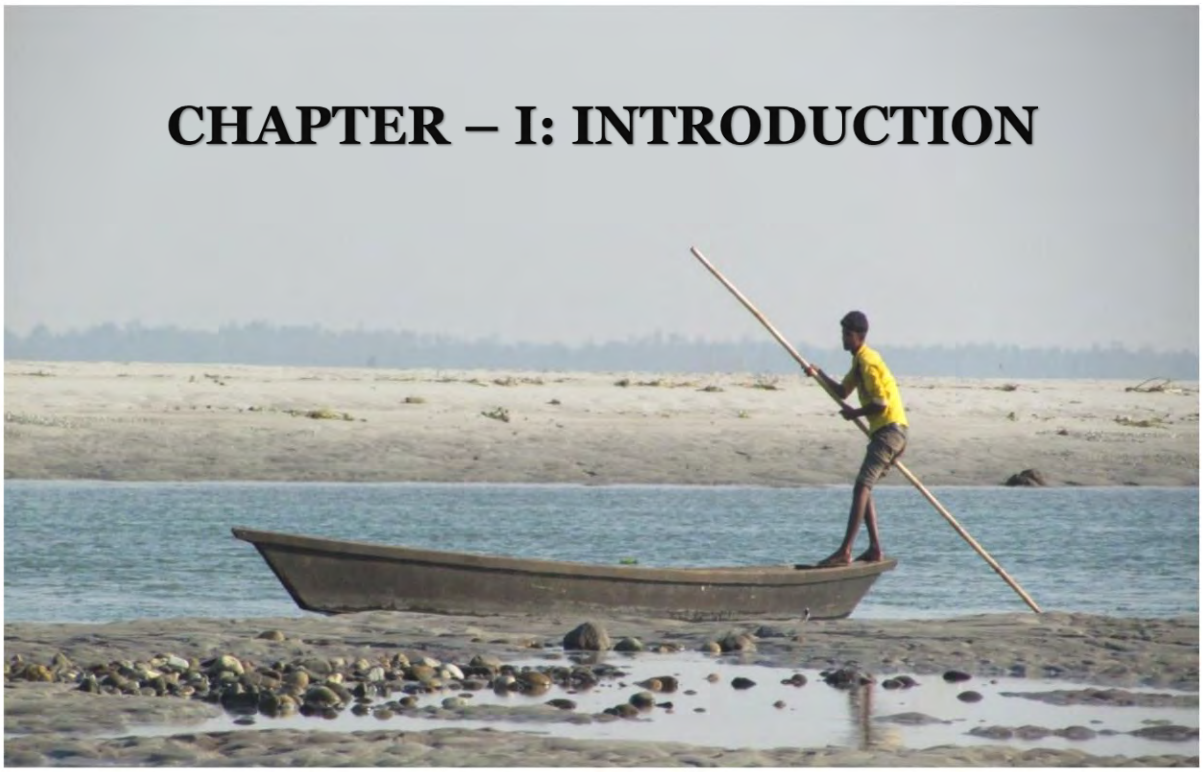
# CHAPTER – I: INTRODUCTION



## Chapter Highlights:

- Manifests the problems of the riparian villages along the Tista River.
- Research objectives and hypothesis.
- Relevant literature review.
- Methodological framework of the research.
- Expected outcomes of the research.

# **CHAPTER I:** INTRODUCTION

## 1.1 Introduction

Interactions between human and river is a mutual process in the natural system of the Earth. Human-Resource symbiosis is a common phenomenon in a river basin (Dasgupta, 2013). Human beings are the most important creation of the Earth and have started their journey with the first interaction with nature. With the passage of time, interaction has been increasing and reaching higher levels in its scope and extent. The interaction processes have different directions and aspects of reality. There is mutual adjustment between humans and the environment as their relationship is coevolution and coadaptative type (Lill et al., 2006). River water has multiple uses in society. The river water can be used as a source of water supply for drinking, industrial, municipal and irrigation purposes, recreational activities, fishing, navigation and it has some aesthetic value. River provides various facilities to the people who are settled along it. Rivers have an influence on the customs, ideas and social behaviour of a particular person or society (Wantzen et al., 2016). A particular community of people worshipped rivers as God viz., '*Tista Burir Puja*' is celebrated by both the Rajbhanshi and Bengali communities to worship the Tista River, which constitutes the lifeline of Jalpaiguri District (Attractions of Jalpaiguri, 2018). The earliest recorded river valley civilisation of the world was found in Mesopotamia, starting to form around 4000 BCE in the basin of the Tigris and Euphrates of the Middle East (Kuiper, 2011). Others were the Egyptian civilisation of the Nile River, the Indus Valley civilisation of the Indus River, Huang-Ho River civilisations of the Yellow River. These civilisations are denoted as a *hydraulic empire* or *hydraulic despotism* by Karl August Wittfogel in his book '*Oriental Despotism'* (1957), as rivers play a major role in the growth of the civilisations. It can be said that human beings depend on the river economically, morally, emotionally, ecologically, politically, etc. Interdependencies of humans and rivers in the natural environment is a worldwide concept and various authors worked on it like Birkholz (2009) on the Kant River, Strydom (2009) on the Buffalo and Hartenbos and Klein Brak Rivers, Nijenhuis (2012) on the Mekong River, Dasgupta (2013) on the Matla River, Nayak and Panda (2016) on the Brahmaputra River. The interdependencies can stay at complex patterns in a river basin (Nijenhuis, 2012). The river creates some imprints of its existence on the socio-economic life of the people. The presence of the river in any region is a vital physical component which facilitates the developmental processes of that region. The multipurpose

activity of the river turns into lifeline for anywhere. Therefore, the interactions between human beings and rivers are an important issue for discussion.

The Himalayas considered the '*water tower*' of Asia (Jaitley, 2009), contributed to the origin of the perennial rivers of northern India, viz., the Ganges, the Indus, and the Brahmaputra. The River Tista is a right bank tributary of the Brahmaputra river system, which is usually used to flow through the states of Sikkim and West Bengal in India. It is observed that the mighty Tista is utilised as a source of livelihood for the people of Sikkim and West Bengal and it has importance in the national economy. Sarkar (2011), in his research work, has a detailed analysis of the agrarian lifestyle and agrarian culture of the people of the Tista River basin in West Bengal. The socio-economic life of the people of West Bengal, mainly in the northern part influenced by the Tista (Mukhopadhyay, 1982). Different aspect of the social life of the riparian people along the Tista River is interrelated with the river. The River Tista is an issue of conflict for water sharing between India and Bangladesh (Islam, 2016). 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 (The Asia Foundation, 2013). The riverine gaps of the Tista River between the India-Bangladesh border area are also used for cattle smuggling between the two countries. About 2 million cattle are smuggled from India into Bangladesh each year, becoming a huge industry (Tiwary, 2015; Wirsing et al., 2016). 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.

