Statistical Analysis of Flood Peak data of North Brahmaputra Region of India based on the methods of TL-moment

Surobhi Deka & Munindra Borah

Abstract:
TL-moment method has been used in an analysis to determine the best fitting distribution to 10 stream flow gauging sites of the North Brahmaputra region of India. Three extreme value distributions viz. generalized extreme value distribution, generalized logistic distribution, generalized Pareto distribution are fitted for this purpose using the method of TL-moment. The performances of the distributions are valuated using three goodness of fit tests namely relative root mean square error, relative mean absolute error and probability plot correlation coefficient. Further, TL-moment ratio diagram is also used to confirm the goodness of fit for the above three distributions. Finally, goodness of fit test results are compared and generalized extreme value distribution is empirically proved to be the most appropriate distribution for describing the annual flood peak series for the majority of the stations in North Brahmaputra region of India when the parameters are estimated by using TL-moment method.

Key Words: TL-moments, Extreme value distribution, Quantile function, North Brahmaputra region.

1. INTRODUCTION
Flooding in the plains and valleys during the rainy season is a common hazard in North-East India. It causes immense destruction of crops, property and even of life in the region. Information on flood magnitude and their frequencies are needed for design of Hydraulic structures such as dams, spillways, road and railway bridges, culverts, urban drainage systems, flood plan zoning, economic evaluation of flood protection projects etc. There are hundreds of different methods that have been used for estimating floods. Hosking, J.R.M., Wallis, J.R. and Wood, E.F. (1985) used the method of probability- weighted moments method for the estimation of parameters of extreme- value distribution. Hosking (1990), Hosking and Wallis (1997), introduce the concept of L-moments as parameter estimation method for various probability distributions in flood frequency analysis. Since then this procedure has been used for flood frequency analysis by various researchers. L-moments based regional flood frequency analysis was carried out by Paradia et al. (1998), Kumar et al. (1999, 2003), Atiem and Harmancioglu (2006), Modarres (2007), Saf (2008) and Hussain and Pasha (2008) to develope flood frequency relationship for both gauged and ungauged catchments of different regions. Kumar and Chatterjee (2005) used L-moments to develop regional flood frequency relationship for both gauged and ungauged catchments of North Brahmaputra region of India. Later Bhuyan et al. (2010) used LH-moments for regional flood frequency analysis of the same region and a comparative study has been made between L-moments and LH-moments. In the present study, an attempt has been made to analyze the statistical modeling of flood peak data using Trimmed L-moment(TL-moment (1,1)). Elamir and Seheult (2003) developed the TL-moments as a generalization of the L-moments and with more advantages over L-moments and conventional moments. TL-moments assign zero weight to extreme observations, they are easy to compute and more robust than L-moments when used to estimate from a sample containing outliers. A few studies have been made regarding the TL-moments method; see Hosking (2007), Asquith (2007), Moneiem (2007), Moniem and Selim (2009), Noura et al. (2010). So far no rigorous work barring the work by Shahri et al. (2011) pursued in connection to the application of TL-moment in flood frequency analysis, an effort has been made to find the best fitting probability distribution to describe flood peak data of North-Brahmaputra region using TL-moment.

Department of Mathematical Sciences, Tezpur University, Napaam, Tezpur-784028, Assam, India, e-mail: surobhi@tezu.ernet.in
For this purpose, three 3-parameter extreme value distributions viz. Generalized Extreme Value distribution (GEV), Generalized Logistic distribution (GLD), Generalized Pareto distribution (GPD) are considered. The estimation of the parameters for each distribution has been done using the methods of TL-moment.

2. DATA

Series of annual maximum peak flood data of ten stream flow gauging sites lying in the North Bank region of the river Brahmaputra (Figure 1), is considered in this study. The Brahmaputra river basin extends over an area of 580,000 km² and lies in Tibet, Bhutan, India and Bangladesh. The drainage area of the basin lying in India is 194,413 km² which forms nearly 5.9% of the total geographical area of the country. The mean annual rainfall over the basin excluding Tibet and Bhutan is about 2,300 mm. The mean annual peak floods of these sites vary from 99.60 to 8,916.07 m³/s and their catchments areas range from 148 to 30,100 km². The name of the gauging sites and length of the records for each sites are given in Table 1.

