Volume: 3 **Issue: 3** **Pages: 09-15**

Flood Frequency Analysis of Mayurakshi River: A Geographical Appraisal of Narayanpur

[1] Anwesha Mondal and *[2]Sanat Kumar Purkait

[1] Alumni & Independent Researcher, Department of Geography, Diamond Harbour Women's University, West Bengal, India.

*[2]Associate Professor & Head, Department of Geography, Raidighi College (C.U.), West Bengal, India.

Article Info.

E-ISSN: 2583-6528
Impact Factor (SJIF): 5.231
Peer Reviewed Journal
Available online:
www.alladvancejournal.com

Received: 08/Feb/2024
Accepted: 10/Mar/2024

***Corresponding Author**
Sanat Kumar Purkait
Associate Professor & Head, Department of Geography, Raidighi College (C.U.), West Bengal, India.

Abstract

Flood is one of the most significance natural phenomena which sometimes emerged as natural hazards and disasters because of its extensive ability to damage of human life and properties to access the flood situation of any river basin at difference scales it is really required to measure water level and discharge of the respective river. Flood is a frequent occurrence in the Mayurakshi River basin of Eastern India. However, in recent decades, it has become increasingly irregular, with a significant rise in frequency. The aim of this project is analysis risk of the river site Narayanpur with the help of Normal and Gumble Distribution. The data represents peak annual water level 1978-2011. Gumbel distribution with parameters estimated by method of moments has the best upper tail fit (from Table: D-Index). Hence this should be used for necessary decisions concerning maximum values. RMSE for Gumbel distribution though, is slightly higher than that of Normal distribution. This implies that Normal distribution can be used for making decisions except from maximum values. In our present setup, we are concerned about yearly maximum of gauge values. Therefore, Gumble is the more suitable option. With the help decision future construction like dam, barrage etc. will be success.

Keywords: Mayurakshi river, flood probability, normal distribution, gumble distribution, return period.

1. Introduction

The simplest definition of flooding is "an excess of water in a new location," but from a technical perspective, it occurs when water exceeds its normal boundaries and inundates an area typically dry. Flooding is a natural event where a piece of land or area that is usually dry suddenly becomes submerged under water. While some floods can happen abruptly and recede swiftly, others develop gradually, taking days or even months to build up before discharging.

Here flood mean a peak height water level of annual at river site of Mayurakshi River. For future development planning programme we need to risk analysis of flood. That make those programme in secure for future. In this project used two distribution-

1. Normal distribution.
2. Gumble distribution.

Extreme Value Theory finds extensive application among researchers in various applied sciences for modeling extreme values in phenomena like ocean wave behavior, wind engineering, earthquake thermodynamics, and risk assessment in financial markets. Initially, research focused on independent observations; however, contemporary models for extreme values now incorporate the more realistic consideration of temporal dependence. The Gumbel distribution holds particular significance in practical applications owing to its behavior in extreme value scenarios. It is utilized either as the primary distribution or as an asymptotic approximation to characterize extreme wind speeds, sea wave heights, floods, rainfall, age at death, minimum temperature, drought-related rainfall, electrical strength of materials, air pollution issues, geological challenges, naval engineering, and other relevant domains.

2. Location of the Study Area

The River Mayurakshi, spanning a catchment area of 5325 sq. km. with a length of 288 km, extends from 23°15’N to 24°34’15’’N latitude and 86°58’E to 88°20’30’’E longitude. Classified as a 5th order rain-fed tributary of the Bhagirathi, the Mayurakshi River holds significance in the flood dynamics of West Bengal, serving as a transitional zone between the physiographic provinces of the Chottanagpur plateau fringe and the Bengal basin. This is well-documented in studies by Konar (2008), Saha (2011), and Bhattacharya (2013).

Originating from Trickut Pahar in Jharkhand, the river meanders southeastward, incorporating tributaries such as Motihari, Dhobi, Pusaro, Bhamri, Tepra, Kushkarani, Sidhweswari, among others, in its upper course (O’Malley, 1914). The lower catchment exhibits a complex network of tributaries, distributaries, anabranching loops, and spill channels, including the Manikornika, Gambhira, Kana Mayurakshi, Mor, Beli or Tengramari, which converge into the Hizole wetland in Murshidabad district. From Hizole, the river Babla commences its journey, ultimately flowing into the Bhagirathi (Mukhopadhyay and Pal, 2009).

