \).

The smallest values of RRMSE and RMAE correspond to the best fitting distribution where as in the case of PPCC, the distribution with the computed PPCC closest to 1 indicates the best. In order to confirm the goodness of fit for the above five distributions we additionally applied L-moment ratio diagram. L-moment ratio diagram was first introduced by Hosking (1990) which can be drawn by plotting L-kurtosis \( \tau_4 \) as ordinate and L-skewness \( \tau_3 \) as abscissa. According to Hosking and Wallis (1997), the simple explicit expressions for \( \tau_4 \) in terms of \( \tau_3 \) for the assumed distributions can be written as

\[
\tau_4 = \sum_{k=0}^{8} A_k \tau_3^k
\]  
(3.3.4)
where the coefficients $A_k$ are given in the Table 1. Although this is a crude method, it can provide some insights on the selection of the best fitting distribution.

Table 1. Polynomial approximations of $\tau_4$ as a function of $\tau_3$.

<table>
<thead>
<tr>
<th>$A_i$</th>
<th>GPD</th>
<th>GEV</th>
<th>GLD</th>
<th>LN3</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_0$</td>
<td>0</td>
<td>0.10701</td>
<td>0.16667</td>
<td>0.12282</td>
<td>0.1224</td>
</tr>
<tr>
<td>$A_1$</td>
<td>0.20196</td>
<td>0.11090</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$A_2$</td>
<td>0.95924</td>
<td>0.84838</td>
<td>0.83333</td>
<td>0.77518</td>
<td>0.30115</td>
</tr>
<tr>
<td>$A_3$</td>
<td>-0.20096</td>
<td>-0.06669</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$A_4$</td>
<td>0.04061</td>
<td>0.00567</td>
<td>-</td>
<td>0.12279</td>
<td>0.95812</td>
</tr>
<tr>
<td>$A_5$</td>
<td>-</td>
<td>-0.04208</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$A_6$</td>
<td>-</td>
<td>0.03763</td>
<td>-</td>
<td>-0.13638</td>
<td>-0.57488</td>
</tr>
<tr>
<td>$A_7$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$A_8$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.11368</td>
<td>0.19383</td>
</tr>
</tbody>
</table>

The observed sample L-skewness $t_3$ for all the nine stations are substituted in place of $\tau_3$ in Eq. (3.3.4) to get the estimated L-kurtosis $\tau_4$ for the assumed distributions. These computed values $(\tau_3, \tau_4)$ for each distributions along with the observed $(t_3, t_4)$ are plotted on the L moment ratio diagram. For a particular station, the distances between $(\tau_3, \tau_4)$ and $(t_3, t_4)$ for all distributions are compared and evaluated. The distribution corresponding to the smallest distance is considered to be the best.

Fig. 3. L-moment ratio diagram for annual maximum rainfall of 9 stations of North East India.

4. RESULTS AND DISCUSSION

The extreme rainfall amount can be characterized by mean, standard deviation and coefficient of variation. Table 2 provides a quantitative comparison between the rain gauge stations, and it can be concluded that Cherrapunji received the highest mean and standard deviation of annual maximum daily rainfall amount during Indian summer. The coefficients of variations for Mohanbari followed by Pasighat are found to be higher as compared to the stations in other areas. This may indicate that the amounts of extreme rainfall in those two stations are relatively more spread as compared to the other regions of North East India.
The next analysis involves the estimation of parameters for each distribution using L MOM and LQM. The estimated values are given in Table 3. The computation is carried out using the software Matlab 6. Subsequent analysis involves selection of the best fitting distribution out of the five candidate distributions. Results for all GOF tests for each station based on L-moment and LQ-moment are presented in Table 4. The distribution that is found best at least twice out of the three GOF tests will be selected as the best fitting distribution for both the LMOM and LQM. Then, we summarize the results based on the L-moment ratio diagram (Figure 3), LMOM and LQM under the three GOF tests to decide the best fitting distribution for a particular station in Table 5.