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<tr>
<th>Serial no.</th>
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<tr>
<td>10</td>
<td>Sankush</td>
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</tbody>
</table>

Figure 1 Index map of Brahmaputra river system
3. METHODOLOGY

In order to describe the behavior of extreme flood at a particular area, it is necessary to identify the distribution(s), which best fit the data and the performance of a particular distribution depends on the method of the estimation of the parameters. The good estimator of the parameters may be obtained by selecting the proper method of estimation. In this study, the parameters for each of the aforesaid distributions are estimated using the method of TL-Moment

3.1 METHOD OF TL-MOMENT

The fundamental steps of TL-moments are essentially the same as L-moments. Let \( X_1, X_2, \ldots, X_n \) be a sample from a continuous distribution function \( F(\cdot) \) with quantile function \( Q(F) \) and let \( X_{1n} \leq X_{2n} \leq \ldots \leq X_{nn} \) denotes the order statistics. Then the \( r \)th L-moment \( \lambda_r \) is given by

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

In TL-moments defined by Elamir et al. (2003), the expectations term \( E(X_{r-k}) \) in Eq.(1) will be replaced by \( E(X_{r+t_1-k+t_1+t_2}) \). That is, for each \( r \), the conceptual sample size will be increased from \( r \) to \( r + t_1 + t_2 \) and work only with the expectations of the \( r \) order statistics \( Y_{k+t_1+t_2}, \ldots, Y_{k-t_2+t_2} \) by trimming the \( t_1 \) smallest and \( t_2 \) largest from the conceptual sample. Thus the \( r \)th TL-moment \( \lambda_r^{(t_1, t_2)} \) is defined as

\[
\lambda_r^{(t_1, t_2)} = r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} E(X_{r+t_1-k+t_1+t_2}), \quad r = 1, 2, \ldots
\]

For \( t_1 = t_2 = 0 \), TL-moments yields the original L-moments and when \( t_1 = t_2 = t \), then the \( r \)th TL moment is defined as

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

In our study, we have considered TL-moments for \( t=1 \) to estimate the parameters of each of the aforesaid distributions. When \( t=1 \) the first four TL-moments can be expressed as

\[
\lambda_1^{(1)} = E[X_{2:3}] = 6\beta_1 - 6\beta_2,
\]

\[
\lambda_2^{(1)} = \frac{1}{2} E[X_{3:4} - X_{2:4}] = 6(-2\beta_2 + 3\beta_2 - \beta_1),
\]

\[
\lambda_3^{(1)} = \frac{1}{3} E[X_{4:5} - 2X_{3:5} + X_{2:5}] = \frac{20}{3}(-5\beta_4 + 10\beta_3 - 6\beta_2 + \beta_1),
\]

\[
\lambda_4^{(1)} = \frac{1}{4} E[X_{5:6} - 3X_{4:6} + 3X_{3:6} - X_{2:6}] = \frac{15}{2}(-14\beta_5 + 35\beta_4 - 30\beta_3 + 10\beta_2 - \beta_1).
\]

The alternative expressions for the first four TL-moments when \( t = 1 \) are
\[ \lambda_1^{(1)} = 6 \int_0^1 Q(u)(1-u)du, \]  
\[ \lambda_2^{(1)} = 6 \int_0^1 Q(u)(1-u)(2u-1)du, \]  
\[ \lambda_3^{(1)} = \frac{20}{3} \int_0^1 Q(u)(1-u)(5u^2 - 5u + 1)du, \]  
\[ \lambda_4^{(1)} = \frac{15}{2} \int_0^1 Q(u)(1-u)(14u^3 - 21u^2 + 9u - 1)du, \]  