### 1.2 Human and river interactions

Human and river interactions have a significant impact on the environment and societies around the world. Rivers are crucial sources of water, food, and transportation for millions of people. However, human activities such as damming, pollution, and deforestation have led to the degradation of river ecosystems and the loss of biodiversity. Rivers are critical for providing water resources and for economic development in many countries. However, human activities have led to the degradation of many river ecosystems around the world. Pollution, overfishing, and damming are some of the major challenges facing river ecosystems globally. The Amazon River, for example, is the largest river in the world and home to the largest rainforest. However, deforestation and pollution have caused significant harm to the river and its surrounding environment (Fearnside, 2017). Another example is the

Mekong River in Southeast Asia, which provides fish for millions of people. However, the construction of hydropower dams has disrupted the natural flow of the river, impacting fisheries and the livelihoods of people who depend on them (Campbell et al., 2017). The impact of human activities on rivers is not limited to these regions but is a global phenomenon. India is home to some of the world's most significant rivers, including the Ganges, the Brahmaputra, and the Indus. These rivers are crucial for the country's agriculture, transportation, and hydroelectric power generation. However, they are also among the most polluted rivers in the world. The Ganges, for example, is heavily polluted due to industrial waste, sewage, and religious practices such as immersing idols and ashes in the river (Dwivedi et al., 2019). The construction of dams is another major challenge facing India's rivers. The Narmada River, for example, has been the site of a controversial dam project that has displaced thousands of people and led to significant environmental impacts. The damming of rivers also affects fish populations and the livelihoods of fishermen. To address the challenges facing rivers, it is essential to consider sustainable and integrated approaches. This includes promoting responsible management practices, improving water quality, and ensuring the conservation of biodiversity. In the global context, international cooperation and collaboration are crucial for the conservation of transboundary rivers. The Mekong River Commission, for example, is a regional intergovernmental organisation that aims to promote sustainable development and environmental management in the Mekong River basin (Campbell et al., 2017). In India, the government has launched several initiatives to address the pollution of rivers. The Namami Ganga program, for example, aims to clean and rejuvenate the Ganges River. The program includes a range of measures, such as the construction of sewage treatment plants, the installation of floating trash collectors, and the promotion of eco-tourism (Dwivedi et al., 2019). The government has also launched schemes to promote sustainable agriculture and the conservation of forests and wildlife, which can contribute to the conservation of river ecosystems. Human and river interactions have significant impacts on the environment and societies around the world. Pollution, overfishing, damming, and deforestation are among the major challenges facing river ecosystems globally. In India, the pollution of rivers and the construction of dams are significant challenges. However, sustainable and integrated approaches can help address these challenges. International cooperation and collaboration are crucial for the conservation of transboundary rivers, while initiatives such as the Namami Ganga program in India can contribute to the conservation of river ecosystems.

### 1.3 Study area

The Tista River originates from the Pauhunri glacier near the Khangchung Lake at an elevation of 7128 masl of North Sikkim in India. The name of the river is derived from the word 'Trisrota' and historical records revealed that in earlier times the Tista River was a tributary of the Ganges River, but in present days it is a tributary of the Brahmaputra River (Mukhopadhyay, 1982; Mukherjee, 1996). It is an antecedent river in the Eastern Himalayas and a sub-basin of the Brahmaputra River system. Mukhopadhyay (1982), in his investigation, the Tista floodplains has been divided into three major units, i.e.

**The Upper Tista Basin:** From its source to the Tista-Rangit confluence zone at Tista Bazar,

**The Middle Tista Basin:** From the Tista-Rangit confluence zone to the Tista-Sevoke Khola confluence zone at Sevoke Bazar and

**The Lower Tista Basin:** From the Tista-Sevoke Khola confluence zone to the Brahmaputra-Tista confluence zone at Tistamukh Ghat in Bangladesh.

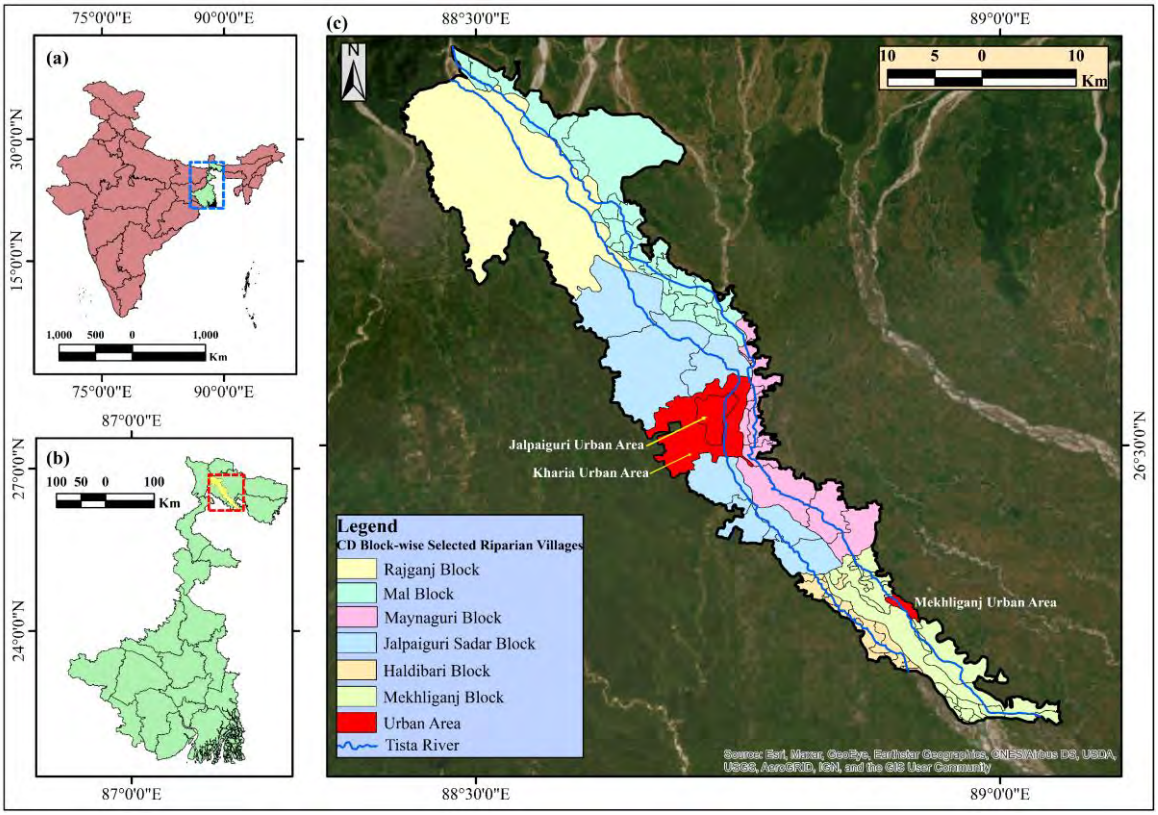



**Figure 1.1** Location Map of the Study Area (a) India, (b) West Bengal and (c) Community Development (CD) Block-wise selected riparian villages.
Source: Village boundary map has been delineated from: Census of India 2011, District Census Handbook, Jalpaiguri and Koch Bihar District, Village and Town Directory, Directorate of Census Operations, West Bengal, Govt. of India, New Delhi.

