

A model developed for flood frequency analysis of North Bank Region of the Brahmaputra River, Assam

Abhijit Bhuyan

Assistant Professor, Department of Commerce, C.K.B. College, Teok, Jorhat, Assam, India

Abstract

In the present study a flood frequency analysis model is developed for north bank region of the Brahmaputra River of Assam by using Trimmed L-moment (TL-moment) method. For this study, generalized extreme value (GEV), generalized logistic (GLO), generalized Pareto (GPA) probability distributions are used. Best fitting distribution for the study region is identified by using Z-statistics criteria and TL-moment ratio diagram. It has been observed that the GEV distribution is the best fitting distribution for our study region. The regional flood frequency models for both gauged and ungauged catchments are developed. The efficiency of the model is tested.

Keywords: Flood frequency analysis, North Bank Region, Brahmaputra River, Assam, trimmed l-moments (tl-moments)

Introduction

In rainy season flood is a major problem in North Brahmaputra region of Assam, India. Due to flood in this region a huge loss of property and life of living beings in the region. Flood estimates is essential for protection of Hydraulic structures. In literature two types of flood frequency analysis approaches are available one is at-site another one is regional. As flood data of a particular site is not sufficient for an unbiased estimate of the parameter of an underline probability distribution therefore region as a whole is used. The regional flood frequency analysis based on L-moment parameter estimation method was carried out by various researchers [8, 9, 12, 13]. Again, in another study the L-moment based regional flood frequency relationships for gauged and ungauged catchment areas of North Brahmaputra region of Assam was developed by using L-moment approach [10]. The LH-moments parameter estimation was used for the same region and a comparative study has been made between L-moments and LH-moments [2]. In this study, we are trying to develop a model for flood frequency of both gauged and ungauged sites of north bank region of the river Brahmaputra by using TL-moment. The TL-moments is a generalization of the L-moments and with more advantages over L-moments and conventional moments [3]. A few studies have been made regarding application of the TL-moments method for frequency analysis. [1, 7, 14].

In this study, we try to find a best fitting probability distribution which will be useful for development of the model and for these GEV, GLO and GPA distributions are considered.

Material and Methodology

For this study yearly, maximum flood data of 14 gauging sites of north bank region of the river Brahmaputra are taken. The number of observations available for our study is from 11 to 36 years. It is observed that the 1st TL-moment are ranging from 40.04 to 8505.67 m cub. /s and catchments areas from 148 to 30,100 km². The name of the gauging sites, record length, TL-moments and D_i^{TL} values for each site are calculated (see Table 1).

The detail methodologies used for our study are given in the following sub-sections,

Method of TL-moment

let $X_{1:n} \leq X_{2:n} \leq \dots \leq X_{n:n}$ denotes the order statistics. Then the r^{th} TL-moments defined as see [3].

$$\lambda_r^{(t_1, t_2)} = r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} E(X_{r+t_1-k:r+t_1+t_2}), r = 1, 2, \dots \quad (1)$$

If $t_1 = t_2 = t$, then the r^{th} TL moment is defined as

$$\lambda_r^{(t)} = r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} E(X_{r+t-k:r+2t}), r = 1, 2, \dots \quad (2)$$

In our study, we have considered TL-moments for $t=1$ and the first four TL-moments can be expressed as

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

$$\lambda_2^{(1)} = \frac{1}{2} E[X_{3:4} - X_{2:4}] = 6(-2\beta_3 + 3\beta_2 - \beta_1) \quad (4)$$

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

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

TL-coefficient of variation (TL-Cv) ($\tau_2^{(1)}$), TL-coefficient of skewness (TL-Sk) ($\tau_3^{(1)}$) and TL-coefficient of kurtosis (TL-Ck) ($\tau_4^{(1)}$) are defined as

$$\tau_2^{(1)} = \frac{\lambda_2^{(1)}}{\lambda_1^{(1)}}, \quad \tau_3^{(1)} = \frac{\lambda_3^{(1)}}{\lambda_2^{(1)}}, \quad \tau_4^{(1)} = \frac{\lambda_4^{(1)}}{\lambda_2^{(1)}} \quad (7)$$

Result and Discussion

The detail procedures for regional flood frequency are explained in the following sections. For this purpose, the Fortran-77 subroutine for L-moments [6] have been used after some modification.