The TL- coefficient of variation \((\tau_2^{(1)})\), TL-coefficient of skewness \((\tau_3^{(1)})\) and TL-coefficient of kurtosis \((\tau_4^{(1)})\) are defined as 
\[ \tau_2^{(1)} = \frac{\lambda_2^{(1)}}{\lambda_1^{(1)}}, \quad \tau_3^{(1)} = \frac{\lambda_3^{(1)}}{\lambda_1^{(1)}}, \quad \tau_4^{(1)} = \frac{\lambda_4^{(1)}}{\lambda_2^{(1)}}. \]

The rth TL-moment \(\lambda_r^{(1)}\) can be estimated from the sample by replacing \(E(X_{r+t-kx+2t})\) with its unbiased estimator 
\[ \hat{E}(X_{r+t-kx+2t}) = \frac{1}{n} \sum_{i=1}^{n} \binom{n-1}{r+t-k-1} \binom{n-i}{t} X_{i,n} \]
which can be obtained from the results established by Downton (1966) as 
\[ \hat{E}(X_{k+1+k_{x+1}}) = \frac{1}{n} \sum_{i=1}^{n} \binom{n-1}{k} \binom{n-i}{l} X_{i,n} \]

Thus the rth sample TL-moment \(I_r^{(1)}\) is defined as 
\[ I_r^{(1)} = r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} \hat{E}(X_{r+t-kx+2t}), \quad r = 1, 2, \ldots n-2t, \]
which on simple re-arrangement gives the alternative form 
\[ I_r^{(1)} = r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} \binom{i-1}{r+t-1-k} \binom{n-i}{t+k} \binom{n}{r+2t} X_{i,n} \]

Now we are in a position to discuss the TL-moment for each extreme value distribution.

**TL-moments for Generalized Extreme Value (GEV) Distribution:**
The probability density function for GEV is given by 
\[ f(x) = \frac{1}{\alpha} \left[ 1 - k \left( \frac{x - \xi}{\alpha} \right) \right]^{\frac{1}{k}-1} \exp \left[ - \left( 1 - k \left( \frac{x - \xi}{\alpha} \right) \right) \right]^{\frac{1}{k}}, \]
where \(-\infty < x \leq \xi + \frac{\alpha}{k} \) for \(k > 0\) and \(\xi + \frac{\alpha}{k} \leq x < \infty \) for \(k < 0\).

Quantile function of GEV: 
\[ Q(u) = \xi + \alpha Q_0(u), \]  

where
\[
Q_0(u) = \left[1 - (-\log u)^k \right]/k.
\]
Then combining the identities (2-5) with (6), we get the first four TL-moments for GEV as a system of equations involving the parameters \(\alpha, \xi\) and \(k\) [see, Eq. (7)-(10)]

\[
\lambda_1^{(i)} = \xi + \frac{\alpha}{k} \left\{ 1 - \Gamma(1+k) \left( \frac{3}{2^k} - \frac{2}{3^k} \right) \right\}, \quad (7)
\]

\[
\lambda_2^{(i)} = 6\alpha \Gamma k \left\{ \frac{1}{2(4^k)} - \frac{1}{3^k} + \frac{1}{2^{k+1}} \right\}, \quad (8)
\]

\[
\lambda_3^{(i)} = \frac{20\alpha \Gamma k}{3} \left\{ \frac{1}{5^k} - \frac{5}{2(4^k)} + \frac{2}{3^k} - \frac{1}{2^{k+1}} \right\}, \quad (9)
\]

\[
\lambda_4^{(i)} = \frac{-15\alpha \Gamma k}{2} \left\{ \frac{7}{5^k} - \frac{7}{3(6^k)} - \frac{15}{2(4^k)} + \frac{10}{3^{k+1}} - \frac{1}{2^{k+1}} \right\}. \quad (10)
\]

In the evaluation of the of the parameters, the sample TL-moments \(l_r^{(i)}, r=1,\ldots,4\) may be used directly. So the shape parameter \(k\) can be estimated by numerically solving the highly non linear equation given by

\[
\hat{\xi}_3^{(i)} = \frac{l_3^{(i)}}{l_2^{(i)}} = \frac{10}{9} \left\{ \frac{1}{5^k} - \frac{5}{2(4^k)} + \frac{2}{3^k} - \frac{1}{2^{k+1}} \right\}, \quad (11)
\]