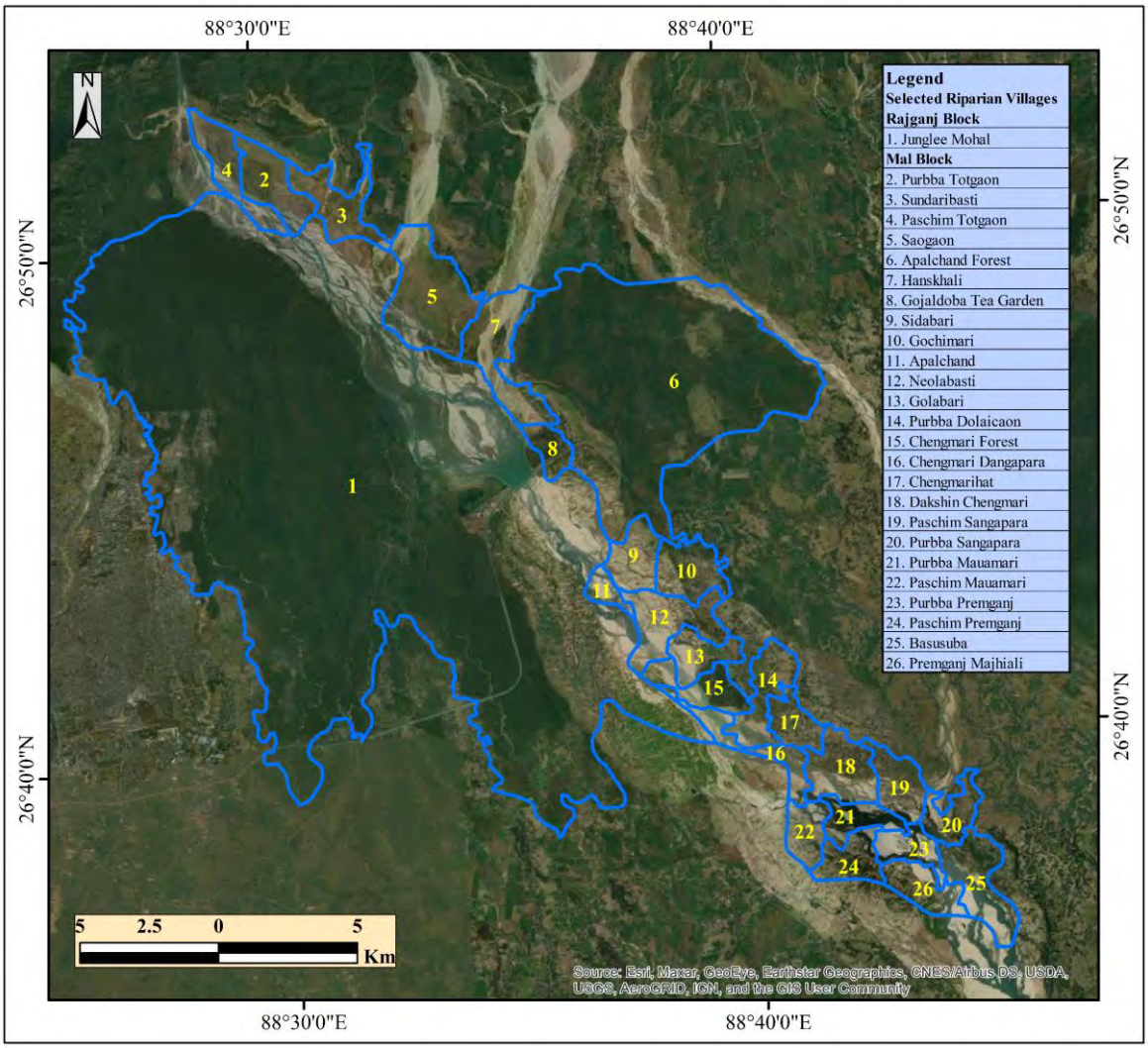



**Figure 1.2** Selected riparian villages of the Tista River from Rajganj and Mal Block.

In West Bengal, the total catchment area of the Tista River is about 3012 sq. km and the length is about 121 km across the Districts of Darjeeling, Kalimpong, Jalpaiguri and Koch Bihar (Annual Flood Report of West Bengal, 2013, 2015, 2016 and 2019). The Tista basin falls under the extension of 26°14' N to 27°15' N and 87°59' E to 89°02' E in West Bengal. The river enters West Bengal after Rangpo (Sikkim), where joined by the Rangpo River and then it travels through the mountainous area of Darjeeling and Kalimpong Districts. It descends to the North Bengal alluvial plains at Sevoke, 22 km away from Siliguri town. In sub-Himalayan North Bengal, the river meets with the Great Rangeet, Ramam, Rangpo, Leesh, Ghish, Chel, Mal, Neora and Karala rivers. It enters Bangladesh in the Dimla upazila of Nilphamari District and flows through the Gaibandha, Kurigram, Lalmonirhat, and Rangpur District in Bangladesh. The base level of erosion of the river is situated at Tistamukh Ghat (20 masl) in Rangpur District, where it merges with the Brahmaputra.