Geologically, the catchment undergoes Dharwanian sedimentary deposition in the upper part, Hercinian orogeny, lateritic soil, and hard clay deposition in the middle, and recent alluvial deposition in the lower regions. With relief ranging from 12 m to 400 m, the basin constitutes the farthest eastern extension of the Chotonagpur Plateau in the West and the Moribund Delta in the East, commonly referred to as Rahr Bengal (Bagchi and Mukerjee, 1983; Biswas, 1987). Morphologically, the basin features rolling uplands and lateritic badlands in the upper part, followed by undulating plantation surfaces and low-lying flat and depressed lands in the middle and lower parts. The lower catchment's depressed and flat slope renders it highly susceptible to prolonged flood stagnation and frequent flood incidents (Pal, 2010).

This region preserves imprints of Late Pleistocene ferruginous formations and remnants of tropical deciduous forests. The catchment experiences a dry, mild, sub-humid, and subtropical monsoonal climate, with rainfall varying between 829 mm and 2179 mm, influenced by elevation, during the period 1901-2013. The South-West Monsoon (June to September) contributes over 80% of the total annual average rainfall, leading to water accumulation in the lower catchment of the basin.

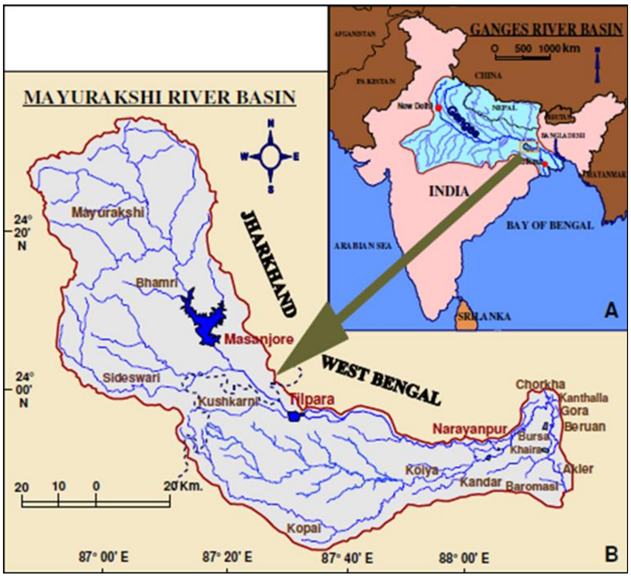

Fig 1: Location Map of the Mayurakshi River Basin

3. Objectives of the Study

1. To make inference about flood level at the site, so that future development work and different safety measure regarding local people and their properties can be done will ensure. Development works can be done with least cost labour and time keeping its safety factor uncharged.
2. Any flood variable is random variable in character in statistical analysis. That is its value are uncertainly in occur therefore we require statistical analysis to make their inference about their true nature.

4. Databases and Methodology

Annual heighest level of flood (m) of Mayurakshi River at Narayanpur river site since 1978-2011 have obtained from Irrigation and water ways department, Kandi, Murshidabad (2011). Using the statistical analysis of given data processes for flood frequency analysis of the particular river site of Mayurakshi river. For the analysis of flood frequency analysis use two statistical distribution-

1. Normal distribution
2. Gumble distribution.

Table 1: Worksheet for Flood probability assessment

Years	Annual Highest Level of Flood (m)
1978	31.1
1979	26.28
1980	26.55
1981	26.94
1982	25.89
1983	27.24
1984	23.79
1985	26.62
1986	27.82
1987	28.5
1988	26.12
1989	26.32
1990	26.8
1991	25.15
1992	27.23
1993	27.54
1994	27.12
1995	26.33
1996	27.02
1997	27.14
1998	26.73
1999	29.35
2000	29.79
2001	25.98
2002	25.77
2003	24.25
2004	28.57
2005	24.65
2006	27.77
2007	27.15
2008	25.68
2009	24.81
2010	23.78
2011	24.72

Source: Irrigation and Water Ways Department, Kandi, Murshidabad (2011).

