Comparative Assessment of Gumbel and Log Pearson Type III Methods: Teesta River Flood Frequency Analysis

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Abstract:- Floods are recurring natural disasters, especially in the flood-prone region of northern Bangladesh, where flash floods regularly affect communities living along rivers like the Teesta. This study employs flood frequency analysis to understand the occurrence and characteristics of these floods. Hydrological data spanning 32 years (1979-2021) from the Teesta River in Bangladesh is analyzed to determine flood frequency, particularly focusing on return periods of 5, 10, 50, and 100 years. The results reveal that the Teesta River basin experienced its highest annual flow in 2003, with 1998 recording the second-highest flow. The Gumbel's Extreme Value Distribution and Log Pearson Type III Distribution methods are both used for flood frequency analysis. The study calculates peak discharges for various return periods, demonstrating that Gumbel's method provides more accurate estimates compared to the Log Pearson method for the Teesta River. These findings are vital for flood risk assessment, disaster preparedness, and infrastructure development in flood-prone areas, contributing to informed decision-making and improved flood management strategies. Understanding flood frequency and characteristics is crucial in a region where flooding is a recurring and challenging issue.

Keywords:- *Flood, Flood Frequency Analysis, Return periods, Gumble'sMethod ,Pearson Method.*

I. INTRODUCTION

Floods are a recurring event in rivers that involve high discharge and related overbank flow. These are an essential component of a river's fluvial cycle and are connected to high water, when the river overflows its banks and floods the nearby areas [8]. In northern Bangladesh, flash floods happen on a regular basis in the places that are close to the rivers, especially in the lower Teesta River basin. For example, a flash flood happened recently in the lower Teesta River area, mainly in the Nilphamari, Lalmonirhat, and Kurigram districts in August 2017 [2]. It submerged a lot of land and killed five people. NIRAPAD, the network for information, response, and preparedness actions on disasters, says that the flash flood hurt about 6.8 million people and damage more than 560,000 hectares of croplands. The August 2017 flash flood was thought to have caused up to US$10 million in damage [1].Flood frequency analysis is widely regarded as the primary statistical tool for understanding the nature and extent of major flood events in a river. This technique aids in determining the time between occurrences of a specific peak discharge magnitude. Analysis of the frequency of flooding can be used to assess the hydraulic and flow behavior of the river 3. Hydrologist utilized a statistical method known as flood frequency analysis in order to make predictions regarding flow levels that are associated with particular return times or probabilities along a river [15]. It is used to assess the frequency with which floods of a certain magnitude may occur and to make predictions about the likely magnitude of floods that may occur during a certain time period [6]. The analysis of flood frequency is required in order to construct bridges, dams, and levees. The determination of the design flood is accomplished through the use of flood frequency analysis, which makes use of historical data of peak flows to generate information about the projected behavior of future flooding. Because Bangladesh is a nation that frequently experiences flooding, the Teesta River has been chosen as the research location for this examination [9]. The aim of the study is to construct flood frequency curves using the annual-maximum series of flood peaks of the Teesta River of Bangladesh. Probability distributions are fitted to samples of flood peaks and the estimated parameters of the distribution are then used to predict the average recurrence intervals of floods of chosen magnitude at the site. The theoretical probability distributions Log Pearson and Gumbel's III are employed to suit the observed sample distributions of the station's annual maximum flood.[5].

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II. MATERIAL AND METHODS

A. Study Area:

One of the biggest floodplains in Bangladesh is the Teesta floodplain, which is in the northern part of the country. This northern area has a higher rate of poverty, which is marked by low income and income that isn't spread out Rangpur station had a rains a little more than 1900 mm a year on average in this area 4. The Teesta basin was cut through by the Teesta River, which is one of the most important rivers in the northern part of the country. As shown in Figure 1, this river flows through Sikkim and West Bengal in India as well as Nilphamari, Lalmonirhat, Kurigram, Rangpur, and Gaibandha in Bangladesh. It is Bangladesh's fourth biggest river that flows across borders, after the Ganges, the Brahmaputra, and the Meghna7.