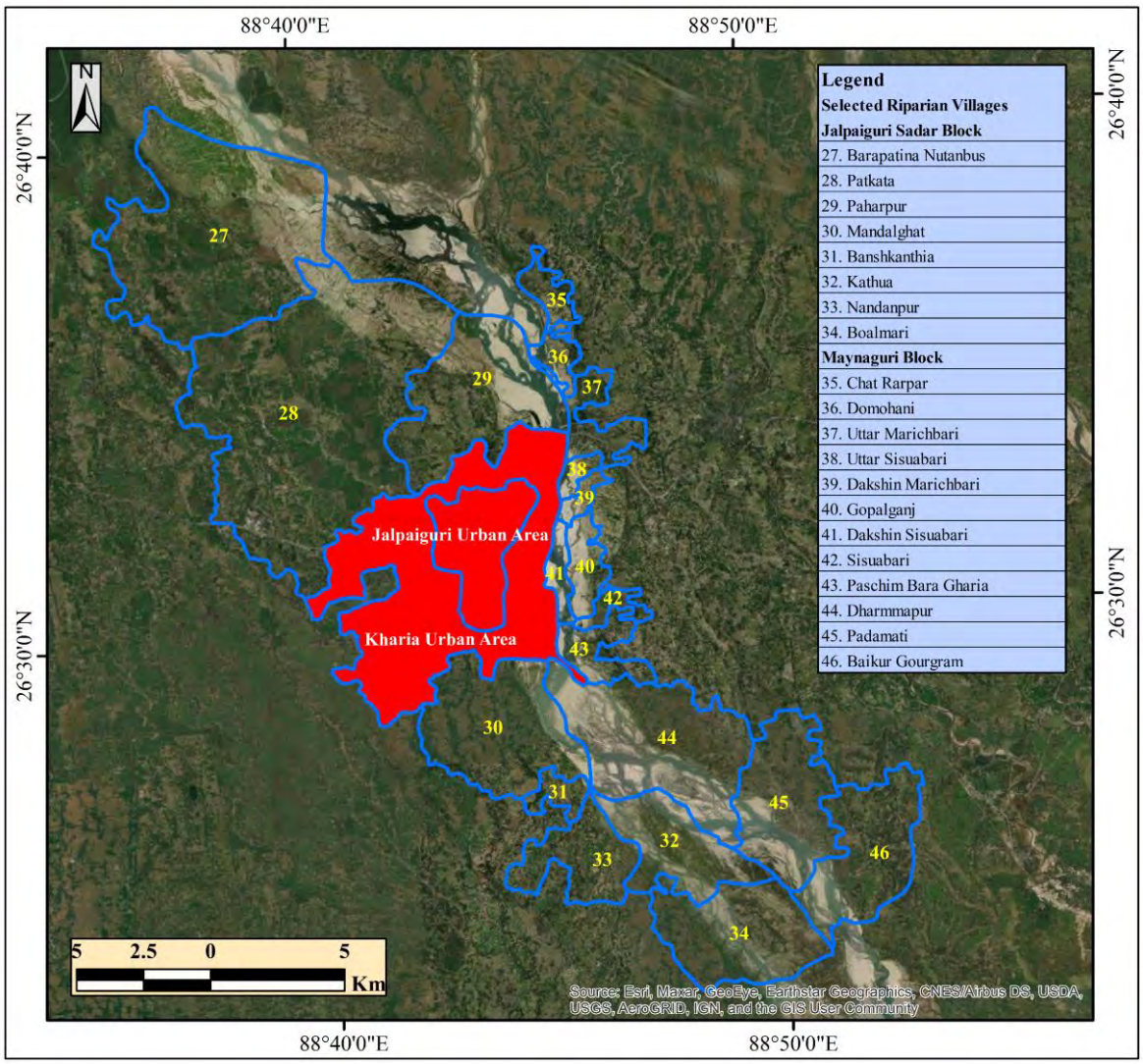



**Figure 1.3** Selected riparian villages of the Tista River from Jalpaiguri Sadar and Maynaguri Block.

The C.D. Blocks of West Bengal fall under the Tista basin are Sukhiapokhri, Darjeeling Pulbazar, Rangli Rangliot, Kurseong, and Matigara Blocks of Darjeeling District; Kalimpong-I, Kalimpong-II, and Gorubathan Blocks of Kalimpong District; Mal, Mateli, Jalpaiguri, Rajganj, and Maynaguri Blocks of Jalpaiguri District and Mekliganj and Haldibari Blocks of Koch Bihar District (West Bengal Administrative Atlas, 2011; Kalimpong District official website of the District Magistrate, 2019). The average density of the population of the four districts was about 680 persons/km$^2$ in 2011, while the state represents 1028. The region is characterised by a moderately high density of population. The river has the mountainous and plain course in the entire four Districts of West Bengal. The study site is situated in the lower Tista basin (Mukhopadhyay, 1982), mainly in the alluvial plains of North Bengal.


**Figure 1.4** Selected riparian villages of the Tista River from Haldibari Block.

The present study has been confined to the riparian villages along the Tista River, which occupy the Jalpaiguri and Koch Bihar Districts in the state of West Bengal of India (Figure 1.1). The block-wise selected riparian villages of the Tista River have been depicted in Figure 1.2 to 1.5. The village maps are obtained from the District Census Handbook (2011) of Jalpaiguri and Koch Bihar District. Since village-wise data are available in the Census of India, only the villages will be selected, which are situated in the river chars and along both banks of the River Tista as the study area. The upstream starts from Rajganj Block at the right bank and Mal Block at the left bank of the Tista River in Jalpaiguri District to downstream at the Bangladesh border where Haldibari Block at the right bank and Mekliganj Block at the left bank in Koch Bihar district. 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), which have been considered by the researcher based on field Survey, District Census Handbook of Jalpaiguri and Koch Bihar District (2011). Among the 85 riparian villages, 1 village will be selected from Rajganj Block, 25 villages

from Mal Block, 8 villages from Jalpaiguri Sadar Block, 12 villages from Maynaguri Block, 14 villages from Haldibari Block and 25 villages from Mekliganj Block.

The hydrodynamic characteristics of the region in West Bengal are controlled by the Himalayan Rivers and Tista Barrage Project at Gajaldoba. The region is also prominent in agrarian communities. The River Tista is very important for the riparian people due to its water resources, small-scale navigation and utilising the river chars for agricultural production. The river has unique characteristics and significant role in the development of the districts of North Bengal.

