

## ABSTRACT

**Title: Human and River Interactions in Riparian Villages along the Tista River of Jalpaiguri and Koch Bihar District, West Bengal**

### **1. Introduction**

Due to its limited supply and vulnerability, issues over water allocation are becoming increasingly serious on a global scale as a result of population increase and rising income levels. It should be necessary to manage the water resources judiciously, which is helpful to the riparian inhabitants and the river's natural environment. The river water plays a beneficial activity to the adjacent people along it. Therefore, the river basin can be called the most suitable location for economic prosperity. Without supportive factors, the dwellers can't settle along the river. Human-Resource symbiosis is a common phenomenon in a river basin. Human and river interactions have a significant impact on the environment and societies around the world. The socio-economic life of the people of West Bengal, mainly in the northern part influenced by the Tista. Different aspect of the social life of the riparian people along the Tista River is interrelated with the river. The government focuses on the River Tista to utilise its water by hydroelectric power generation, facilitate irrigation for agricultural development, increasing the tourism industry and recreational activities for the benefit and better opportunities of the stakeholders. In this present research work, attempts have been made by the researcher to explain the people's interactions with the River Tista and its impact on their socio-economic life.

Continued population growth in the riparian areas of the river and interferences on the health of the river caused a state of environmental problems throughout the river in West Bengal. The Tista Barrage Project has introduced negative impact on the surrounding environment. The morphology and hydrological character of the river have been changed as a result of human-river interaction processes prevailing in this area. The Baikunthapur and Apalchand forest in this region has shown a decreasing trend in their area caused by human encroachment scenarios in the past fifty years. The pilot survey by the researcher in some selected places of the study area revealed that the region faced the problem of improper right bank and left bank canal management at several places, abnormal waste dumping activities in the river, growing up settlements in the river bed, and the huge amount of river bed material extraction activities. The char areas of Chengmari, Takimari, Kathua, Boalmari,

Nandanpur, Domohani, Sisuabari, Chat Rarpur, Nijtaraf, Bajejama Khasbas have been congested by the inhabitants, and they have changed the land use pattern and interferences the natural environment of the river. The main goals of the current study are: (i) To study on the physical set up of the region and socio-economic condition of the riparian inhabitants for better understanding of human and river interactions in the study area, (ii) To assess the role of the Tista River on the livelihood of the riparian inhabitants, (iii) To assess the effect of the riverine hazards like floods, bank erosion and river channel shifts on socio-economic life of the riparian inhabitants, (iv) To assess the human interferences on the Tista River at several sites and (v) To study on perceptions of the riparian inhabitants concerning the Tista River. The hypothesis of this research taken into consideration are: (i) There are livelihood dependencies of the riparian inhabitants on the River Tista, (ii) The inhabitants have suffered from occasional floods, bank erosion and river channel shifts, (iii) Human interferences have affected the nature of the River Tista and (iv) Awareness of the riparian inhabitants have affected their living standard.

## **2. Study area**

The present study has been confined to the riparian villages along the Tista River, which occupy the Jalpaiguri and Koch Bihar Districts in West Bengal of India. In Jalpaiguri and Koch Bihar District along the Tista River total number of riparian villages considered for this study is 85 (23 from the right bank and 62 from the left bank). Physically, the study area is characterised by 30-53 m elevation class,  $<2^{\circ}$  slope class, very low ruggedness index (0-3.87), sand, silt and clay in lithological units (54%), geomorphologically piedmont alluvial plain (44%), very high annual rainfall, average maximum and minimum temperatures vary from 25.42 to 29.48<sup>0</sup>C and 11.32 to 18.74<sup>0</sup>C, and dominance of fluventic eutrochrepts (fine loamy) soil taxonomic character. On the other side, among the selected riparian villages, 69 villages are inhabited villages, and 16 are uninhabited villages (based on Census 2011). The total population of the selected riparian villages is 232742, and the total number of households is 52138. Socio-economically, the riparian villages have dominant SC population, low mean literacy rate (56.96%), Hindus constitute the majority in religion, mean percentage of total, main and marginal workers are 41.29%, 29.12% and 13.12%, mean percentage of net sown area is 59.28%, 39 villages had irrigation facilities, most of the villages (45) located far away from banks, and only in 28 villages the agricultural marketing society facility is available. The hydrodynamic characteristics of the region in West Bengal are controlled by the Himalayan Rivers and Tista Barrage Project at Gajaldoba.

### 3. Data sources and methodology

This research employed a multidisciplinary approach that incorporated both quantitative and qualitative techniques to attain its goals. In the targeted riparian villages along the Tista River, comprehensive fieldwork was carried out, including interviews, household surveys, and direct observations. The obtained data were analysed using thematic analysis and statistical techniques, providing a comprehensive understanding of the human-river interactions in this region.