People who live near the Teesta River are vulnerable to storms, bank erosion, and droughts from time to time. For people who live near rivers or streams, floods are the worst of these disasters. People take a variety of steps to lower their risk of flooding. River overflow, especially when the barrage lets water out, heavy rain, uneven rainfall, and bad drainage are the main reasons why the Teesta River floods. In 1998, 2001, 2003 the Teesta River had highest discharge 10. In 2017, it faced flood that was especially bad. It destroyed homes and fields badly and killed more than fifty people in those five northern districts. The water level in the Dalia station of the Teesta River rose above the danger level five times, and on August 13, 2017, it hit its highest point, 53.05 meters 11. People who live along the Teesta riverbank are used to flooding.Avoid combining SI and CGS units, such as current in amperes and magnetic field in oversteps. Dimensional inaccuracies in equations are a common result of this. If you must use mixed units, clearly state the units for each quantity that you employ in an equation.

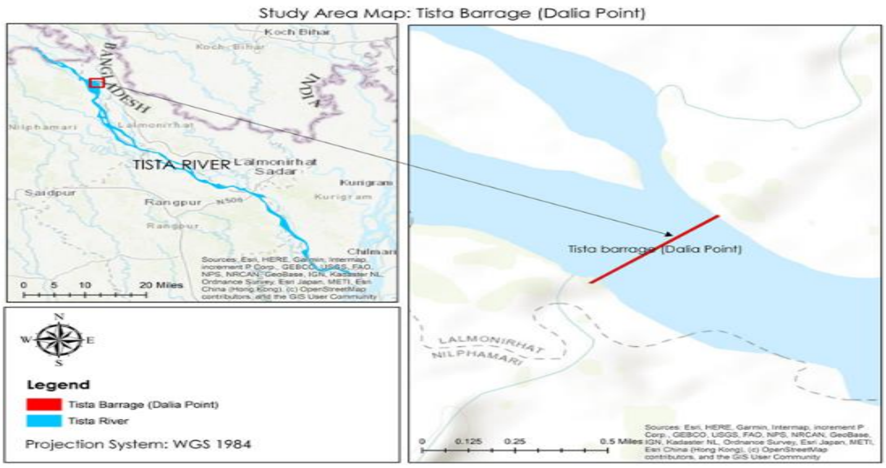

Fig. 1: Teesta River

B. Data and Methods:

Data for this study were gathered from the Directorate of Hydrology under Bangladesh Water Development Board (UWBD), which releases hydrological data on a regular basis. The hydrological data, which includes the Teesta river's peak flood discharges, would cover the years 1979 through 2021 and be utilized for a flood frequency analysis. Secondary data were gathered in order to achieve the study's aims.

There are two processes in the analysis of flood frequency. First, hydrological data are gathered from the Bangladesh Water Development Board's "Directorate of Hydrology," which releases them on a regular basis. Thus, the analysis of flood frequency makes use of the hydrological data. Second, recurrence and interval are calculated based on this standard data and shown on a hypothetical probability distribution of yearly maximum floods.The computation of flood frequency analysis follows a fairly straightforward set of steps. The following formula determines the plotting places for the array of individual items:

$$T=(n+1)/m$$

Where, T= recurrence interval (in years)
n = Number of years record
m= Rank of flood

Next, these data are often shown on logarithmic probability paper for each station individually. In the current study, the observed sample distribution of the yearly maximum floods of the Teesta River in Bangladesh is fitted using the Gumble's extreme value distribution and the log-Pearson type III distribution papers.

C. The Gumbel's Distribution Method:

A probabilistic theory of statistics is the Gumbel's distribution. It serves as a model for the distribution of maximum numbers among the different samples. Predicting future natural disasters like floods, earthquakes, and droughts is helpful [9]. For the Gumbel's distribution method of frequency analysis to provide a probabilistic future prediction, at least ten years' worth of yearly maximum historical data are required. The generalized extreme value distribution method is another name for it.