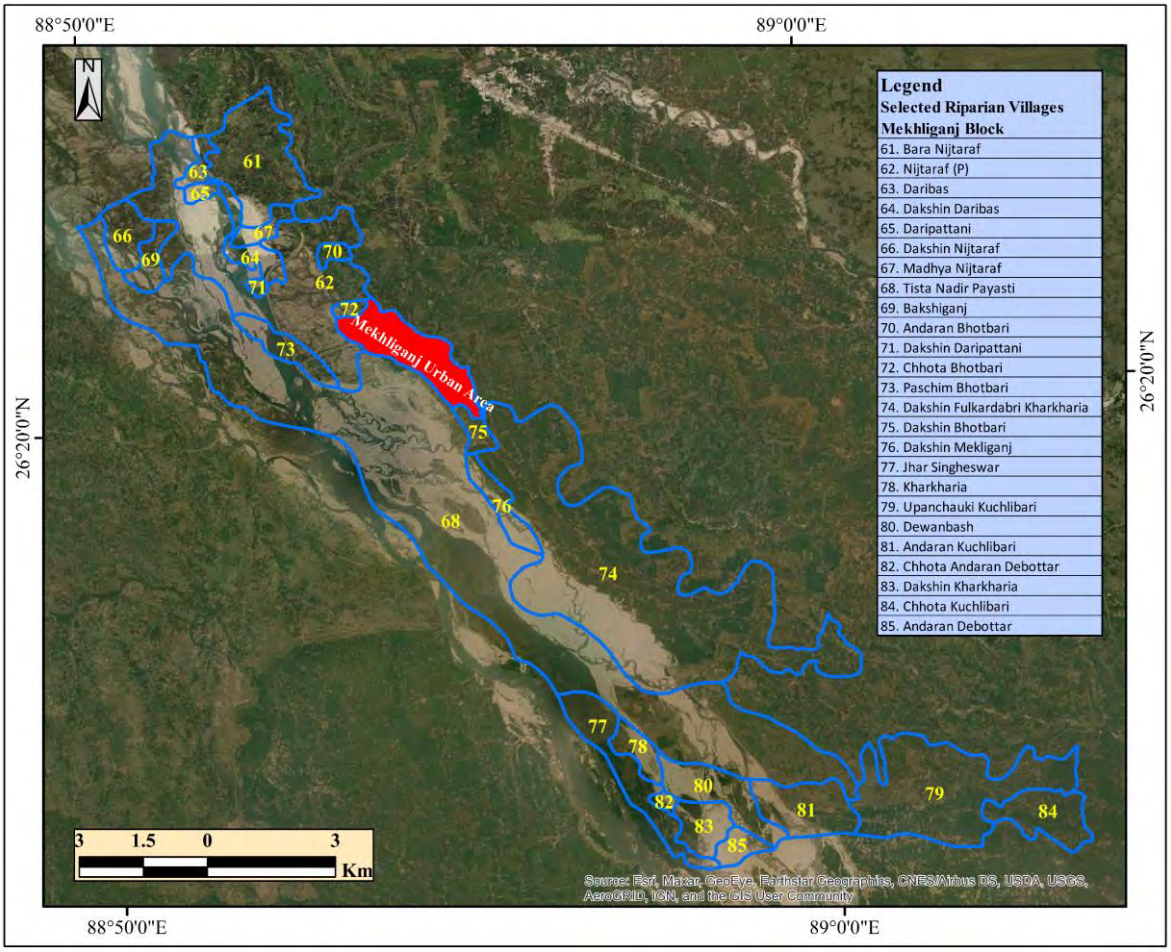



**Figure 1.5** Selected riparian villages of the Tista River from Mekhliganj Block.

### 1.4 Statement of the problem

The benefits of instream water use have been carried out a noticeable influence on any country. Mullick et al. (2013) investigated the uses of the Tista River water by the people of Bangladesh. In mountainous parts of Darjeeling Himalayas, the River Tista is used as a source of drinking water, hydroelectric power generation, terrace farming practices, recreational activities etc. Throughout its course in North Bengal plains, the basin is

characterised by fertile alluvial soil, availability of water, abundant natural resources potentiality etc. The Tista River was controlled after the construction of the Tista Barrage Project at Gajaldoba (1976), which caused a drastic change in the agricultural development of North Bengal. This project helps to utilise river water to facilitate the irrigation system of the region through canals. The Tista-Jaldhaka Main Canal provided irrigation facilities in the villages of Mal and Maynaguri blocks, whereas the Tista-Mahananda Link Canal in the villages of Rajganj and Jalpaiguri blocks through several distributaries of the respective canals. Human beings have settled in this region and interacted with the river and environment from earlier times. The overall favourable geographical condition of the basin has promoted the growth of settlements with time. Keith et al. (2013) discussed the limits to population growth in the river valley. 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 hydro-morphological state of the River Tista has been shaped by extreme human activities (Wiejaczka et al., 2014). The Tista Barrage Project has introduced negative impact on the surrounding environment (Banik, 2016; Mukherjee et al., 2016). The morphology and hydrological character of the river have been changed as a result of human-river interaction processes prevailing in this area (Khan et al., 2015; Islam, 2016). The Baikunthapur and Apalchand forest in this region has shown a decreasing trend in its area caused by human encroachment scenarios in the past fifty years. On the basis of Milligan's Settlement Records, the Baikunthapur forest covered 209.79 sq. km area as protected forest in 1960. The inhabitants occupied the forest lands and converted them into settlements, roads, and cultivation lands (Banerjee et al., 2009). According to Nagendra et al. (2009), the Baikunthapur forest experienced greater rates of deforestation (17%) compared to the Mahananda Wildlife Sanctuary (10.70%) due to the greater density of settlements and increased accessibility and road connectivity during 1990-2000. Indian Institute of Forest Management, Bhopal and RWDEP, Bangkok (2000) stated that 93% of households collected wood for fuel from the Baikunthapur forest. The rivers in the Duars region of West Bengal have been facing problems of rising river bed levels, bank failure, channel widening, shifting of river courses and as a result, loss of land, forest resources, biodiversity, tea gardens, cultivated lands, settlements, and deterioration of soil quality, water quality and health hazard occurred (Chakraborty et al., 2012). In the Siliguri edition of the Telegraph Newspaper with the headline *'Green activists see red on north rivers'* Jayanta Basu awaked the people of North Bengal due to human encroachments and waste dumping in the Atreyi, the Tista, the Mahananda and some other river (Basu, 2018). The

National Green Tribunal (2016) has been urged to stop the work at the Gajaldoba Eco-Tourism Hub due to the proposed extensive constructional activities in the forested area along the Tista River. Environmentalists and fluvial geomorphologists have been concerned about saving the natural resources and the health of the River Tista. So it is a matter of concern that the region has been severely changed due to anthropogenic activities in its physical environment.

The field survey by the researcher during 2017-2020 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 huge amount of river bed material extraction activities. Most important events have been observed in the char areas. The char areas of Chengmari, Takimari, Kathua, Boalmari, Nandanpur, Domohani, Sisuabari, Chat Rarpur, Nijtaraf, Bajejama Khasbas villages along the Tista River have emerged widely due to drop-down of the water level in the riverbed in and around Jalpaiguri and Koch Bihar district. People congested the chars by using the land for various activities to sustain their livelihood. They have changed the land use pattern and interferences the natural environment of the river. The mountainous part of the basin is susceptible to landslides, and the plains are affected by floods in the monsoonal season (Das, 2011; Pal et al., 2016; Chakraborty et al., 2018). The flood-prone areas of the Tista Basin in Jalpaiguri District are Jalpaiguri City (Jalpaiguri Block), Denguajhar (Jalpaiguri Block), Domohani (Maynaguri Block), Kranti (Mal Block), and Gangadevi (Mal Block), where consecutive years of occurrences of the flood are 1968, 1973, 1975, 1993, 2015 (Pal et al., 2016).