- To investigate the physical set up (elevation, ruggedness, lithology, geomorphology, climatic condition, and soil characteristics) and socio-economic condition (demography, literacy, sex ratio, religious orientations, caste composition, occupational structure, working population, net sown area, irrigation status) of the proposed area, data were obtained from the various documents, maps, and information of different published sources.
- The role of the Tista River on the livelihood of the riparian inhabitants has been assessed by extensive and regular household survey carried out by the researcher during 2020-2022 based on Mullick et al. (2013), Baki et al. (2015) and Islam et al. (2018). The sample size for the primary survey has been estimated based on Cochran's sampling method (1963) for the finite population. The total sample size was considered 400 (responded: 381 and non-responded: 19), and the stratified random sampling technique was adopted for considering the respondent. The sample size for each village was subsequently determined using proportional allocation techniques. On the basis of certain parameters, viz., agro-climatic condition, the role of Tista in the economy of the inhabitants (natural indicator), general livelihood scenario in the overall region, demography (human indicator), inhabitants' connection with the Tista in terms of spirituality, customs, cultures (social indicator) that observed in the pilot survey, the researcher has taken into account five livelihood dimensions, viz., social, economic, physical, environmental and risk to find out the role of the Tista River on livelihood of the riparian inhabitants. The *Structural Equation Model (SEM)* of different livelihood dimensions of the inhabitants has been constructed using Amos Graphics software (version 21).
- To assess the nature and extent of the riverine hazards, several works have been conducted, viz., Flood susceptibility zonation mapping of the study area using Saaty's Analytical Hierarchy Process method, channel shifting risk-prone areas mapping and bank erosion vulnerability zonation mapping of the study area. Besides these, to know

the severity of the riverine hazard on the socio-economic life of the riparian inhabitants, livelihood vulnerability index (LVI) calculation for the riparian villages has been conducted based on data obtained from the household survey by employing the LVI and LVI-IPCC framework of Hahn et al. (2009).

- The direct and indirect effects of human interventions on the Tista River have been assessed by the researcher. The indirect effects include the detailed analysis of increasing population pressure, land use change scenario and groundwater fluctuations in the riparian villages of the Tista. On the other side, direct effects were studied by investigating the river bed materials extraction activity, the negative impact of the Tista Barrage Project, interventions of the Tista River by embankments and spurs, water quality assessment and channel transformation and habitat modification of the Tista River using River Habitation Survey (RHS) method used by Raven et al. (1998).
- The household survey data regarding the level of agreeeness and disagreeeness of the riparian inhabitants was also used to evaluate the perceptions of the inhabitants concerning the Tista River based on Eniko (2002), Birkholz (2009), Strydom (2009), Groot et al. (2009). In respect of this purpose, eight constructs were formulated, and their reliability was tested by observing the value of Cronbach's alpha. The eight constructs are: (a) Perception of communities' association with the linear nature of the Tista River, (b) Perception concerning the availability of information on the Tista River, (c) Understanding the benefits (goods and services) and perception connection to use aspects of the Tista River, (d) Perception concerning the significance or value of the Tista River, (e) Perception concerning the health of the Tista River, (f) Perception of human interferences on Tista River, (g) Perception on conservation and management of the Tista River and its water resources, and (h) Understanding the inhabitants' opinion on participation in Tista River management activities.

#### **4. Results and discussion**

- **Role of Tista River on the livelihood of the riparian inhabitants**

The socio-economic life of the people has been formed with the diversified livelihood pattern of an area. The study area is agro-climatically rich, and Tista irrigation canals, with their distributaries, have made input to develop the agricultural prosperity of the region. Several positive and negative variables have affected riparian inhabitants' different dimensions of livelihood. Here inhabitants are also socio-culturally connected with the river, and hence

river affects their livelihoods. The culture and tradition of the inhabitants have been intimately involved with the occupation inter-related with the Tista River. Interviews with the local inhabitants revealed that the '*Dotra Danga*' song is a well-known folk song of the fisherman (Jele) and reflects the connections between culture, occupation, and the Tista River. Villages like Tangmari, Putimari, Darikamari, Folimari, Boalmari, Takimari, Khattimari are famous, where fishing activities merge with their culture. Thus, fishing activity has a significant role in enhancing the culture of the riparian inhabitants. The household survey to figure out how dependent people are on the Tista River for irrigation purposes indicates that, with the exception of three to four monsoon months, the majority of people (60%) use river water for irrigation for five to nine months out of the year.