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The Gumbel's Distribution time (T) dependent probability frequency analysis equation is (1):

$$XT = X + K .\sigma X \text{.....................................}(1)$$

XT stands for Gumbel's Distribution with respect to the return time, X represents the mean value, πX represents the standard deviation, and "K" represents the Gumbel method's frequency factor. The equation gives us the mean number and πX. (2 and 3):

$$\bar{\bar{X}} = \frac{\sum X}{N} \text{ .... } (2)$$

where "X" is the measurement of the discharge, "$\bar{\bar{X}}$" is its mean, and "N" is the number of samples.

$$\sigma = \sqrt{\frac{\sum_{(i-1)}^{n}(Xi-\bar{\bar{X}})^2}{n}} \text{......................................}(3)$$

where σ = standard deviation, "n" is the number of sample, " Xi " is the each value of the sample and $\bar{\bar{X}}$ is the mean value of this sample.

The "K" value was calculated using the following equation (4):

$$K = \frac{Y_T-\overline{Y_n}}{S_n} \text{... } (4)$$

Where The equation (5) is used to find the reduced variate Y_T. Gumbel's extreme value distribution chart was used to find the Sn and (Y_n) values, which rely on the sample size.

$$Y_T = -[L_n.L_n\left(\frac{T}{T-1}\right)] \text{.................................}(5)$$

where "T" is the predicted time period.

$$P = \frac{(m-a)}{(N-a-b+1)} \text{.......................................}(6)$$

where "P" is the plotting point, "m" is the rank, "N" is the sample's lowest order, and "a" and "b" are fixed values.[4].

D. Log Pearson Type III Method:

It is also called the Gamma distribution, and more and more people in India are hearing about it. A lot of academics think of it as a standard way to do flood frequency research. The US Water Resource Council has backed it because it can be changed to fit different needs 13. To find the estimated peak discharge for a certain recurrence interval or the chance of an event exceeding the limit, the annual peak discharge series must first be changed to base-10 logarithms. The mean, standard deviation, and coefficient of skewness must then be found.14.

The intended flood's logarithm,

$$\boldsymbol{Z = Z_{ave} + kz\sigma_{n-1}}$$

The frequency factor for the Gamma or Log Pearson Type III distribution can be determined by referring to the frequency factor table. This calculation involves considering the recurrence interval and the coefficient of skewness. In this context, Z_ave represents the mean of the logarithm series, is the standard deviation, and kz denotes the frequency factor.3.

III. RESULT AND DISCUSSION

The Teesta river basin's flood frequency has been determined by analyzing discharge data for 32 years (1979–2021). To identify the flood events associated with each annual maximum discharge, an extreme value analysis was also performed on the data. Figure 2 displays the annual maximum flow at the barrage's Dalia point.

The Figure shows that the highest annual flow was recorded in 2003, with 1998 recording the second-highest flow. The trend line, which is depicted as a dotted line and demonstrates a dramatic drop in yearly maximum flow over time, is the figure's most noticeable characteristic.

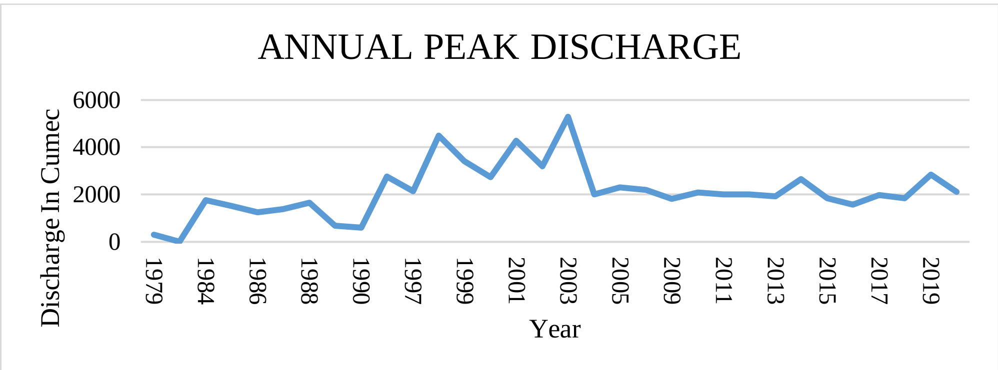

Fig. 2: Annual Peak Discharge

The Gumbel's Extreme Value Distribution and the Log Pearson Type III Distribution have been generated from the annual peak discharge series. The two techniques in Tables I and II are used separately to estimate the peak discharge for the 5, 10, 50, and 100 years return periods. Figures 3 and 4, which depict the graph with the values shown, show this.