5. Relevance of the Study

1. Help of the flood probability assessment we reside that in future return period what should be the peak level of water.

2. From the value of return period the future development planning will be success in that river site, such as barrage, dam etc.
3. The analysis give security of future planning.
4. A forecasting giving by that process.

6. Limitation
1. Limitation of data source of flood related at particular river site.
2. Lack of time to collected the data from various office and calculation for the data.
3. Confusion about used of various flood related analysis distribution.

7. An Overview of Literature
- Accurate estimates of flood frequency are crucial for effective floodplain management. This is essential for safeguarding the public, minimizing flood-related costs for both government and private entities, designing and situating hydraulic structures, and evaluating hazards associated with floodplain development (Tumbare, 2000). However, determining flood flows at various recurrence intervals for a specific site or group of sites remains a common hydrological challenge. While numerous statistical distributions have been applied to assess the probability and intensity of floods, none has gained universal acceptance applicable to all countries (Law and Tasker, 2003). Flood frequency analysis entails fitting a probability model to the sample of annual flood peaks recorded over an observation period in a catchment within a given region. The established model parameters can then be utilized to predict extreme events with large recurrence intervals (Pegram and Parak, 2004).
- The normal distribution is a widely employed model for fitting general data derived from natural phenomena. In frequency analysis, it is commonly used to fit empirical distributions to hydrological data and for data simulation. Given that many statistical parameters exhibit an approximate normal distribution, it is frequently employed for statistical inferences. An early instance of applying the normal distribution to hydrological variables was pioneered by Hazen (1914), who introduced the normal probability paper for the analysis of hydrologic data. Markovi (1965) discovered that the normal distribution could effectively fit the distribution of annual rainfall and runoff data. Additionally, Slack et al. (1975) demonstrated that, in the absence of specific information regarding the distribution of floods and economic losses associated with flood reduction measures, the use of the normal distribution outperforms other distributions such as extreme value, lognormal, or Weibull.
- Recently, several q-type distributions, including q-exponential, q-Weibull, and q-logistic distributions, along with various pathway models, have been introduced in fields such as information theory, statistical mechanics, and reliability modeling. The q-exponential distribution is conceptualized as an extended model (Beck (2006), Beck and Cohen (2003)) of the exponential distribution, where the exponential form is attained as q approaches 1. A significant theorem applicable to stress-strength analysis was established by Jose and Naik (2009). They applied this model to data concerning the remission times of cancer patients, comparing it with the Weibull and q-Weibull models. The comparison affirmed that the q-Weibull model provides a superior fit.

The Gumbel distribution, a statistical technique commonly employed to forecast extreme hydrological occurrences like floods, has been utilized in this investigation for flood frequency analysis. This choice is informed by the river's minimal regulation, indicating limited influence from reservoir operations, diversions, or urbanization. Additionally, the flow data exhibit homogeneity and independence, lacking long-term trends. The peak flow data encompass a relatively extensive record of more than 10 years, characterized by high quality. Furthermore, the river lacks major tributaries whose inflow might impact the flood peak.

8. Flood Frequency Analysis
River: Mayurakshi
Site: Narayanpur
Position: 24.10’59.34” N, 88.09’56.80” E
Data: Yearly maximum gauge data of 34 years from 1978 to 2011 collected from the office of The Narayanpur

Fig 2: River site of Narayanpur.

8.1 Distributions Used
1. Normal distribution.
2. Gumbel (GEV1) distribution.

Parameter Estimation
Method of moments: Parameters are found by equating the theoretical moments to the sample moments.

8.2 Test for Goodness of Fit
To meet the requirement of frequency χ^2 test, classes are formed in a way that expected frequency in each class is at least 5. The probability of an observation falling in any class is taken to be 0.2.
We test H: Data fits the distribution, against K: Data does not fit the distribution,

Test statistic: $$\chi^2 = \sum_{i=1}^{k} \frac{(f_{0i} - f_{ei})^2}{f_{ei}} \sim \chi^2_{k-1-m}$$ …………. (eq.i)

Where, f_{0i} and f_{ei} are the observed and expected frequencies of the i^{th} class
k = the number of classes
m = the number of estimated parameters of the distribution.