The first step of regional frequency analysis is the screening of the data for this the discordancy measure [5] for L-moments is used in TL-moment environment. The discordancy measure for TL-moments can be defined as

$$D_i^{TL} = \frac{1}{3}NS(u_i - \bar{u})^T S^{-1}(u_i - \bar{u}) \tag{8}$$

Table 1: Name of sites, sample size, catchments areas, sample TL-moment statistics and discordancy measures

Site	Catchment Area	Number of observations	1 st TL-mom	TL-Cv	TL-Sk	TL-Ck	D_i^{TL}
Monas	30100	17	5797.61	0.0912	0.1370	0.0006	0.45
Nonai	148	11	94.06	0.0898	-0.1341	0.0969	1.71
Borolia	310	15	188.25	0.1294	0.0816	0.0533	0.09
Dhansiri	530	21	1297.26	0.0970	0.0952	0.1802	0.90
Pachnoi	198	22	202.74	0.1506	0.1418	0.0450	0.72
Jiabharali	11000	36	4057.47	0.1311	0.1190	0.0193	0.30
Subansiri	25886	27	8505.67	0.0897	0.1376	0.0493	0.44
Beki	1331	13	759.34	0.1439	-0.1370	0.1413	1.63
Sankush	9799	12	1880.90	0.0660	0.0741	-0.1442	1.61
Gaurang	1023	17	944.69	0.1645	0.0747	0.2262	1.06
Champawati	1142	22	756.64	0.1092	0.3176	0.2569	1.63
Ghiladhari	670	20	69.16	0.1579	0.3652	0.2371	1.63
Noanadi	745	13	40.04	0.1036	-0.0909	-0.1371	1.15
Ranganadi	2941	19	961.96	0.1437	0.0563	-0.0043	0.69

The test of heterogeneity measure of a region is the second step of regional analysis. For this purpose the heterogeneity measure for TL-moments is used and can be defined as

$$H_i^{TL} = \frac{V_i - \mu_{V_i}}{\sigma_{V_i}}, i = 1, 2, 3. \tag{9}$$

where, V_i , μ_{V_i} and σ_{V_i} ($i=1,2,3$) are the measure of variability, the mean and standard deviation, respectively (for details see [4, 5]).

The heterogeneity measures for our study regions are $H_1^{TL} = 0.83$, $H_2^{TL} = 0.13$ and $H_3^{TL} = 0.86$.

If the heterogeneity measure given in Equation. 9 is less than 1 then region is considered as homogeneous, otherwise it is heterogeneous. It has been observed that the heterogeneity measure is less than 1 therefore the study region is homogeneous.

The third step of regional flood frequency analysis is the selection of best fitting probability distribution. For this purpose, the two goodness-of-fit tests namely Z-statistics criteria and TL-moment ratio diagram are used.

The Z-statistics criteria for TL-moments can be defined as

$$H_i^{TL} = \frac{V_i - \mu_{V_i}}{\sigma_{V_i}}, i = 1, 2, 3. \tag{9}$$

where, $\hat{\tau}_4^R$ = regional average of TL-Ck and B_4, σ_4 = bias and standard deviation of TL-Ck, respectively (for details see [4, 5]).

Table 2: The $|Z_{TL}^{DIST}|$ -statistic values

Distribution	Z-statistics
GEV	0.22
GLO	0.88
GPA	1.87

$S = \sum_{i=1}^{NS} (u_i - \bar{u})(u_i - \bar{u})^T$, $\bar{u} = NS^{-1} \sum_{i=1}^{NS} u_i$ and u_i is the vector containing the sample TL-Cv, TL-Sk and TL-Ck for site i .

It has been observed that the D_i^{TL} values (Table 1) for all sites are less than the critical value 2.971 for 14 sites given by [5]. Therefore, no sites found to be discordant and all sites can be considered for regional flood frequency analysis.

From Table 2, we observed that the $|Z_{TL}^{DIST}|$ -statistic values are less than 1.64 for GEV and GLO distribution. Therefore, these distributions can be considered as best representative for this region. Out of these two distributions, the GEV distribution has the lowest $|Z_{TL}^{DIST}|$ -statistic value i.e. 0.22. Therefore, the GEV distribution is the best fitting distribution for this region.

The TL-moment ratio diagram is a graph between TL-ck and TL-sk. It has been observed from TL-moment ratio diagram (Figure. 1) that the regional average value lies close to GEV distribution. Therefore, GEV distribution can be considered as best fitting distribution for our region. Thus, based on both TL-moment ratio diagram and $|Z_{TL}^{DIST}|$ -statistic criteria, it can be concluded that the GEV distribution is best fitting distribution.