Under LMOM, it is found that the number of stations identified best using GLD, GEV, LN3, GPD and P3 are 3, 3, 0, 1 and 2 respectively. On the other hand, under LQM, it is found that the number of stations identified best using GLD, GEV, LN3, GPD and P3 are 3, 1, 2, 0 and 3 respectively. Further in the L-moment ratio diagram, number of stations identified best using GLD, GEV, LN3, GPD and P3 are 3, 1, 3 and 1 respectively. This information can be summarized in Table 6 by ranking them in descending order to show the best fitting distribution for all the stations in North-East India.
Table 4. Outcomes of the GOF tests based on LMOM and LQM methods

<table>
<thead>
<tr>
<th>Stations</th>
<th>LMOM</th>
<th>LQM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RRMSE</td>
<td>RASE</td>
</tr>
<tr>
<td>Cherrapunji</td>
<td>GLD</td>
<td>GLD</td>
</tr>
<tr>
<td>Guwahati</td>
<td>GEV</td>
<td>GEV</td>
</tr>
<tr>
<td>Imphal</td>
<td>GEV</td>
<td>GEV</td>
</tr>
<tr>
<td>Mohanbari</td>
<td>GLD</td>
<td>GLD</td>
</tr>
<tr>
<td>North Lakhimpur</td>
<td>GEV</td>
<td>GEV</td>
</tr>
<tr>
<td>Pasighat</td>
<td>GLD</td>
<td>GLD</td>
</tr>
<tr>
<td>Shillong</td>
<td>P3</td>
<td>GEV</td>
</tr>
<tr>
<td>Silchar</td>
<td>P3</td>
<td>P3</td>
</tr>
<tr>
<td>Tezpur</td>
<td>GPD</td>
<td>GPD</td>
</tr>
</tbody>
</table>

Table 5. Best fitting distributions based on L-moment ratio diagram, LMOM and LQM methods for all rain gauge stations

<table>
<thead>
<tr>
<th>Stations</th>
<th>LMOM</th>
<th>LQM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diagram</td>
<td></td>
</tr>
<tr>
<td>Cherrapunji</td>
<td>GLD</td>
<td>GLD</td>
</tr>
<tr>
<td>Guwahati</td>
<td>GEV</td>
<td>LN3</td>
</tr>
<tr>
<td>Imphal</td>
<td>GEV</td>
<td>LN3</td>
</tr>
<tr>
<td>Mohanbari</td>
<td>GLD</td>
<td>GLD</td>
</tr>
<tr>
<td>North Lakhimpur</td>
<td>GEV</td>
<td>GEV</td>
</tr>
<tr>
<td>Pasighat</td>
<td>GLD</td>
<td>GLD</td>
</tr>
<tr>
<td>Shillong</td>
<td>P3</td>
<td>P3</td>
</tr>
<tr>
<td>Silchar</td>
<td>P3</td>
<td>P3</td>
</tr>
<tr>
<td>Tezpur</td>
<td>GPD</td>
<td>P3</td>
</tr>
</tbody>
</table>

Table 6. Ranking (in descending order) of the distributions for all stations based on methods of LMOM, LQM and L-moment ratio diagram

<table>
<thead>
<tr>
<th>Ranking</th>
<th>LMOM</th>
<th>LQM</th>
<th>LQM Ratio Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GEV, GLD</td>
<td>GLD, P3</td>
<td>GLD, LN3</td>
</tr>
<tr>
<td>2</td>
<td>P3</td>
<td>LN3</td>
<td>GEV, GPD, P3</td>
</tr>
<tr>
<td>3</td>
<td>GPD</td>
<td>GEV</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>LN3</td>
<td>GPD</td>
<td>-</td>
</tr>
</tbody>
</table>

5. CONCLUDING REMARKS

This study reveals that the results of the best fitting distributions may differ for a particular station depending on either LMOM or LQM is used. However, GLD is found to be more consistent in comparison to the other three best fitting distributions. If we consider LMOM, GEV shares the first rank with GLD but fails to perform under LQM and in LMOM ratio diagram. For LQM, P3 is found to be best fitting distribution along with GLD but receives second rank in LMOM and works poorly in case of LMOM ratio diagram. Further, in case of LMOM ratio diagram LN3 distribution holds the first rank with GLD but it is found to be least frequently selected under LMOM methods. From the above discussions, it can be concluded that GLD is the most suitable distribution to describe the annual maximum rainfall in North East India, which also agrees with the result obtained by Zin et al. (2008). But GPD is found to be the least frequently selected distribution. This result differs from the result obtained by Zin et al. (2008) for extreme rainfall in Peninsular Malaysia.
6. ACKNOWLEDGEMENT

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