In order to solve Eq. (11) for \(k\) numerically, we first generate 1,000 different values for \(k\) in the interval \([-1, 1]\) for suitable step size and those values are used to calculate the right hand side of the Eq. (11). If we denote the approximate right-hand side by the symbol \(\tau_{3k}^{(i)}\) for a particular value of \(k\), then \(k\) is chosen in such a way that \(|\hat{\xi}_3^{(i)} - \tau_{3k}^{(i)}|\) is minimum. The estimates of the other two parameters \(\alpha\) and \(\xi\) are

\[
\hat{\alpha} = \frac{\hat{\xi}_3^{(i)} - \frac{1}{l_2^{(i)}}}{6\Gamma k \left\{ \frac{1}{2(4^k)} - \frac{1}{3^k} + \frac{1}{2^{k+1}} \right\}}, \quad (12)
\]

\[
\hat{\xi} = l_1^{(i)} - \frac{\hat{\alpha}}{k} \left\{ 1 - \Gamma(1+k) \left( \frac{3}{2^k} - \frac{2}{3^k} \right) \right\}. \quad (13)
\]

**TL-moments for Generalized Pareto Distribution (GPD):**

The probability density function for GPD is given by

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

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

Quantile function of GPD:

\[
Q(u) = \xi + \alpha Q_0(u), \quad (14)
\]

where
The first four TL-moments of GPD can be obtained as

\[
\begin{align*}
\lambda_1^{(1)} &= \xi + \frac{\alpha(k+5)}{(k+3)(k+2)}, \\
\lambda_2^{(1)} &= \frac{6\alpha}{(k+2)(k+3)(k+4)}, \\
\lambda_3^{(1)} &= \frac{20\alpha(1-k)}{3(k+2)(k+3)(k+4)(k+5)}, \\
\lambda_4^{(1)} &= -\frac{15\alpha(k-1)(k-2)}{2(k+2)(k+3)(k+4)(k+5)(k+6)}.
\end{align*}
\]

The estimates of the parameters of GPD are then given by

\[
\begin{align*}
\hat{k} &= \frac{10 - 45\hat{\xi}_3^{(1)}}{10 + 9\hat{\xi}_3^{(1)}}, \\
\hat{\alpha} &= \frac{l_2^{(1)}}{6(k+2)(k+3)(k+4)}, \\
\hat{\xi} &= \frac{l_1^{(1)}}{(k+2)(k+3)} - \frac{\hat{\alpha}(k+5)}{(k+2)(k+3)}.
\end{align*}
\]

**TL-moments for Generalized Logistic Distribution (GLD):**

The probability density function for GLD is given by

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

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:

\[
Q(u) = \xi + \alpha Q_0(u),
\]

where

\[
Q_0(u) = \left[1 - \left\{(1-u)^k\right\} / k\right].
\]
The first four TL-moments of GLD can be obtained as

\[ \lambda_1^{(i)} = \xi + \frac{\alpha}{k} + \frac{\alpha \pi (1 - k^2)}{\sin(\pi k)}, \]  \hspace{1cm} (23)

\[ \lambda_2^{(i)} = -\frac{k \pi \alpha (k^2 - 1)}{2 \sin(\pi k)}, \]  \hspace{1cm} (24)

\[ \lambda_3^{(i)} = -\frac{5 \alpha k^2 \pi (k^2 - 1)}{18 \sin(\pi k)}, \]  \hspace{1cm} (25)

\[ \lambda_4^{(i)} = -\frac{k \alpha \pi (7k^2 + 2)(k^2 - 1)}{48 \sin(\pi k)}. \]  \hspace{1cm} (26)