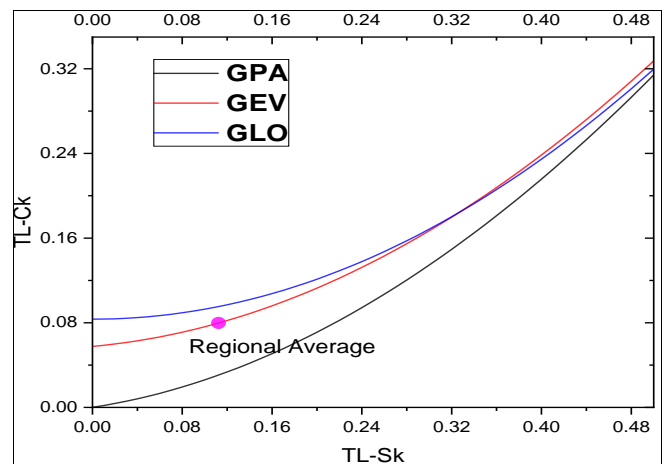


Fig1: TL-moment ratio diagram

The regional parameters of all the three probability distributions are given in Table 3

Table 3: Parameters of three probability distribution

Distribution	Parameters		
	ξ	α	k
GEV	0.842	0.339	-0.017
GLO	0.969	0.236	-0.202
GPA	0.511	0.758	0.449

Fourth step is to development of regional flood frequency model for both gauged and ungauged sites. The Equation. 11 and Equation. 12 provided below are the model for gauged and ungauged catchment area of our North Brahmaputra region.

$$Q_T = \left[-19.09 + 19.94 \left(-\ln \left(1 - \frac{1}{T} \right) \right)^{-0.017} \right] * \lambda_1^{(1)} \quad (11)$$

Where, Q_T is the magnitude of flood for T year return period and $(\lambda_1^{(1)})$ is the 1st TL-moment of the catchment.

$$\lambda_1^{(1)} = 1.784(A)^{0.798} \quad (12)$$

Where, $(\lambda_1^{(1)})$ is the 1st TL-moment (m³/s) of the ungauged catchment area and A is the catchment area in sq. km. For Equation. 12, the correlation coefficient is, r = 0.8331.

Conclusion

Regional flood frequency analysis has been carried out by using TL-moment for North Brahmaputra region. The screening of data shows that no sites found to be discordant therefore all 14 sites are considered for regional frequency analysis. The homogeneity of the region is tested by using heterogeneity measure. It has been observed from homogeneity measure that our region under study is homogeneous. On the basis of Z-statistics criteria for TL-moment and TL-moment ratio diagram the GEV distribution is identified as best fitting probability distribution. The regional flood frequency relationship for gauged catchment of our region is developed by using the best fitting GEV distribution. Again, for ungauged catchments of the study area the developed relationship can be used for estimation of floods of desired return periods.

Acknowledgement

I acknowledged the receipt of helps provided by Dr. Rakesh Kumar for data and guidance for completing this paper.

References

1. Ahmad UN, Shabri A, Zakaria ZA. An analysis of annual maximum streamflows in Terengganu, Malaysia using TL-moments approach. *Theoretical and Applied Climatology*,2013;111:649–663.doi:10.1007/s00704-012-0679-x
2. Bhuyan A, Borah M, Kumar R. Regional flood frequency analysis of north-bank of the river Brahmaputra by using LH-moments. *Water Res. Manage*,2010;24(9):1779-1790.
3. Elamir EA, Seheult AH. Trimmed L-moments. *Comput Stat Data Anal*,2003;43:299–314.
4. Hosking J R M, Wallis JR. Some statistics useful in regional frequency analysis. *Water Resour. Res.*,1993;29(2):271-281.

5. Hosking J R M, Wallis JR. *Regional frequency analysis- An approach based on L-moments*, Cambridge University Press, New York, 1997.
6. Hosking J R M. *Fortran Routines for Use with the Method of L-moments*, Version 3, 2005, 04.
7. Hosking J R M. Some theory and practical uses of trimmed L-moments. *J Stat Plan Infer*,2007;137:3024–3039.
8. Kumar R, Singh RD, Seth SM. Regional flood formula for seven subzones of zone 3 of India. *J. Hydrologic Eng.*, ASCE ,1999;4(3):240-244.
9. Kumar R, Chatterjee C, Kumar S, Lohani AK. Development of regional flood frequency relationship using L-moments for Middle Ganga Plains Subzone 1(f) of India. *Water Resour. Manage*,2003;17:243-257.
10. Kumar R, Chatterjee C. Regional flood frequency analysis using L-moments for North Brahmaputra Region of India, *J. Hydrologic Eng*,2005;4(3):240-244.
11. Kumar R. Development of regional flood frequency relationships using L-moments for gauged and ungauged catchments of India, *Water Utility Journal*,2019;23:37-47.
12. Parida BP, Kachroo RK, Shrestha DB. Regional flood frequency analysis of Mahi-Sabarmati Basin (Subzone 3-a) using index flood procedure with L-moments. *Water Resour. Manage*,1998;12:1-12.
13. Saf B. Regional Flood frequency analysis using L-moments for the West Mediterranean region of Turkey, *Water Resour. Manage*,2009;23(3):531-551.
14. Shabri AB, Daud ZM, Ariff NM. Regional analysis of annual maximum rainfall using TL moments method, *Theor Appl Climatol*,2011;104:561– 570.