In the rainy season, the char areas have been facing the problem of water logging in the agricultural fields, houses, roads, schools and the people shifted away from the chars. The inhabitants have suffered from riverine problems such as floods, bank erosion, bank failure, and river course changes in plain areas almost every year. The char area is not static and as a fact, the inhabitants are suffering from land loss due to bank erosion and bank failure. Flood hazard in the River Tista is a common phenomenon almost every year. River course changes are another phenomenon which hampers the riparian people. Occupational shift and livelihood diversification also play a noticeable role in the socio-economic life of the people due to riverine hazards in riparian villages. Thus, the Tista River has a determinant role in their life. Therefore, the study has a significant role in the proper use of river water, resources and the environment and making up awareness among the people along the Tista River in Jalpaiguri and Koch Bihar District of West Bengal. Along with the study focusing on the

socio-economic condition of the inhabitants settled in the chars for dependencies on the River Tista.

### 1.5 Aims and objectives

The aims and objectives of the 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.

(v) To study on perceptions of the riparian inhabitants concerning the Tista River.

### 1.6 Hypothesis

The following hypothesis has been tested:

(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.

(iv) Awareness of the riparian inhabitants have affected their living standard.

### 1.7 Data sources and methodology

The following data sources and methodology have been adopted to fulfil the overall research work:

#### 1.7.1 To study the physical set up of the region and the socio-economic condition of the riparian inhabitants

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 data sources are as follows:

(i) SOI (Survey of India) Topographical maps (78A/4, 78A/8, 78A/12, 78A/16, 78B/5, 78B/9, 78B/10, 78B/11, 78B/13, 78B/14, 78B/15) in 1:50000 scale, USGS maps for India in 1:250000 scale,

(ii) Elevation, slope and ruggedness data from CartoDem (30 m spatial resolution),

(iii) Lithological maps from the Geological Survey of India (GSI),

(iv) Geomorphological maps from GSI,

(v) Soil map from NBSS & LUP,

(vi) Rainfall and temperature records will be collected from India Meteorological Department (IMD),

(vii) NDVI from satellite images from USGS,

(viii) Google Earth images (free source) and Bhuvan (free source) satellite data,

(ix) District Census Handbook (2011), District Gazetteer, Statistical Accounts of Bengal by W. W. Hunter (1974), Agricultural Contingency Plan of Jalpaiguri and Koch Bihar (2001, 2011). The riparian village map has been delineated from the District Census Handbook, Village and Town Directory (2011) of Jalpaiguri and Koch Bihar District.

### 1.7.2 To assess the role of the Tista River on the livelihood of the riparian inhabitants

The role of the Tista River on the livelihood (Mullick et al., 2013; Baki et al., 2015) of the riparian inhabitants has been assessed by extensive and regular household survey carried out by the researcher during 2020-2022. For deciding the sample size, a pilot survey was conducted to ascertain the target population, i.e., the riparian inhabitants who depended on the river and were affected by the river. As for increasing distance from the river, the effect of the river and the dependencies of the people is decreasing, so the researcher has selected the riparian villages as the study area (Baki, 2014; Rahmatullah et al., 2015; Qayoom et al., 2016; Islam et al., 2018).

Household surveys have been conducted in the selected riparian villages along the Tista River. As 16 selected riparian villages have been observed as having uninhabited households as per the District Census Handbook of Jalpaiguri and Koch Bihar (2011), therefore 69 villages were finally reconsidered for determination of the sample size. The sample size for the primary survey has been estimated based on Cochran's sampling method (1963) for the finite population as follows:

$$n_{\circ} = \frac{Z^2 p(1-p)}{e^2}$$

Here, Z is the standard error associated with the chosen level of confidence, e is the desired level of precision (i.e., the margin of error), p is the (estimated) proportion of the population which has the attribute in question, and q is $1 - p$.

$$n = \frac{n_o}{1 + \frac{n_o}{N}}$$

Here, $n_o$ is Cochran's sample size recommendation, $N$ is the population size, and $n$ is the new, adjusted sample size. Based on Cochran's method (1963), at the 95% confidence level and ± 5% precision, computed the total sample size of 381. Therefore, 381 households from 69 riparian villages will be surveyed by the researcher. Subsequently, proportional distribution technique was employed to compute the sample size for each riparian village. The respondent riparian household has been selected based on stratified random sampling technique. A detailed description of the computation of the sample size has been presented in Table 1.1.

**Table 1.1** Calculation of sample size based on Cochran's method (1963).

| | | | |
|---|---|---|---|
| **$Z^2$** | **Z score** | 1.96 | 3.84 |
| | **Confidence Interval** | 95% | |
| | **Alpha divided by 2** | 0.025 | |
| **p** | 0.5 | | |
| **Error** | 0.05 | | |
| **Population size** | 52138 | | |
| **$n_0$** | 384.15 | | |
| **n** | 1.01 | | |
| **Responded sample size** | 381 | | |
| **Non-responded sample size** | 19 | | |
| **Total sample size** | 400 | | |

Source: Computed by the researcher.

The primary data has been collected through structured questionnaire, and case studies. Population Census, Government of India (2011) were used to find out the demographic characteristics of the riparian villages along the river. The questionnaire on livelihood dimensions, vulnerability of the riparian inhabitants along the Tista River and their perception concerning the Tista River in Jalpaiguri and Koch Bihar District, West Bengal, is demonstrated in Table E.1 of Appendix-E. Different statistical techniques were used to show the relationship among the different variables observed in the tenure of research work.

The GIS software, GPS and other digital instruments will be used for preparing the necessary maps and calculation of different parameters.

### 1.7.3 To assess the effect of the riverine hazards on socio-economic life of the riparian inhabitants

Use of the Annual Flood Reports of West Bengal (2013, 2015, 2016, 2017, 2018, 2019 and 2020), SOI (Survey of India) Topographical maps, Satellite images of USGS, Google Earth images (free source) satellite data and field survey were done to understand the behaviour of the river towards floods, bank erosion and river channel shifts (Baki, 2014; Islam et al., 2018).

**A.** Firstly, to assess the nature and extent of the riverine hazards, several works have been conducted, viz.,

**(i)** Flood susceptibility zonation mapping of the study area using Saaty's Analytical Hierarchy Process method (Saaty, 1987; Saaty and Vargas, 1991),

**(ii)** Channel shifting risk-prone areas mapping and

**(iii)** Bank erosion vulnerability zonation mapping of the study area.

**B.** Secondly, to know the severity of the riverine hazard on the socio-economic life of the riparian inhabitants (Rosgen, 1996, 2001, 2006; Kean, 2003; Mohan et al., 2011; Ganguly et al., 2015; Reza et al., 2016; Dey et al., 2018; Sarkar et al., 2018; Mitra et al., 2020, Mitra and Mandal, 2022), livelihood vulnerability index (LVI) calculation (Hahn et al., 2009) for the riparian villages has been conducted based on data obtained from the household survey.