8.3 Choice of the Better Distribution
Since we are concerned with maximum values, we consider upper tail-based method by D-Index.
Let, $x^{(1)} \geq x^{(2)} \geq \ldots \geq x^{(n)}$
The initial estimate of probability of non-exceedance (plotting position) is taken as given by Weibull,

$\overline{p}_i = \frac{i}{n+1}$. Let, $F(o_i) = 1 - \overline{p}_i$

Then, D-Index = $\frac{\sum_{i=1}^{6} |o_i - x^{(i)}|}{\overline{x}}$ ……………… (eq.ii)

Another measure is *root mean square error* (rmse), which is most commonly used for comparing overall performance.

RMSE = $\sqrt{\sum_{i=1}^{n} \frac{(o_i - x^{(i)})^2}{n}}$ …………… (eq.iii), but we will not use it here.

8.4 Statistical Risk Analysis

8.4.1 Return Period

The return period of an observation exceedance is the reciprocal of the probability of exceedance in one year. This can be interpreted as the expected time between two consecutive exceedances of a flood event.

Let, X= annual maximum and *F = P(X<=Q(F))*

Return period of *Q(F) is T =1/(1-F)……………..(eq.iv)*
Or, *F=1-1/T.*

The Probabilities

Let, $p = \frac{1}{T} = 1 - F$ is the probability of exceedance in one year
and Y= number of exceedances in *T* years.

Then, the probability that X will exceed *Q(F) r*-times in *T* years is

$$P(Y = r) = \binom{T}{r} p^r (1-p)^{T-r}; r = 0,1,..,T \quad \text{\_\_\_\_\_\_\_\_(1)}$$

Therefore, the probability that X will exceed *Q(F)* at least once in *T* years is

$$1 - P(Y = 0) = 1 - (1-p)^T = 1 - F^T$$

And, the probability that X will exceed *Q(F)* exactly once in *T* years is

$$P(Y = 1) = T.p(1-p)^{T-1} \quad \text{…………………..(eq.v)}$$

8.4.2 Error Estimation and Asymptotic Confidence Intervals

Let, $F(x_T) = 1 - \frac{1}{T}$ be the probability of having a flood event of magnitude x_T or smaller corresponding to the return period *T*.

Then the standard error of x_T is

$$s_T = \sqrt{E\{\hat{x}_T - E(\hat{x}_T)\}^2} \text{ ………(eq.vi), where } \hat{x}_T$$

is the sample estimate of x_T .

An asymptotic $(1-\alpha)\%$ confidence interval for x_T is given $\hat{x}_T \mp \tau_{\alpha/2} s_T$, where τ is a standard normal variate.

8.5 Analysis

Descriptive Measures of Sample Data

Data size *(n)* = *34*, Data mean $(\overline{x})$ =*26.661765*,
Data standard deviation (s) = *1.6091274*,
Data skewness (g_a) = 0.46130359

8.5.1 At Site Analysis through Normal Distribution

P.D.F. = $\frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{x-\mu}{\sigma})^2}, -\infty < x < \infty$ ……………(eq.vii)

Location parameter = $\mu, \ -\infty < \mu < \infty$

Scale parameter = $\sigma, \ \sigma > 0$

Analysis with Parameters Estimated by Method of Moments

$\hat{\mu} = \overline{x} = 26.661765$

Estimate of σ is $s = 1.6091274$

But, s being a biased estimator of σ, we use the unbiased estimator $\sqrt{\frac{ns^2}{n-1}}$ to estimate σ.

Hence we take, $\hat{\sigma} = 1.633326$.

Test for Goodness of Fit

Since the probability of an observation falling in any class is 0.2 the expected frequency for each class is 0.2*n = 6.8.

Table 2: Worksheet for the observed frequency in different class

Class	Observed Frequency
<25.287391	7
25.287391-26.248642	5
26.248642-27.074887	9
27.074887-28.036138	8
28.036138 <	5

$\chi_2^2 = 1.8823529$, p-value $= 0.39016904, df = 2$

Decision: For the test H: Data fits Normal distribution, against K: Data does not fit Normal distribution,
H is accepted at both 5% and 1% level of significance.