The estimates of the parameters of GLD are then given by

\[ \hat{k} = -\frac{9 \hat{\tau}_1^{(i)}}{5}, \]  \hspace{1cm} (27)

\[ \hat{\alpha} = -\frac{2 \hat{l}_2^{(i)} \sin(\pi \hat{k})}{\pi \hat{k}(\hat{k}^2 - 1)}, \]  \hspace{1cm} (28)

\[ \hat{\xi} = \hat{l}_1^{(i)} + \frac{\pi \alpha (\hat{k}^2 - 1)}{\sin(\pi \hat{k})} - \frac{\hat{\alpha}}{\hat{k}}, \]  \hspace{1cm} (29)

### 3.2 GOODNESS OF FIT (GOF)

The next step in our analysis is to evaluate the performance of the distributions. The tests applied for judging the goodness of fit for the fitted distributions for annual flood peak data 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

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

\[ \text{RMAE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{X_{in} - \hat{Q}(F_i)}{X_{in}} \right|, \]

\[ \text{PPCC} = \frac{\sum_{i=1}^{n} (X_{in} - \bar{X}) (\hat{Q}(F_i) - \overline{Q}(F))}{\sqrt{\sum_{i=1}^{n} (X_{in} - \bar{X})^2} \sqrt{\sum_{i=1}^{n} (\hat{Q}(F_i) - \overline{Q}(F))^2}}, \]

where \( X_{in} \) 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. We additionally applied TL-moment ratio diagram which can be drawn by plotting TL-kurtosis \( \tau_4^{(l)} \) as ordinate and TL-skewness \( \tau_3^{(l)} \) as abscissa. The simple explicit expressions for \( \tau_4^{(l)} \) in terms of \( \tau_3^{(l)} \) for the assumed distributions can be written as

\[
\tau_4^{(l)} = \sum_{k=0}^{8} A_k \left( \tau_3^{(l)} \right)^k
\]  

(30)

where the coefficients \( A_k \) are given in the Table 2. Although this is a crude method, it can provide some insights on the selection of the best fitting distribution.

<table>
<thead>
<tr>
<th>( A_i )</th>
<th>GPD</th>
<th>GEV</th>
<th>GLD</th>
</tr>
</thead>
<tbody>
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<td>0.0833</td>
</tr>
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<td>( A_1 )</td>
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<td>0</td>
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<td>-0.0745</td>
<td>0</td>
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<tr>
<td>( A_4 )</td>
<td>0.0168</td>
<td>0.0373</td>
<td>0</td>
</tr>
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</table>

The observed sample TL-skewness \( \tau_3^{(l)} \) for all the ten stations are substituted in place of \( \tau_3^{(l)} \) in Eq. (30) to get the estimated TL-kurtosis \( \tau_4^{(l)} \) for the assumed distributions. These computed values \(( \tau_3^{(l)}, \tau_4^{(l)} \) for each distributions along with the observed \(( \tau_3^{(l)}, \tau_4^{(l)} \)) are plotted on the TL moment ratio diagram. For a particular station, the distances between \(( \tau_3^{(l)}, \tau_4^{(l)} \) and \(( \tau_3^{(l)}, \tau_4^{(l)} \) for all distributions are compared and evaluated. The distribution corresponding to the smallest distance is considered to be the best.
4. RESULTS AND DISCUSSION

The first step in our analysis involves the estimation of parameters for each of the aforesaid distribution using the method of TL-moment. The parameters for each of GEV, GPD and GLD distribution are estimated for each of the ten stream flow gauging sites using the methodology as mentioned above and the estimated values are given in Table 3. The computations are carried out using the software Matlab 6. The next step in our analysis involves the selection of the best fitting distribution out of the three candidate distributions. The performances of the distributions are assessed with the help of three goodness of fit tests which are mentioned in the section 3.2. The results of all GOF tests are given in the Table 4. As the results in Table 4, it is seen that the minimum RRMSE and RASE appears at GEV distribution in all the sites.
Table 3: Estimates of the parameters for each distribution using TLMOM

<table>
<thead>
<tr>
<th>Stations</th>
<th>GPD TLMOM</th>
<th>GLD TLMOM</th>
<th>GEV TLMOM</th>
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<td>3358.7</td>
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<td>-.0800</td>
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<td>5560.0</td>
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<td>245.3542</td>
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<tr>
<td></td>
<td>1342.8</td>
<td>1859.7</td>
<td>1724.4</td>
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</tbody>
</table>

But in the PPCC test the results varies from site to site. In this tests the value of PPCC closest to one appears at GEV distribution for sites Monas and Dhansin, at GPD distribution for the sites Borolia, Belsiri, Jiabharali and Beki.