### 1.7.4 To assess the human interferences on the Tista River

The impact of anthropogenic activities on the river has been analysed to visualise the morphological changes of the river due to human and river interactions in the basin (Panda et al., 2011; Reza et al., 2016). The study of the anthropogenic impact on the morphology of the river includes bridges and barrages, bank stabilisation, artificial levees, human settlements on the side of the river banks, intensive agriculture, sand mining (Khan et al., 2015), bed material extraction activity (Tamang, 2013) which poses various negative impact on the river. Extensive field survey, interpretation of satellite images, and incorporation of different methods include the following aspects in this evaluation:

**Table 1.2** Assessment of the human interferences on the Tista River.

| To know the indirect effects of human interferences on Tista River | To know the direct effects of human interferences on Tista River |
|---|---|
| **(a)** Investigations of channel encroachment scenario and increasing population pressure on the Tista River | **(a)** River bed materials extraction activity in the bed of the Tista River |
| | **(b)** Negative Impact of Tista Barrage Project on Tista River |
| **(b)** Detailed study on land use change scenario of the study area (Singh et al., 1992; Dadhwal et al., 2010) | **(c)** Water quality assessment of the Tista River |
| **(c)** Groundwater scenario of the study area | **(d)** Interventions of the Tista River by embankments and spars |
| | **(e)** Assessment on channel transformation and habitat modification of the Tista River using River Habitation Survey (RHS) method (Wiejaczka et al., 2014; Raven et al., 1998; Hawley et al., 2002). |

### 1.7.5 To study on perceptions of the riparian inhabitants concerning the Tista River

According to Schnetler (1989) and Fink (1995) questionnaire-based surveys are a popular method for collecting data relating to the knowledge, attitude, and behavior of people. Various authors work on the perceptions study among riverside residents viz., Eniko (2002), Birkholz (2009), Strydom (2009), Groot et al. (2009) through incorporating several methods. The household survey data was also used to evaluate the perceptions of the inhabitants concerning the Tista River and for this purposes, eight constructs were formulated.

A detailed description to carry out the methodological framework has been discussed in each chapter of the thesis.

## 1.8 Literature review

Leopold et al. (1963) emphasise landform development under the processes associated with running water. They discussed the characteristics of the drainage basin, measured the hydraulic characteristics and sediment in the channels and also investigated channel form and process. According to them, the shape of the cross-section of a river at any location is a function of the flow, the quantity and character of the sediment in movement through the section, and the character or composition of the materials making up the bed and banks of the channel.

Mukhopadhyay (1982), in his study detail, analysed on the Tista River. The forms, processes, landform development, drainage characteristics, etc., were preciously evaluated and environmental management was assessed in the context of the fluvial environment.

Morisawa (1985) is concerned with the morphology of rivers and their watersheds and with the mechanics by which rivers perform their functions. He elaborately discussed about

the hydraulics of stream flow in an open channel and gave a clear picture of the dynamics of fluid flow, which are necessary for the understanding of the degradation, transportation and aggradation carried on by the fluvial system.

A detailed study of the nature and characteristics of fluvial dynamics of the twin basins of the Lish-Gish River was done by Ghatwar (1986).

A detailed account study on geo-environmental appraisal of the upper Mahananda basin of the Darjeeling Himalaya was made by Sarkar (1989).

The development of alluvial fans in the foothills of the Darjeeling Himalayas was studied by Basu et al. (1990). He especially studied the physical set-up, geomorphological, pedological and drainage characteristics of this region with respect to the formation of alluvial fans.

Bhattacharya (1993) has been made investigated work on '*A Comprehensive study on the Problems of Management of the Rakti Basin in the Darjeeling Himalaya'*.

Blake et al. (1994) described the human-environment interaction in the first volume of the book '*Illinois History Teacher*' through a manifestation of the relationship between the Illinois River and the people living in its basin.

Lansing et al. (1998) evaluated the value of the Skokomish River for the Skokomish tribe as it is used as a form of natural capital for them. Human civilisations have been interrelated with the river from ancient times to the contemporary period.

Eniko (2002) discussed the interdependence of humans and the natural environment in his research work on the riverine populations of the Mures River. With the help of the questionnaire method, the author evaluated the relationship of the people with the Mures River.

The work on the environmental geomorphology of the Balason River basin was done by Lama (2003).

Datta (2004) studied the locational pattern and morphometric characteristics of alluvial fans in the Himalayan foothills region of Assam. He stated that the alluvial fans reflect the tectonic events and climatic changes which have characterised the eastern Himalayas from the Pleistocene age. He mentioned that the formation of the alluvial fans in the Himalayan foothills is related to the events of debouches on the piedmont, channel widening, bifurcation of streams and distributary formation, deposition of alluvial sediments, channel shifting and reduction of velocity of stream water discharge in the down fan direction.

Lill et al. (2006) stated human activity and environmental degradation by using *Drivers-Pressures-State-Impact-Response (DPSIR)* model given by the European Environmental Agency (EEA).

Birkholz (2009) carried out the research work on 'Human-River Relationships in the Kant River Catchment and the implications for Integrated Water Resource Management (IWRM): an exploratory case study'.

Groot et al. (2009) studied 'Room for river measures and public vision in the Netherlands: A survey on river perceptions among riverside residents'.

Strydom (2009) detailed an account of 'The Impact of State-of-Rivers Reporting on People's Attitude towards River Conservation: A Case Study of the Buffalo and Hartenbos and Klein Brak Catchments in South Africa'.

Dadhwal et al. (2010) analysed the hydrology of the Mahanadi River basin and assessed the land cover changes' impact on stream flow based on VIC (Variable Infiltration Capacity, a macro-scale hydrological model). According to them, VIC is a model primarily designed to assess and evaluate long-term climate and land cover changes on basin hydrology and it ignores the effect due to human-induced activities. They have viewed that the river basin has been facing adverse hydro-meteorological conditions such as floods, droughts and cyclones in the contemporary period, which indicate a shift in the hydrological response of the basin attributed to land cover changes.

Mohan et al. (2011) showed the way to prevent or reduce the damage that occurs due to floods by preparing flood zone maps. They have also analysed the flood hazard vulnerability and management covering the parts of Uttar Pradesh and Bihar by using remote sensing data and GIS techniques.

Panda et al. (2011) discussed the morphodynamic changes of the Bhagirathi River in Murshidabad district. The study manifested morphological aspects such as channel geometry, fluvial dynamics, hydraulic geometry, changes of channel capacity, width, depth, meander, the discharge of water and sediment and also its effect on Bhagirathi River bank erosion. They have observed that fluctuation of water discharges from the Farakka Barrage through the feeder canal at Jangipur and the overall soil structure of the region are the main causes of Bhagirathi River bank erosion.