Quantile Estimation

For a given return period T, we calculate a variable *u* as,

$$u = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3} + \varepsilon(P) \text{ ………………..(eq….viii)}$$

Where,

$C_0 = 2.515517, \quad d_1 = 1.432788$
$C_1 = 0.802853, \quad d_2 = 0.189269$
$C_2 = 0.0100328, \quad d_3 = 0.001308$

$W = \sqrt{-2ln(P)}$ for P < 0.5, where P=1-F

For P > 0.5, we replace P by (1-P) and *u* by *(-u)*.

$\varepsilon(P)$ is small and can be ignored.

Then the quantile estimate is

$\hat{x}_T = \hat{\mu} + u.\hat{\sigma}$

Table 3: Worksheet for the quantile values for different return periods

T=Return Period (yr)	Quantile (mt)
5	28.036138
10	28.755246
20	29.348932
50	30.016925
75	30.282531
100	30.462164

8.5.2 At Site Analysis Through Gumbel (GEV1) Distribution

$$\text{P.D.F.} = \frac{1}{\alpha} e^{\left[-\left(\frac{x-\beta}{\alpha}\right) - e^{-\left(\frac{x-\beta}{\alpha}\right)}\right]}, \quad -\infty < x < \infty \text{ (eq…..ix)}$$

Location parameter $= \beta, \; -\infty < \beta < \infty$

Scale parameter $= \alpha, \; \alpha > 0$

Analysis with Parameters Estimated by Method of Moments

$$\hat{\alpha} = \frac{\sqrt{6}}{\pi} s = 1.254631$$

$$\hat{\beta} = \bar{x} - 0.45005 s = 25.93758$$

Test for Goodness of Fit: To meet the requirement of frequency χ^2 test, classes are formed in a way that expected frequency in each class is at least 5. The probability of an observation falling in any class is taken to be 0.2. Expected frequency for each class is 0.2*n = 6.8.

Table 4: Worksheet for the observed frequency in different classes

Class	Observed Frequency
<25.34052	7
25.34052-26.047262	4
26.047262-26.78035	7
26.78035-27.819451	10
27.819451<	6

$\chi^2_2 = 2.7647059$, p-value $= 0.2509878, df = 2$

Decision: For the test H: Data fits Gumbel distribution, against K: Data does not fit Gumbel distribution, H is accepted at both 5% and 1% level of significance.

Quantile Estimation

$$\hat{x}_T = \hat{\beta} - \hat{\alpha}.ln\left[-ln\left(1 - \frac{1}{T}\right)\right] \text{ (eq…..x)}$$

Table 5: Worksheet for the quantile values for different return periods

T=Return Period (yr)	Quantile (mt)
5	27.819454
10	28.760962
20	29.664079
50	30.833073
75	31.346023
100	31.70907

8.6 Choice of the Better of Distribution

Table 6: Worksheet for the D-index ans RMSE values for different distubutions

Distribution	Method of Parameter Estimation	D-Index	RMSE
Normal	Method of Moments	0.10790662	0.32585167
Gumbel	Method of Moments	0.069318249	0.32959636

From the above table we can say that, for the given sample, Gumbel distribution fits the data better on the basis of the upper tail, when its parameters are estimated by method of moments.

Hence, for this site, Gumbel distribution should be used for necessary purposes concerning maximum values.

8.7 Error Estimation and Asymptotic Confidence Intervals using Gumbel Distribution

For the Gumbel distribution,

$$s_T = \frac{\alpha}{\sqrt{n}} \sqrt{1.15894 + 0.19187Y + 1.1Y^2},$$

$$Y = -ln[-ln(1 - \frac{1}{T})]$$

The following table shows the quantiles with their standard errors and 95% confidence intervals, probabilities of exceedances at least once $(p\_\neq 0)$ and exactly once (p_1) for the best fit distribution corresponding to different return periods.

Table 7: Worksheet for Standard Errors and Confidence Intervals.

