Vulnerability Assessment of Women and Children due to the Jamuna Riverbank Erosion: A Study of Kastapara Village of Bhuapur Upazila, Tangail

SUBMITTED TO THE FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE MASTER OF PHILOSOPHY (M.Phil.) IN GEOGRAPHY AND ENVIRONMENT

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Above thesis work or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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CERTIFICATE OF APPROVAL

This is to certify that the thesis work entitled "Vulnerability Assessment of Women and Children due to the Jamuna Riverbank Erosion: A study of Kastapara Village of Bhuapur Upazila, Tangail" has been carried out by AFROZA, M.Phil. researcher, Registration No. 039, Session 2017-18, Department of Geography and Environment under the Faculty of Earth and Environmental sciences in the University of Dhaka, Bangladesh, under my supervision directly.

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DEDICATION FOR

To the people of Kastapara Village

ACKNOWLEDGEMENTS

At the very start, I express my heartfelt gratitude and profound appreciation to Almighty Allah for blessing me with the opportunity to complete this research successfully.

I would like to express my deepest gratitude to my research supervisor Professor Dr. Nazmun Nahar, Department of Geography and Environment, University of Dhaka, for the continuous support to my M.Phil. Study and research work with her patience, invaluable guidance and advice. Her guidance helped me in all the time to complete this thesis. Beside my advisor, I would like to express my profound gratitude and earnest thanks to Professor Dr. Serajul Islam and Dr. Asib Ahmed, Associate professor, Department of Geography and Environment, University Dhaka, for their valuable suggestions and comments which have helped me to develop the quality of the research. I would like to thank the Dean of the Faculty of Earth and Environmental Sciences, the chairman of the M.Phil. Committee, the Chairman of the Department of Geography and environment for their cooperation to complete my research work on time successfully.

I am greatly thankful to the Ministry of Education, Bangladesh, Directorate of Secondary and Higher Education, Dhaka, Bangladesh for allowing me to complete my M.Phil. Study successfully. My sincere gratitude goes to the authorities of Gabindashi union parishad, Bhuapur upazila porishad, District Statistical Office, District Water Development Board office & District Agricultural Office, Tangail and other officials for providing with valuable information's regarding the study. Thanks to the local people especially women who are living in the Kastapara village, provided necessary information, helpful discussion and explanation during the field work of the study. Finally, my thanks go to all the people who have supported me to compete the research work directly or indirectly.

AFROZA

ABSTRACT

Bangladesh faces frequent natural disaster, including cyclone, storms, droughts, thunderstorms, earthquakes, landslides, floods and riverbank erosion, which occur almost annually. Among these, riverbank erosion stands out as one of the most frequent and destructive phenomena, often linked to flood occurrences. This disaster causes significant destruction, displacing people from their homes, destroying infrastructure, agricultural land, crops and essential belongings. Bangladesh predominantly a patriarchal society, where men typically act as the primary earners and head of households. In this patrichal structure, crucial decisions regarding a family's and women's life such as education, participation in economic activities, marriage and family planning are usually made by male family members. Women's role are often limited to biological reproduction, caregiving and managing household chores. Women are also continue to lag behind due to lack of security. Incidents of violence and harassment against women as well as children have become alarmingly frequent in Bangladesh. Because of these harassment women and children faces difficulties due to any disaster as well as riverbank erosion.

This study examines the erosion induced vulnerabilities of women and children in kastapara village, under Bhuapur upazila, Tangail district. The study also attempts to find out their survival and copping strategies during and after riverbank erosion. In this study, primary data collected through questionnaire survey has been used to determine the vulnerability. Sample size has been calculated using Cochran's modified formula for known population. All respondents are women. A total of 230 questionnaire survey has been conducted using purposive sampling techniques. Collected data systematically arranged and entered into Microsoft Excel spreadsheet (Excel 13), which served as the foundation for subsequent analyses. To further process and summarize the data, statistical analysis software SPSS (16.0) was utilized. Microsoft Word (2013) was used for documenting findings and creating written reports. Furthermore, GIS software (10.1) was used to prepare maps. Secondary information was sourced from a wide range of published and unpublished materials, including documents from government and non-government organizations such as BWBD, LGED and CEGIS. Additional

resources include local government offices, Dhaka University's libraries and online materials like reports, articles, books and news outlets have also been used.