Table 1: Estimation of the Peak Discharge (Gumble's Extreme Value Distribution)

T (Recurrence Year)	Yt	K	Xt(m3/s)
5	1.49994	0.859412	3120.958
10	2.250367	1.529856	3879.064
50	3.901939	3.005395	5547.533
100	4.600149	3.629187	6252.887

Table 2: Estimation of the Peak Discharge (Log Pearson type III Distribution)

T (Recurrence Year)	kz	$Z = Z_{ave} + kz\sigma_{n-1}$	Xt(m3/s)
5	0.636	3.525705897	3355.103
10	0.66	3.537483124	3447.332
50	0.666	3.54042743	3470.783
100	0.667	3.540918148	3474.707

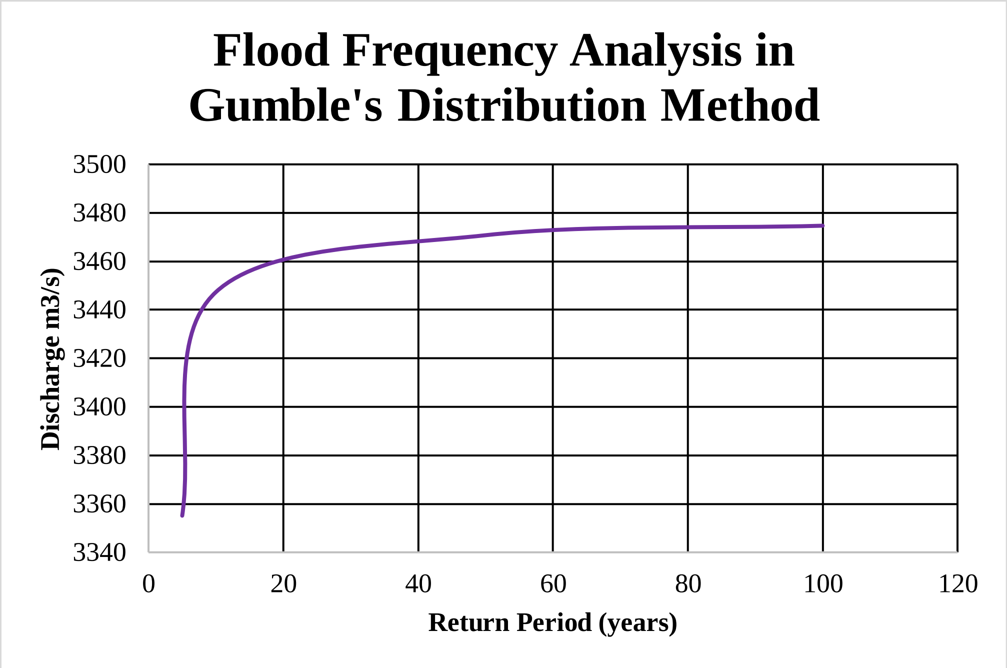

Fig. 3: Flood Frequency analysis for the Teesta River Station applying Gumbel's Analytical Method using Maximum Discharge Values