The Structural Equation Model (SEM) has been significantly tested based on the observed livelihood variables of the respondent riparian inhabitants. The model's CMIN/DF, NFI, RFI, IFI, TLI and CFI value shows 3.599, 0.578, 0.416, 0.785, 0.655 and 0.751, which all are maintained the good fitness of the model. Moreover, as the RMSEA value is less than 0.07, therefore it can be said that the model is fitted with the analysis. The SEM manifests a positive association between respondents' economic, social, physical, risk and environmental livelihood dimensions. Thus, it is proved that there are interdependencies among the different dimensions of livelihood of the riparian inhabitants, which are directly and indirectly connected with the Tista River.

- **Riverine hazards and its effects on the socio-economic life of the riparian Inhabitants**

The prevailing riverine hazards (viz., floods, bank erosion and river channel shifts) in the riparian villages along the Tista River pose threats to human lives, livestock, crops, and infrastructure, causing displacement, property loss, and daily life disruptions. The produced flood susceptibility map of the study area by employing the Analytical Hierarchy Process (AHP) demonstrated that the very high and high flood area covers 14.06% and 21.02% of the total area, respectively, which indicates that the area is at a high risk of flooding. The AUC of the flood susceptibility model is 0.79, which means the model has a good level of accuracy in distinguishing between flood-prone and non-flood-prone areas. Parallely, bank erosion and river channel shifts are significant hazards faced by riparian inhabitants. The maximum distance of 4291.12 m right bank line shifting is observed during the time-frame 2013-2023, while the minimum distance of 170.49 m is noticed during 2003-2013. The

maximum distance of 3713.25 m left bank line shifting was observed during 1993-2003, and the minimum distance of 165.16 m was noticed during the period 2003-2013. The mean distance of the right and left bank line shifting from 1993 to 2023 were computed as 1399.94 m and 1381.49 m, respectively. Therefore, the rate of migration is high on the right bank of the Tista River. Based on eight field-based observed variables, the researcher identified four major bank erosion-prone sites in the studied reaches of the Tista River. In these sites, maximum active channel shifting (1993-2023) was observed between 2500 to 4700 m. After determining the bank erosion-prone sites along the Tista River, the researcher has selected five riparian villages (Domohani, Purba Sangapara and Basusuba in Jalpaiguri District and Nijtaraf (Paschim) and Dakshin Fulkardabri Kharkharia in Koch Bihar District), which are falling under the major bank erosion-prone sites and vulnerable due to the prevailing of multi-hazards.

The computed livelihood vulnerability indexed value based on Hahn et al. (2009) manifests 35 riparian villages were 'moderate vulnerable' (Indexed value 0.201 - 0.400), 14 were 'high vulnerable' (Indexed value 0.401 - 0.450), and 20 were 'very high vulnerable' (Indexed value 0.451 - 0.500). Depending on the LVI-IPCC approach, all the surveyed riparian villages belonged to the 'moderate vulnerable' class. Overall, the study area manifests 'high vulnerable' in terms of the LVI approach and 'moderate vulnerable' in terms of the LVI-IPCC approach. The socioeconomic background of the people, inadequate means of subsistence, poor health care, lack of awareness, flooding nature, and river channel migration behaviour are the primary drivers of differences in the vulnerability index. The high F statistic value and low p-value in the indexed score of LVI and flood hazards, bank erosion and river channel shifts suggest that the observed differences between groups are statistically significant.

- **Human interferences on the Tista River**

The research also evaluated the human interferences on the fluvial dynamics of the Tista River in the studied region. 35 and 24 riparian villages of Jalpaiguri and Koch Bihar District, respectively, show a positive tendency in population growth rate and increasing population pressure on lands.

The analysis of the land use and land cover change from 1991 to 2021 represents a 20% decline in vegetation cover. Sand bars and water bodies both experienced a decreasing trend in their percentage cover in the last 30 years. Overall LULC map classification accuracy for

1991, 2001, 2011, and 2021 is 88.24%, 86.42%, 87.50%, and 89.90%, respectively. Kappa values were successfully calculated for the corresponding years (86.18, 84.05, 85.30, and 88.13), which also signifies higher accuracy.

The groundwater condition of the study area portrayed that the water level reached a maximum of 10-20 mbgl in pre-monsoonal season, and the central and some portion of the north-eastern corner of the study area face the water scarcity situation.

The direct effects of human interferences depict the sedimentation rate in the studied reaches of the Tista River as about 0.014 sq. km/year. Therefore, the sedimentation rate is increased in the lower course of the Tista River due to the reduction in sediment transport capacity for the construction of the Tista Barrage Project at Gajaldoba.