An indicator-based approach has been employed for vulnerability assessment, utilizing the Riverbank Erosion Vulnerability index (REVI) to evaluate the vulnerability of women and children in the study area. The formulation of REVI incorporates multiple variables grouped under eight parameters and three dimensions. The study reveals that most villagers face annual floods and riverbank erosion. The results indicates that, while the overall vulnerability of women and children in this region is relatively low, individual index value for exposure, sensitivity and adaptive capacity suggest high to moderate vulnerability. Women, in particular, faces different types of difficulties. Furthermore, those who seek shelter in temporary accommodations often experience physical and psychological violence and distress. Women have little to no understanding of challenges associated with erosion, and their vulnerability is intensified by insufficient support from the government and other organizations. No prior studies in this area have assessed women's and children's vulnerability using an index-based formula. Therefore, I focused on analyzing the vulnerabilities of both women and children in this region. This study focuses on identifying the vulnerabilities of women and children to aid researchers and planners in creating targeted initiatives and policies, ultimately aiming to enhance their lives and promote a supportive and inclusive environment.

ABBREVIATION

ASA	Association for Social Advancement
BARC	Bangladesh Rural Advancement Committee
BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BWBD	Bangladesh Water Development Board
CC	Climate Change
CCC	Climate Change cell
CEGIS	Center for Environment and Geography Information Services
CDRI	Climate Disaster Resilience Index
CRI	Coastal Resilience Index
CVI	Climate Vulnerability Index
DoE	Department of Environment
DMB	Disaster Management Bureau
EGIS	Environmental and Geographic Information Services
FAO	Food and Agricultural Organization
FSI	Food Security Index
IFRC	International Federation of Red Cross and Red Crescent Societies
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
LVI	Livelihood Vulnerability Index
LGED	Local Government and Engineering Department
NGOs	Non-Governmental Organization

NOAA	National Oceanic & Atmospheric Administration
RCI	Resilience Capacity Index
REVI	Riverbank Erosion Vulnerability Index
SSC	Secondary School Certificate
SSS	Society for Social Service
TB	Tuberculosis
UN	United Nations
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UNISDR	United Nations Office for Disaster Risk Reduction
UNHCR	United Nations High Commissioner for Refugees
UNO	Upazila Nirbahi Officer
WB	World Bank
WHO	World Health Organization

GLOSSARY

Char	A raised land in the river channel formed by heavy siltation or riverbank erosion
Decimal	Measurement unit of area in the metric system which the multiples or sub-multiples by 10
District	An area of a country that has fixed borders are used for official purpose
Hectare	Measurement unit of area in the metric system equals to 10,000 square meters
Parishad	Council
Taka	Currency of Bangladesh
UNO	Upazila Nirbahi Officer works as a chief executive officer at the Upazila level as a representative of the Government of Bangladesh
Union	Union is formed by some wards/ para/ villages
Union Parishad	Is a respective area which is one of the lowest local governmental units of Bangladesh
Upazila	Upazila is formed by some Unions
Village	A small community or group of houses under a Union

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INTRODUCTION AND CONCEPTUAL BACKGROUND

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INTRODUCTION AND CONCEPTUAL BACKGROUND