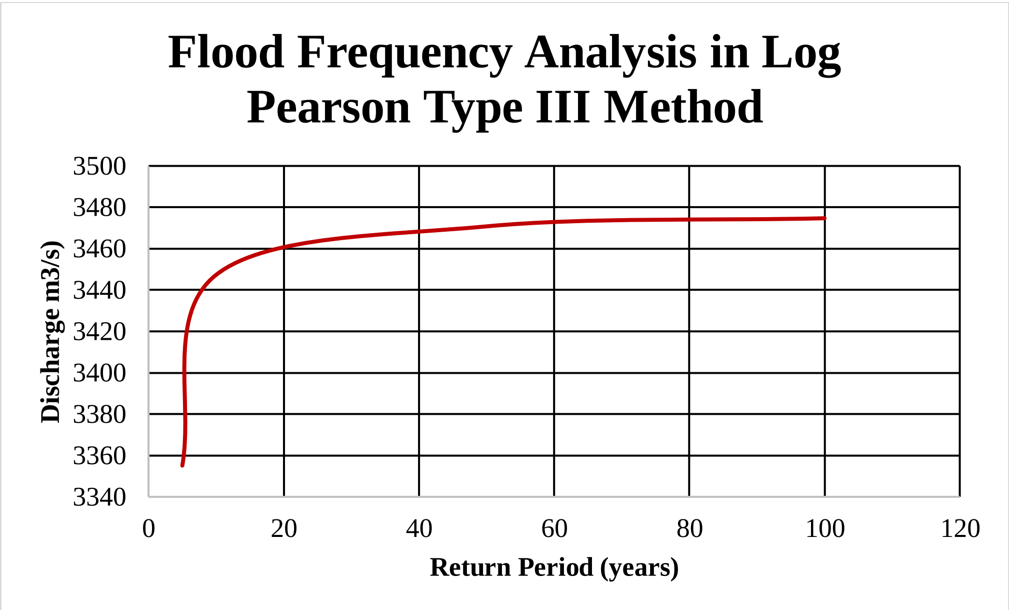

Fig. 4: Flood Frequency analysis for the Teesta River applying Log Pearson III Analytical Method using Maximum Discharge Values

IV. COMPARISONS OF FLOOD FREQUENCY ANALYSES USING GUMBLE'S DISTRIBUTION METHOD, LOG-PEARSON TYPE III

For the Teesta River, comparisons of flood frequency analyses using G, Log-Pearson Type III have been created. The table 3 shows that. This is shown in Figure 5, which depict the graph with the shown values.

Table 3: Comparison of flood frequency analysis

Time (Year Frequency)	Highest Discharge (m3/s) (Gumble Method)	Highest Discharge (m3/s) (Log Pearson Type III)
5	3120.958	3355.103307
10	3879.064	3447.332103
50	5547.533	3470.782752
100	6252.887	3474.706672

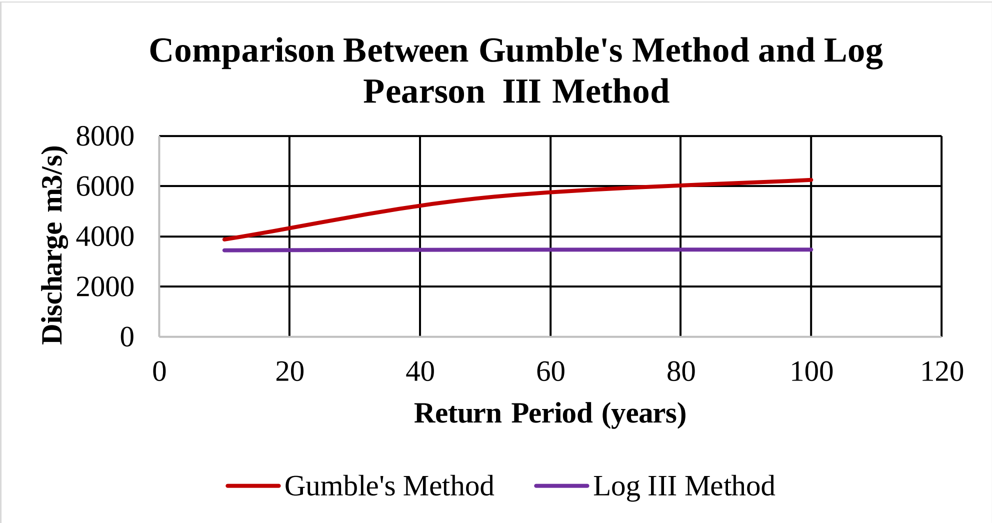

Fig. 5: Comparison of flood frequency analysis for Teesta River among Gumble’s and Log-Pearson method