T=Ret.Period (yr)	Quantile (mt)	Std. Error	95% Conf. Int.		P_=0	P_1
5	27.81945121	0.426093224	(26.98431,	28.65459)	0.67232	0.4096
10	28.76096061	0.575800552	(27.63239,	29.88953)	0.651322	0.387420489
20	29.66407904	0.727542726	(28.2381	31.09006)	0.641514	0.377353603
50	30.8330732	0.929345089	(29.01156	32.65459)	0.63583	0.371601714
75	31.34602338	1.018976205	(29.34883	33.34322)	0.634587	0.370351211
100	31.70906982	1.082681019	(29.58702	33.83112)	0.633968	0.369709638

Discussion

For the Narayanpur Site of River Mayurakshi, for the Given Data Set, Some Observations on the Analysis Are Given Below

1. Gumbel distribution with parameters estimated by method of moments has the best upper tail fit (from Table: D-Index). Hence this should be used for necessary decisions concerning maximum values.
2. RMSE for Gumbel distribution though, is slightly higher than that of Normal distribution. This implies that Normal distribution can be used for making decisions except from maximum values.
3. In our present setup, we are concerned about yearly maximum of gauge values. Therefore, Gumble is the more suitable option.

Conclusion

West Bengal is vulnerable to natural calamities like flood, cyclone, hail storm, thunder squall, drought, landslides and sometimes to earthquakes because of its geo-morphologic, climatic and seismic conditions. Floods and Cyclonic storms occur almost every year in different parts of the State and bring untold hardships and trauma in the lives of the people. In spite of all our preparedness, the economic and social cost on account of the loss in these disasters have been mounting every year. In the flood of the year 2000, the State had to spend almost Rs.477 crores on account of relief, restoration and rehabilitation works. The most affected by such disasters are the poor and the socially disadvantaged groups because they are the least equipped to cope with them.

Flood event shatters the and economy especially that of rural Bengal. The event is called hazard because of socio-technical failure to cope with the extreme natural event. About 42% area of West Bengal is officially declared as flood prone. But in spite of no appreciable change in the rainfall pattern, the flood prone area has been increasing and now more than 70% area of the State is vulnerable to flood (State Environment Report, 2009, Water Resource and its quality in West Bengal).

Effective flood management in any tropical and developing nation poses a challenge for a single organization. Floods present a multidisciplinary challenge where societal involvement is crucial. By engaging local communities and leveraging their knowledge to formulate a disaster management plan that incorporates scientific data, we can bridge the communication gap between residents and decision-makers in irrigation network planning. Planning should be centered on benefiting the people through their experiences, a principle that must be strictly followed. Studies on people's perceptions of flooding along the banks of the Mayurakshi River highlight the existing functional gap between the perspectives of flood victims and flood management authorities. If this gap is appropriately addressed, viable solutions to this enduring problem may emerge.

In our country, floodplain planning has recently gained attention, and the central government has formulated a model bill providing guidelines for regulating urban and rural developments in floodplains. The effective utilization of methods like Gumbel’s or Dickens’s formula can significantly contribute to achieving this goal. Efficient management of the entire Mayurakshi River basin's floods can be realized through the proper implementation of flood frequency analysis, probable peak discharge analysis, and catchment area analysis based on the barrage discharge from Tilpara, which serves as the principal regulator of floods in the entire basin. Unfortunately, floodplain zoning through these numerical processes has not been carried out in the Brahmani River catchments, mainly due to the ignorance of the West Bengal irrigation department. Consequently, floods occur frequently in an unsustainable manner. If these measures are appropriately executed, the flood-related challenges in this river basin will cease to be a persistent concern for its residents.

This work will add new dimension to the academic encyclopedia of research work. The changing hydrological situation and its impact and justification will give a basic frame work to the planner and policy makers when plan regarding drainage hydrology, wetland hydrology, canal plan and agro-economic development is going to be adopted. Moreover, the suggestions of this work to manage hydro-agrological resources also will help them to tally during decision making. Common people will get real idea what is the present scenario of the water use status as irrigation, pattern of land use change which they are performing, its positive and negative impacts etc. It will also guide them how shifting of river, spread of canal, wetland etc. are influencing the land use evolution and how land use pattern should be linked with hydrological evolution. All these will again help them to take decision how to behave with hydrological system dynamics.

Gumbel distribution with parameters estimated by method of moments has the best upper tail fit (from Table: D-Index). Hence this should be used for necessary decisions concerning maximum values. RMSE for Gumbel distribution though, is slightly higher than that of Normal distribution. This implies that Normal distribution can be used for making decisions except from maximum values. In our present setup, we are concerned about yearly maximum of gauge values. Therefore, Gumble is the more suitable option.