1. Introduction

Bangladesh situated in the temperate region, as a result, this country has been experienced vast amount of rainfall throughout the monsoon season. The location of our country is in south Asia and it is a low-lying deltaic country. This is one of the most hazardous areas around the world. Every year Bangladesh has been experienced severe storm, cyclone, drought, flood and flood related riverbank erosion, earthquake etc. (Nizamuddin, 2001; Ahmed, 2006; Rahman 2013, Goosen et al., 2018; Rashid, 2019). During monsoon season massive rainfall and vast amount of running water from the catchment area increase the intensity of flood and flood related riverbank erosion. Major rivers of our country cause erosion at the large scale with high frequency of water flow due to their uneven characters and braided channel pattern. In recent years riverbank erosion occurs frequently and now this is one of the extreme destructive hazards in Bangladesh (Haque and Hossain, 1988; Hannan, 1993; Brammer, 2012; Ghosh, 2014; Chowdhury et al., 2021). Millions of people in our country affected by riverbank erosion annually and they losses homestead land, farmland, crops and other belongings. In recent years the volume of land destruction, economic losses and human vulnerability has been increased intensely because of riverbank erosion. Riverbank erosion has been considered as one of the main causes of country's national poverty (Chowdhury, 1988; Aftab et al., 2006; Bapery, 2011; Bhuiyan et al., 2017). Women are disproportionately impacted by riverbank

erosion and other disasters. This is due to their limited access to land, education, services and resources, as well as their restricted involvement in decision making within families or society (Begum, 1993; Mehta, 2007; Haque, 2014; Chowdhury et al., 2022).

1.1. Background and overview

In recent years flood and related riverbank erosion has been considered one of the utmost devastating natural calamities in Bangladesh. Riverbank erosion is the main aggravated disaster formed by the extensive channel water flow and flood (Pramanik, 1991; Nizamuddin, 2001; Chatterjee, 2013). Bangladesh severely suffered by the flood and riverbank erosion (Rabbi et al. 2013; Mollah and Ferdaush, 2015). Riverbank erosion is the constant process of channel shape, depth and course changing events which causes enormous sufferings for the people lives on the riverbank areas. Riverbank erosion has a multidimensional impact on human lives (Haque, 1988; Rana & Nessa, 2017; Ranaa et al., 2022). In our country major part of the total population lives at the floodplain areas which make them vulnerable to riverbank erosion (Rashid, 1991; Islam and Rashid, 2011; banglapedia, 2015; Soron et al., 2019; Shahriar, 2021).

Jamuna is the downstream channel flow of the Brahmaputra-Jamuna River system which took place after the great earthquake and disastrous flood at 1787. At present the main course of Brahmaputra River continues as Jamuna River between Bahadurabad and aricha. Bangladesh water development board called this whole pattern as the Brahmaputra-Jamuna (Rashid, 1991; banglapedia, 2014, Sarker et al., 2014; Sarker & Rahman, 2018). Jamuna, Padma and Meghna are the main river of our country which gradually demolished about 1590 square kilometers of floodplains area since 1973. As

a result, around 1.6 million people lost their land and became homeless (CEGIS, 2009; Sarker et al., 2013; Rahman & Islam, 2018). A study has been conducted during 1981 and 1993, showed that about 728439 inhabitants were evacuated from their household lands due to riverbank erosion and the 50% of the total homeless people cannot rebuilt their home because of poverty and land loss (MoFDM, 2006; Islam and Rashid, 2011; Rahman, 2013; Roy, 2017).

Women, particularly in developing countries, often face economic disparities, with limited ownership of assets and property and lower earnings for their work. They have frequently have fewer opportunities to develop skills and limited participation in decision-making processes within families and public spaces. (Rashid, 2000; Cannon, 2002; Enarson, 2005; Ariyabandu & Foenseka, 2006). Additionally, women heightened risk of sexual abuse, domestic violence and other forms of harm, often living under dominating social structures. Their vulnerabilities to disaster are intensified by societal norms, expectations and traditional gender roles (UN DAW, 2001; Ariyabandu & Wickramasinghe, 2004; Dasgupta et al., 2010; Enarson, 2011). Bangladesh is mainly a patriarchal society where men are the main wage earner and head of the family. From the early childhood girls are neglected in the society due to superstition, religious sentiment and social customs. Women are considered as the reproductive tool of the society and encouraged to keep themselves busy with the household activities (Begum, 1993; Khan et al., 2014; Hasan et al., 2019). Most of the time women need to rely upon men throughout their whole lives. All the vital decisions of women's life such as education, participation in the job market, marriage and family planning etc. are taken by the male members of the family (Kafi, 1992; Hoque & Haque,