The flood frequency analysis's major findings are that from above graph 3, 4 and 5 shows Gumbel's and Pearson's lines have been extrapolated to predict estimations of the magnitudes of the selected frequency of 32-year floods, or recurrence intervals of the selected magnitudes of the recorded maximum flood of the Teesta River, that are very different from each other. 3 graph shows the Gumbel's technique overestimates discharge for the selected frequency of 32-year floods while underestimating recurrence intervals for the selected greatest recorded flood. 4 graph shows for the selected magnitude and frequency, the Pearson's technique, correspondingly, overestimates the return period and underestimates discharges. Finally 5 graph shows there is a significant difference between the magnitude of discharges that expected for the selected frequency of 32 years flood and the recurrence intervals predicted for the chosen flood discharges with the recorded maximum flood discharges. From the above graphs, it can be seen that Gumble's distribution provides a more accurate result than the other approaches. The distribution provided by Gumble is more exact. Gumble's distribution provides a larger value of discharge than the other techniques in the Teesta River's discharge vs. return period graph. When analyzing the frequency of floods in the Teesta River, Gumble's Distribution and Log Pearson Type III methods should both be utilized. The Gumbel's technique is the best technique for Teesta River flash floods since it overestimates discharge and underestimates time. Accordingly, the Pearson's technique overestimates the return duration and underestimates flows that are appropriate for the river's.

According to the graph above for the Teesta River, the Gumble’s distribution provides a more accurate result than the other method. Distribution by Gumble’s is more precise. The Gumble’s distribution provides a larger value of discharge than the Log Pearson method in the discharge vs. return period graph for the Teesta River.

V. CONCLUSION

Only the Ganges and Brahmaputra have a bigger yearly runoff than the Teesta, one of the most significant trans-boundary rivers of Bangladesh. Bangladesh has long contended that the amount of water available during the dry season has been drastically decreased as a result of India building the Gazaldoba Barrage upstream of Dalia. Additionally, flooding and bank erosion in the downstream are brought on by the flow of water during the monsoon season. The main point of contention between the two nations for a very long time has been the availability of water for irrigation, especially during the lean or dry season. The annual maximum and annual mean flow at the Dalia point are decreasing, according to the examination of secondary flow data. The minimum yearly flow and water level at Dalia indicate very little water availability during the dry season. The maximum water level exhibits an upward trend, indicating a rise in flood intensity. However, a rise in maximum water level coupled with a fall in flow indicates siltation or aggradation in the Teesta Basin. Additionally, in an area already under water stress, the Teesta Basin's water balance will become more crucial given the looming threat of climate change.

The study examines the causes of flooding in Bangladesh, with a focus on both short-term and long-term processes contributing to low-frequency floods. Short-term processes encompass the immediate events associated with flooding, while long-term processes involve gradual, less obvious factors. The research centers on the Teesta River but suggests expanding to other rivers for a more comprehensive understanding. To gain deeper insights into river behavior and flood risks, the study proposes using cross-sectional data for scour analysis. Broadening the range of data sources, including precipitation, river flow, and land use changes, can enhance the understanding of flood dynamics. Increasing the number of monitoring stations along river systems can improve data collection, enabling a more detailed analysis of flood patterns. In terms of flood frequency analysis, the study explores several methods, and future research could consider alternative statistical approaches.

Additionally, given concerns about climate change, investigating its impact on water levels and flooding is crucial. Understanding the relationship between climate change and flooding is vital for assessing evolving flood patterns in Bangladesh. When analyzing the frequency of floods in the Teesta River, Gumble's Distribution and Log Pearson Type III methods should both be utilized. The Gumbel's technique is the best technique for Teesta River flash floods since it overestimates discharge and underestimates time. Accordingly, the Pearson's technique overestimates the return duration and underestimates flows that are appropriate for the river's monsoon flood. Therefore, a hydraulic structure should be built up after analyzing both ways.

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