Table 4: Three goodness of fit test result for each station considered in this study.

<table>
<thead>
<tr>
<th>STATIONS</th>
<th>RMSE</th>
<th>RASE</th>
<th>PPCC</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>GPD</td>
<td>GLD</td>
<td>GEV</td>
</tr>
<tr>
<td>Monas</td>
<td>0.0414</td>
<td>0.0491</td>
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</tr>
<tr>
<td>Nonai</td>
<td>0.1418</td>
<td>0.1978</td>
<td>0.0259</td>
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<tr>
<td>Borolia</td>
<td>0.0759</td>
<td>0.0885</td>
<td>0.0112</td>
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<tr>
<td>Dhansin</td>
<td>0.1481</td>
<td>0.0696</td>
<td>0.0179</td>
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<tr>
<td>Pachnoi</td>
<td>0.0522</td>
<td>0.1034</td>
<td>0.0177</td>
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<tr>
<td>Belsiri</td>
<td>0.0926</td>
<td>0.1633</td>
<td>0.0309</td>
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<tr>
<td>Jiabharali</td>
<td>0.0349</td>
<td>0.1132</td>
<td>0.0233</td>
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<td>0.0532</td>
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</table>

In remaining sites this value appears at GLD distribution. Next we run through the results obtained from TL-moment ratio diagram which can be seen in the Figure 2. As illustrated by Figure 2, for the sites Beki and Nonai the best fitting distribution is GLD, for Borolia, the best fitting distribution is GEV. For the other sites except Dhansin and Sankush, the best fitting distribution is GPD.
Dhansin and Sankush are very far from all the three distributions. As a result it is rather difficult to select one particular distribution for these sites with the help of this diagram.

Table 5. Best fitting distributions according to GOF tests based and TL-moment ratio diagram.

<table>
<thead>
<tr>
<th>Stations</th>
<th>LMOM</th>
<th>RRMSE</th>
<th>RASE</th>
<th>PPCC</th>
<th>TL-MOMENT RATIO DIAGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monas</td>
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<td>GEV</td>
<td>GEV</td>
<td>GEV</td>
<td>GPD</td>
</tr>
<tr>
<td>Nonai</td>
<td>GEV</td>
<td>GEV</td>
<td>GLD</td>
<td>GLD</td>
<td>GLD</td>
</tr>
<tr>
<td>Borolia</td>
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<td>GEV</td>
<td>GPD</td>
<td>GEV</td>
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<tr>
<td>Dhansin</td>
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<tr>
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<td>GEV</td>
<td>GPD</td>
<td>GPD</td>
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<tr>
<td>Jiabharali</td>
<td>GEV</td>
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<tr>
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<td>GEV</td>
<td>GPD</td>
<td>GPD</td>
<td>GLD</td>
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<tr>
<td>Beki</td>
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<td>GEV</td>
<td>GPD</td>
<td>GLD</td>
<td>GLD</td>
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<tr>
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<td>GEV</td>
<td>GEV</td>
<td>GLD</td>
<td>GLD</td>
<td>GLD</td>
</tr>
</tbody>
</table>

We summarize the results based on the three goodness of fit tests and the TL-moment ration diagram to decide the best fitting distribution for a particular site in Table 5. From the Table 5, it is observed that GEV is found to be the best among other fitting distributions under RRMSE and RMAE tests, but perform poorly in PPCC and TL-moment ratio diagram. While GLD and GPD distributions share the same rank in the performance under PPCC test, GPD observed to be best in TL-moment ratio diagram.

From the above discussion, we can conclude that GEV is the best fitting distribution followed by GPD and GLD to describe the annual flood peak data over the stations considered for this study.

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REFERENCE