2013; Begum et al., 2014: Khan et al., 2014). The literacy rate of women in Bangladesh is very poor. In order to limit their contact with males, girls are often taken out of school when they reach puberty (Bhuiyan, 1991; Kafi 1992; Islam & Sultana, 2006). Most often they are forced to get married at the very early stage. As a result women are not getting fair access to education, health, employment and property. Violence against women has become a very common scenario in Bangladesh. The most common acts of violence against women includes stalking, trafficking, physical and mental harassment. (Ikeda, 1995; Khondokar, 1996; Momsen, 2000; Unnayan Onneshan, 2012; Asia News, 2014). Disaster have significant impacts on women, who often severe hardship and challenges, as well adverse effects during such events. They are frequently excluded from various development initiatives like River policy, water policy and other development efforts introduced by government and non-government authorities. In Bangladesh, low level of education, gender-based division of labor and social insecurity are the main factors that contribute to women's vulnerability during disasters. (Khondokar, 1996; Wasata and Haque, 2011; Islam, 2009; Nasreen, 2012; Begum et al., 2014; Khan, 2014).

1.2. Major River system of Bangladesh

About 700 rivers with a total length of 24140 kilometers are flowing across this country. Bangladesh comprises one of the largest river networks around the world. This country is located at the lowermost reaches of the three enormous rivers; The Brahmaputra, the Ganges and the Meghna River (Rashid, 1991; Brammer, 2012; banglapedia, 2015). Bangladesh is dominated by these three rivers and their tributaries. Sediments carried by these rivers made this world's largest delta. These rivers have an effect on people's life in

this country. The people of our country are familiar of these rivers related phenomenon like flood, riverbank erosion, frequently moving from their homestead and they have been adopted their lifestyle with this phenomenon for eras (Sarker et al. 2014; Roy, 2017). There are four major river system in Bangladesh. These are:

1.2.1. The Brahmaputra-Jamuna River system.
1.2.2. The Ganges Padma River system.
1.2.3. The Surma-Meghna River system, and
1.2.4. The Chittagong region river system. (Brammer, 2012; banglapedia, 2021)

1.2.1. The Brahmaputra-Jamuna River system:

The total length of Brahmaputra Jamuna River system is about 2850 kilometers. It is the 22nd largest river in the world. The catchment area of this river system is about 583,000 square kilometers. The Brahmaputra River originates in Tibet and flows as the name of Yarlung Zangbo jiang. Then this river has been passed through Arunachal Pradesh of India as the name of Brahmaputra. Brahmaputra River receives water by five main tributaries. In Bangladesh Brahmaputra meets with Tista River and flows as Jamuna (Map: 1.01). The Brahmaputra-Jamuna River is famous for its shifting channels, formation of sandbars and braided nature. Brahmaputra-Jamuna is the most energetic river and it has the highest stream power among the major rivers of Bangladesh (Rashid, 1991; banglapedia, 2021). The Brahmaputra enters Bangladesh east of Bhabanipur (India) and northeast of Kurigram district in Bangladesh. In Bangladesh the primary flows of this river are to the south and then it turns southeast and travels through the Madhupur track and then it meets the Meghna River near Bhairab bazar. It has four major tributaries

named Dudkumar, Tista, Hursagar and Dharala (Coleman, 1969; Brammer, 1996; banglapedia, 2021). The Jamuna is a typical example of a braided river with high tend to channel shifting. The main characteristics of this river network is interlocking channels with several sandbars. This river deposits sands in one year, very often to be destroyed later and redeposit them in following rainy season. The continuous process of deposition, erosion and redisposition make it difficult to certain demarcate the boundary between the district of Pabna, Sirajganj on one side and the districts of Mymensingh, Tangail and Dhaka on the other side (Hannan, 1993; Best et al., 2008; banglapedia, 2018; Islam et al., 2022).