In terms of the recommended area for mineral concession and mineable mineral potential, Koch Bihar has a comparatively smaller area but a higher potential. On the other hand, Jalpaiguri has a larger recommended area but a slightly lower mineable mineral potential. Channel morphology of the Tista River is altered as a result of the removal of river bed sediments, such as channel widening or depth. These modifications also resulted in channel instability, increased bank erosion, and increased likelihood of flooding.

Different parameters of the water quality of the survey sites have been assessed. Among the 25 parameters, fecal coliform concentrations are significantly higher than the safe limits (500 MPN/100 ml for bathing and 1000 MPN/100 ml for irrigation) set by the CPCB. During the monsoon period, the turbidity values at both sites are much higher than the permissible limit (>5 NTU as prescribed by the Bureau of Indian Standards (BIS) for drinking water), indicating that the water quality has significantly deteriorated during this period due to increased runoff from land due to heavy rainfall. At Site II, the Chemical Oxygen Demand (COD) values during post monsoon seasons are higher than the ideal limit (10-30 mg/l), indicating higher levels of organic pollution. The test results for Total coliform at both Site I and Site II in all three seasons exceed the acceptable limit (5000 MPN/100ml), indicating a high level of bacterial contamination in the water.

The River Habitat Survey (RHS) in six selected sections revealed that the naturalness sections (Sections A and B) have sufficient habitat quality and predominantly unmodified conditions. Among the four human intervention sections, three sections (section near Jalpaiguri Tista bridge, section near Jalpaiguri town and section near Joyee bridge) have low habitat quality and significantly modified conditions, and only one section (Gajaldoba Tista Barrage) has very low habitat quality and severely modified conditions. The human interference sections have different attribute scores compared to the naturalness sections

(based on the non-parametric Mann-Whitney U test), higher diversity index (based on the Shannon-Wiener Diversity Index), and significant differences in attribute abundance. Therefore, investigated sections of the Tista River based on the RHS method depict the human interference sections have changed the natural phenomena of the Tista River due to the direct effect of human interventions, while the naturalness sections remained the same, i.e., they did not affect the natural regime of the river.

- **Perceptions of the riparian inhabitants concerning the Tista River**

This study also examined the perception of the riparian inhabitants concerning the Tista River. For this purpose, the perception survey data of 8 formulated constructs has been considered to get the composite index value of respondents' awareness. The living standard of the respondents was measured based on household survey data of different livelihood dimensions. The mean difference between the CIRA and the CIRLS is 8121, with a standard deviation of 3580. This suggests that, on average, a higher level of awareness concerning the river is associated with a higher living standard for the riparian inhabitants. The 95% confidence interval of the difference is between 8482 and 7760, which means that we can be 95% confident that the true mean difference between awareness and living standard lies within this range. The t-value of 44.27 is highly significant with 380 degrees of freedom, indicating that the observed difference between awareness and living standard is likely due to chance. Therefore, a significant positive relationship exists between awareness of the riparian inhabitants and their living standards. Hence, we can conclude that awareness of the riparian inhabitants has affected the living standards of riparian inhabitants.

## **5. Conclusion**

Regarding environmental management, sustainable development, and enhancing the general welfare of the local inhabitants, it is essential to comprehend the interactions between people and rivers in the riparian communities along the Tista River. According to the study, the Tista River significantly impacts the social, economic, and cultural norms of the people who live along its banks. The horrors of the Tista River floods and the loss of life have often been evoked in society through the famous '*Bhawiaya gann*' (folk song) of the riparian inhabitants. Based on the research findings, a number of policy implications and recommendations can be made to address the problems and promote sustainable development in the region. To maintain the trend of development, it is very needful to implicate the vision, objectives and proposed land use plan of the 'Gazaldoba Development Authority' (GDA). Promote riparian

inhabitants to actively participate in and be involved in river management decision-making processes. This can be done by forming community-based organisations, encouraging forums for discussion, and incorporating conventional ecological knowledge into planning and policy creation. To restore and safeguard the riverine ecosystems, this may involve the implementation of erosion control techniques such as building retaining walls, using bioengineering techniques, and planting vegetation along the riverbanks, wastewater treatment systems, and reforestation initiatives. An effective flood warning system needs to be developed for the overall riparian villages in Jalpaiguri and Koch Bihar District so that everyone can take proper management to minimise their vulnerability. The study area has abundant natural resources, and it is potential for further economic development. The findings of this thesis provide valuable insights into the complexities of human-river interactions in riparian villages along the Tista River. These insights have implications for policymakers, environmental agencies, and community-based organisations as they strive to promote sustainable development and address the challenges faced by these communities.