Major Findings

a) Flood flows exhibited considerable variability, with a slight upward trend in yearly peak discharges. Notably, there is a discernible pattern of high and low flows, with particularly intensive flow characteristics observed between 1998 and 2007.
b) The frequency of flood events has increased following the construction of the Masanjore dam and Tilpara barrage.
c) The regulatory impact of rainfall on flood flow is relatively limited, owing to anthropogenic interventions facilitated by the Tilpara barrage. However, rainfall beyond a critical threshold remains the primary factor influencing barrage discharge and, consequently, contributing to flood events in the current river basin.
d) Effectively managing floods in tropical and developing countries poses a significant challenge for any single agency or organization. Floods are characterized by a multidisciplinary nature where societal participation is crucial. Due to limitations in accurately predicting rainfall, flood forecasting faces challenges in achieving high precision. Engaging local communities and leveraging their knowledge to formulate a disaster management plan, complemented by the integration of scientific data, holds the potential to address some of the uncertainties associated with disaster management.
e) The recent investigation has provided fresh perspectives on the flood patterns and occurrence along the Mayurakshi River, specifically at the Narayanpur river

site. Notably, a consistent pattern of alternating high and low peak flows has been identified in the lower Mayurakshi river basin. A significant surge in flow occurred subsequent to the establishment of the Masanjore dam and Tilpara barrage. These vital anthropogenic structures have played a constructive role in mitigating floods by effectively storing water in their reservoirs. However, instances of excessive rainfall and brimming reservoirs have, at times, triggered extensive flooding events in the river basin's flood history.

Furthermore, while the hydro-engineering structures, such as the dam and barrage, have succeeded in moderating peak floods, they have concurrently heightened the occurrence of medium-small scale subnormal floods. The likelihood of floods has increased notably between September and October, aligning with a shift in the annual peak flow towards these late or extended monsoonal months. The insights provided herein can serve as a foundational resource for emerging scholars and offer decision support for relevant implementations.
The proposition of expanding the network of river gauge stations and implementing systematic data recording is essential. Such measures would undoubtedly contribute to the development of more pragmatic flood models. Importantly, the transformed fluvial system is anticipated to exert a considerable impact on downstream hydrology and geomorphology, leading to alterations in riparian ecosystems. River researchers and managers are encouraged to consider these transformations as they strive towards optimal restoration measures.

References

1. Ankur Patrika. Annual journal of Purandarpur. Kadi, Murshidabad, 2002, 24-26.
2. ARPN Journal of Earth Science. June, 2015.
3. Rao. AR, Hamed KH. Differennce works of J. K. M. Hosking.
4. Bhattacharya A. Evolution of the Hydro-Geonomic Characteristics of Flood in the Mayurakshi river basin of Eastern India, 2013.
5. Birbhum District Gazeteer, 1975.
6. Dhar ON, Nandargi S. Hydrometeorological aspects of floods. Nat.Hazards. 2003; 28(1):1-33. doi: 10.1023/A:1021199714487.
7. Engineering Group. Probable Maximum flood. The Ohio Department of Natural Resources, Division of Water and Dam Safety. Columbus, 2004.
8. Ghosh S. Estimation of flash flood magnitude and flood risk in the lower segment of Damodar River basin, India, 2013.
9. Kandi Area IWD. Flood protection Scheme: Report of the Technical Committee, 1992.
10. Mukhopadhyay S, Pal S. Impact of Tilpara Barrage on the Environment of Mayurakshi Confluence Domain-A Granulometric Approach. Indian Journal of Geomorphology. 2009; 14(1, 2):179-187. n Floods.
11. Pal S, Let S. Channel Morphological Trend and Relationship Assessment of Dwarka River Eastern India. Global Journal of Applied Environmental Science. 2011; 1(3):221-232.
12. Pal S. Changing Inundation Character in Mayurakshi River Basin: A Spatio Temporal Review. Practicing Geographer. 2012; 14(1):58-71.
13. Pal S. et al. Assessment of channel width disparity of the major river within Mayurakshi river basin, 2012.
14. Richards KS. Hydraulic geometry and channel roughness-a non-linear system. American Journal of Science 273, 1973, 877-896.