1.2.2. The Ganges-Padma River system:

The total catchment area of Ganges-Padma River system is about 907,000 square kilometers. The length of Ganges River is about 2600 kilometers. The total drainage area of this river is about 990,400 square kilometers. Ganges has been divided into two sections within Bangladesh, where the first section named as Ganges which is 258 kilometer long and the second section is 126 kilometer long named as Padma. Ganges running from western border of India and joins with Jamuna at Goalandaghat and Padma running from Goalandaghat and joins with Meghna at Chandpur (Map: 1.01). Mahananda is the main tributary of Ganges within Bangladesh and Mathabhanga, Gorai, Kumar, Arial khan are the main distributaries (coleman 1969, Rashid, 1991; Hannan, 1993; banglapedia, 2021).

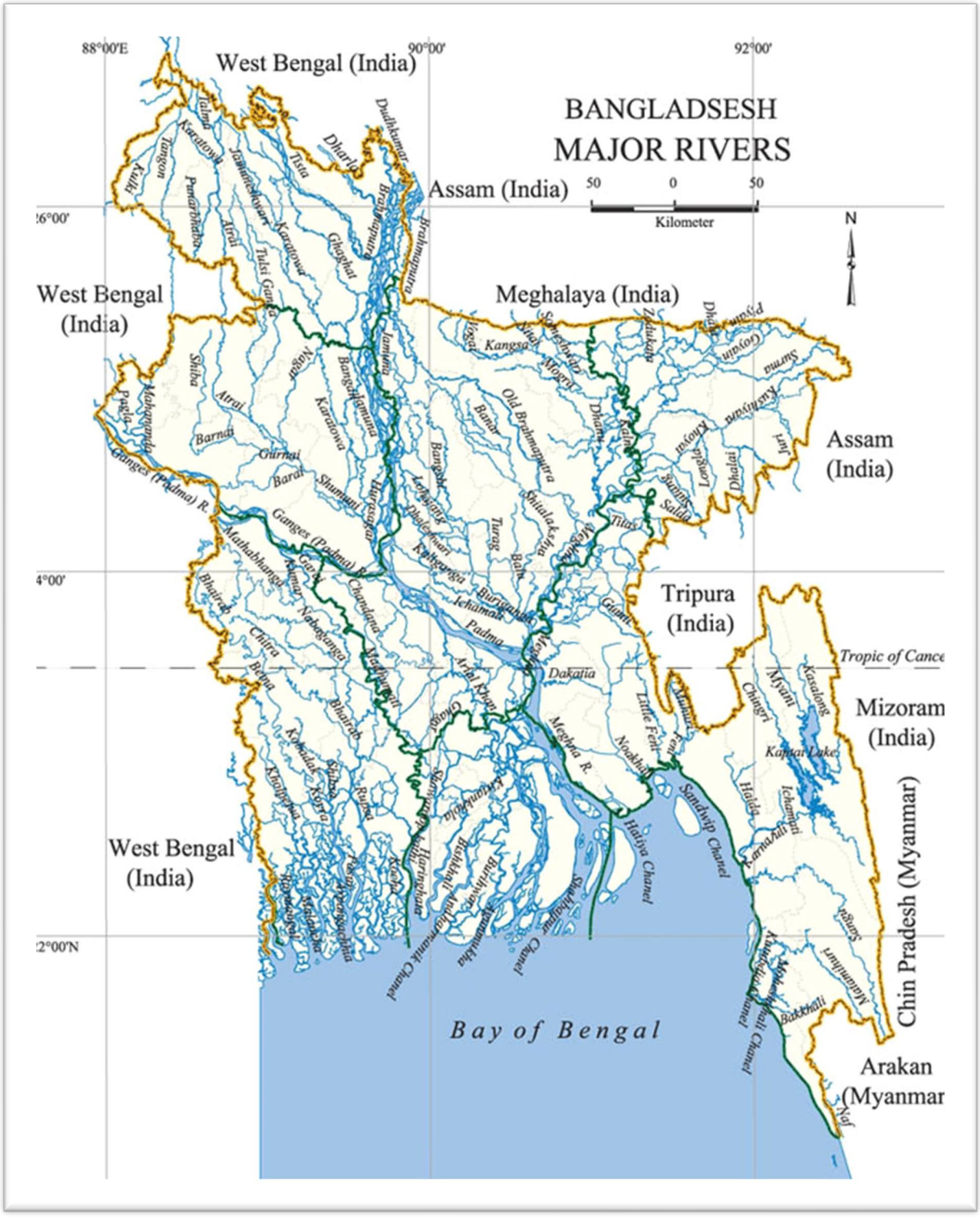
1.2.3. The Surma-Meghna River system:

The length of Surma- Meghna River system is 669 kilometers. Surma River originates from the hills of Shillong and Meghalaya of India. The main source

of this river is Barak River which is bifurcates as Surma and Kushiyara on the border with Bangladesh. These two rivers running within the Sylhet division and flows via Bhairab as the Meghna and joins with Padma at Chandpur (Map: 1.01). The total drainage area of this river system up to confluence with Padma is about 802,000 square kilometers and within Bangladesh this area is about 36200 square kilometers (Rashid, 1991; Hannan, 1993; banglapedia 2021).

1.2.4. The Chittagong Region River System:

The Chittagong region consists of hilly areas. It has a different river system which is not connected with other three river system of Bangladesh (Map: 1.01). The main river of this region is Karnafuli. The other important rivers of this region are the Sangu, Matamuhuri, Bakkhali and Naaf (Hannan, 1993; Rashid, 2019; banglapedia, 2021).



Map 1.01: Major Rivers of Bangladesh (banglapedia)

1.3. River morphology and riverbank erosion:

A river is the overall term for a channel and water flow in it. Channel is the stream flow where water running within down slopes. The drainage basin is the total area of supplying water in to a channel. Different landform has been created through a channel process and the main channel processes are erosion, transportation and sedimentation. River possesses huge number of sediments by weathering of the rocks composing slopes and channel bed. The higher water velocity can transport higher sediment load within mountain area but when the channel reached into a plain land, the capacity of transport sediment load suddenly reduced and the particles which are carried by the flow have been deposited in order to their size and weight and an alluvial plain is formed (Khan & Islam, 2003; CEGIS, 2005; Brammer, 2008). A large amount of water flows through the channel is the main cause of flood. When flood flows from the mountains, the channel on an alluvial plain change their courses and a new channel has been formed. River erosion is a hydraulic process of running water which makes a channel broader and deeper (EGIS, 1999; Rabbi et al, 2012; Chatterjee & Mistri, 2013). If the sediment and water load increases in the channel it may erode their banks on the downstream. Heavy rainfall, high volume and velocity of running water exceeds the resistance of the riverbank soil particles, as a result, erosion will occur (Aktar, 2012; Islam & Rashid, 2012; Pahlowan & Hossain, 2015). There are varieties of natural and human induced factors that influence the erosion process such as floods, loss of riverbank vegetation, climate change, earthquake, urbanization and construction of different infrastructures. Bank line composition has an influence on river erosion. If the riverbank composed of sand and silt it may easily erode, on the other hand bank lines which consists of boulders or rocks