Saha et al. (2011) evaluated the performance of an irrigation command area with special reference to the Mehasana district of the Sabarmati Right Bank Canal, North Gujrat, by satellite remote sensing data. The crop evapotranspiration was estimated using the vegetation

index NDVI and two RS-based performance indices, namely adequacy (AI), and equity (EI) were computed by the authors.

The work on geomorphic hazards in the Duars region has been carried out by Chakraborty et al. (2012). They have stated that hydro-geomorphic conditions of the Duars region of West Bengal introduced some geomorphic hazards such as river bank failure, flash floods, rise in river bed levels, shifting of river courses, channel widening and loss of land, loss of forest resources and biodiversity, loss of tea gardens, arable lands and settlement, deterioration of soil quality, water quality and health hazards, deforestation, landslides etc. The study also reveals that the rivers of this area are incapable of transporting the load efficiently under existing hydrological conditions, mainly along their lower reaches, and thus river beds are elevating at an alarming rate.

Govorushko (2012), in the book entitled *'Natural Processes and Human Impacts-Interactions between Humanity and the Environment*', briefly discussed that in this human-environment interactions process, people are influenced by various natural processes and environment also changed caused by different kinds of human activity.

Nijenhuis (2012) examined the complex interdependencies in the case study of the Mekong River basin. The author tried to describe the economic, socio-environmental, political and hydropower interdependencies in a complex manner by an explanation and justification of the different models for the six riparians within the catchment, i.e., China, Myanmar, Laos, Thailand, Cambodia and Vietnam.

Dasgupta (2013), in his research work, evaluated the Man-Environment Relationship of the left bank of the Matla River in the Sundarban region of West Bengal.

Dutt et al. (2013) described the socio-economic life of the people living in the chars of the Damodar River.

Gogoi (2013) has made an attempt to find out the braided index of four segments of the Brahmaputra River near Majuli Island by the braiding index of Germanoski and S. A. Schumm. He found the variation of the braiding index in his work and hence determined the aggradation and degradation behaviour of the River Brahmaputra. These variations are affected by variations in discharge, the role of bank erosion and the rate of erosion in the catchment area of the basin.

Keith et al. (2013), in the study on the '*Limits to Population Growth and Water Resource Adequacy in the Nile River Basin'* examined how the population growth of Egypt, Sudan, and Ethiopia depended on the water resources in the Nile Basin and concern about the problems taking place in a different perspective through the models.

Mullick et al. (2013) carried out a work on *'Benefit functions for instream water uses - a case of the Teesta River, Bangladesh'*.

Tamang (2013) has made a precious and intensive study to manifest the effect of boulder lifting activity on the fluvial characteristics of the lower Balason basin. He examined the annual volume of bed material extraction from the river bed, which exceeds the annual replenishment by the river.

The Asia Foundation (2013), in their report on '*Political Economy Analysis of the Teesta River basin*', showed that the trans-boundary Tista River is influenced by different parameters like social, political, economic, and institutional, which govern its water sharing in India and Bangladesh. Along with this, the report mentioned the interests of different stakeholders at different sites of the basin.

Wiejaczka et al. (2014), in the paper on *'Human role in shaping the hydromorphology of Himalayan rivers: study of the Tista River in Darjeeling Himalaya',* emphasised the transformation of channel morphology by a significant degree of anthropogenic pressure expected in the parts of the river located near bridges on the basis of the British River Habitat Survey (RHS) method. In their study, it is found that the analysed sections of the Tista River with noticeable human interference, i.e. river bank modifications, are characterised by small or considerable modifications of the river habitat which involve concrete walls or river bank reprofiling occur in the long channel sections and their function is to protect road infrastructure and buildings from river erosion. Despite a large human impact on river bank morphology, the studied channel sections of the Tista are characterised by a considerably large amount and diversification of natural morphological elements.

Ganguly et al. (2015) illustrated the flood hazard zonation mapping and spatio-temporal analysis of the flood of the West Tripura district by using hydro-meteorological data, toposheets and SRTM DEM. It has been found in their research work that the upper part of all the rivers in this region pass through narrow gorges while their lower part becomes a broad sluggish river and during each flooded year, heavy rainfall accelerates the flood condition in the lower reaches, giving rise to river discharge. Along with this, huge deforestation, cutting of slopes, and construction of roads are factors accelerating the process of sedimentation in a rapid manner resulting in the swallowing of the river bed and unusual erosion of banks also creates tremendous problems in protecting the district and sub-divisional towns, villages and other permanent structures and borderlands on the river banks.

Khan et al. (2015) deal with the anthropogenic impact on the morphology of the Tista River in Northern Bangladesh. They have noticed that these activities are important for the

development and welfare of human being, but it has an adverse impact on river morphology and on its natural characteristics.

Rasul (2015) stated from an economic perspective about the water for growth and development in the Ganges, Brahmaputra and Meghna basins.

Islam (2016) carried out his work on Tista water-sharing issues from an international perspective. He also finds out the regional importance of the Gajaldoba (India) and Dalia (Bangladesh) barrage project through an extensive field-based comparative socio-economic survey.

Mukherjee et al. (2016), in their work on Tista Barrage Project at Gajaldoba (India), briefly stated the unattained goals and associated changes that have been taken into account after the construction of the barrage for the overall region of the Tista basin.

Nayak et al. (2016) worked on 'Brahmaputra and the Socio-Economic Life of People of Assam'.

Reza et al. (2016) assessed the changes in fluvial morphology and channel dynamic of the Padma River and recommended for some protective measures for the future. Their findings proved that the changes in channel dynamics indicate that the river needs to monitor for temporal shifting each year.

Tamang et al. (2016) also estimated the fall velocity of the sampled coarse sediments with respect to their diameter (mm) and water temperature ($^{\circ}$C). He has analysed the surface coarse sediments and suspended sediments of the lower part of the Balason River and their relation with discharge, run-off and fall or settling velocity. The relationship revealed that during the hyper-concentrated flows occurring very rarely, the efficiency of sediment delivery by lateral erosion and mass movement caused substantial transformations in the channel geometry.

### 1.9 Expected outcome

The entire research work can be helpful in understanding the human and river interactions between the inhabitants and the Tista River throughout the District of Jalpaiguri and Koch Bihar in West Bengal. We can assess the contribution of the river to the economic development of the region. It will provide the picture of how the inhabitants depend on the river for their daily life. The nature, type and characteristics of the interdependencies in the Tista River can be known throughout the work. The riverside resident's perceptions and attitudes towards the proper use and conservation of the river may be visualised by this work. The study will look at the factors responsible for riverine hazards in the region and their

impacts on the people. The researcher will try to give some suggestions and recommendations for further development that can make a healthy, eco-friendly condition of the concerned region. The study can be helpful for planners, geographers, naturalists, economists and others interested in such work. The findings of this study will be effective for government agencies, multipurpose companies, planners, policy-makers and others to identify priority areas in their developmental efforts.

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