are more resistant to erosion. Geomorphology of riverbank, nature of riverbank topography, elevation of riverbank dunes, bank line exposure to wind and waves, structure types along the riverbank, density and development etc. are another factor of riverbank erosion (Hannan, 1993; Biswajit et al., 2013; Rahman & Islam, 2017; Munna, 2018, Rashid & Habib, 2022). The monsoon climate, geomorphological location, diversity of rivers makes Bangladesh highly vulnerable to flood and riverbank erosion. Bangladesh has limited high land with a vast area of plain land which washed by river water every year. Huge quantities of water and sediments carried by the major rivers of Bangladesh are responsible for flood and riverbank erosion (Elahi, 1991; CEGIS, 2005; Sarker et al., 2003; Das et al., 2014; Rahman & Islam, 2018). Shifting nature of river channel one of the main causes of massive riverbank erosion. Unstable River flows another cause of bank migration (Haque & Hossain, 1998; EGIS, 1999; Rob & Billah, 2013). Bangladesh experienced 2400 kilometers of bank line erosion last few years. Jamuna is a braided and one of the most dynamic rivers around the world, which is highly inclined to erosion, the average width of the Jamuna has often 5.6 kilometers to 15 kilometers (Islam, 1995; Hasan et al., 1997; CEGIS, 2008; banglapedia, 2014). Jamuna had eroded 40150 hectares of floodplain within 1984 to 1992 time period, where the accretion rate was about 900 hectares (Disaster summary sheet, 2019). During 1981 to 1993, about 729000 people were displaced by riverbank erosion in Bangladesh and more than half of those displacement was along the Jamuna River. In 1993, Government of Bangladesh officially announced riverbank erosion as a natural disaster for its destructive nature (Elahi & Rogge, 1990; Chowdhury, 1988; EGIS, 1999; Sarker et al., 2013; Van, 2020; Chowdhury et al., 2021).

1.3.1. Cause of riverbank erosion:

Rivers naturally undergo changes in their magnitude and intensity, seeking balance through erosion and deposition. Bank erosion occurs when the stresses from river water and sediment exceed the resistance of the riverbank (Haque & Hossain, 1988; Islam & Rashid, 2011; Hasan et al., 2017; Akter et al., 2019). Factors such as hydrologic processes, pore water pressure and moisture content within the bank line significantly influence riverbank erosion (Simon and Collison, 2002; Chatterjee & Mistri, 2013; Hasan et al., 2018). Initial weakening of the bank occurs through sub-aerial processes like weathering, which precede fluvial erosion. Fluvial erosion involves the removal of particles due to rivers hydraulic action, while mass failure refers to the collapse of bank materials (Elahi & Rogge, 1991, 2006; Hossain et al., 2007; Uddin & Basak, 2011; Islam et al., 2022). Heavy siltation and deforestation along the major river systems further weaken the banks, increasing their susceptibility to erosion (Ashworth et al., 2000; Philip et al., 2002; Uddin and Basak, 2011). Most erosion occurs during the flood season, with some taking place during low-flow periods. Significant bank erosion occurs due to the direct impact of flowing water, the collapse of bank materials, and soil properties that increase erodibility. (Thorne, 1982; Islam et al., 2007; Fuller, 2009; Basar et al., 2012; Biswajit et al., 2013; Islam & Sarker, 2017).

1.3.2. Bank erosion along the major rivers of Bangladesh:

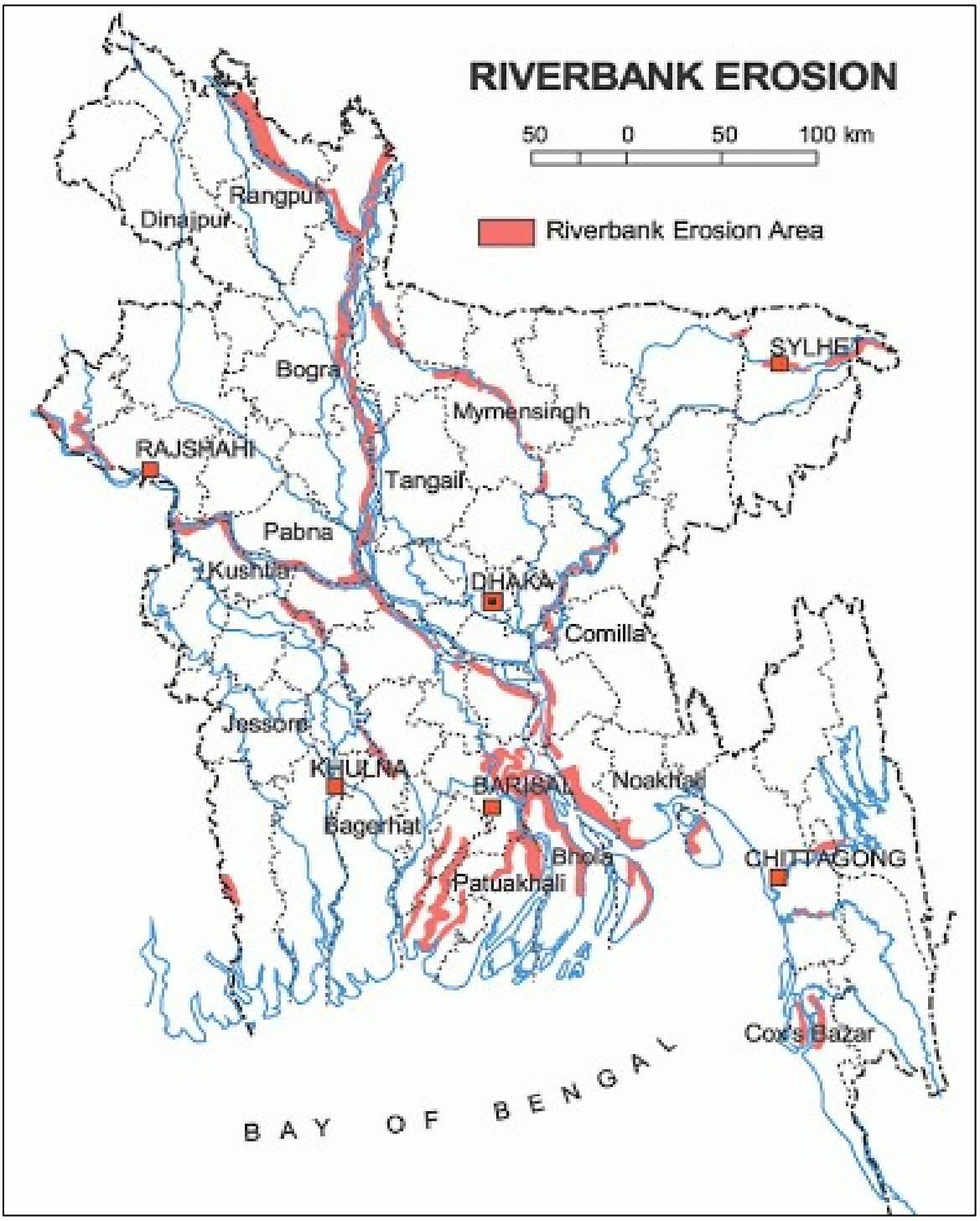
People's livelihood standard became low due to riverbank erosion. The bank line of major three rivers of Bangladesh are highly prone to erosion, spatially in the monsoon season. The Padma River is particularly unstable in nature and

the left bank of Padma is highly erosion prone area. The Brahmaputra-Jamuna River faced frequent and acute bank line erosion past few years (Khan & Islam, 2003; CEGIS, 2005; Bhuiyan et al. 2014; banglapedia, 2015: Islam et al., 2022). Last few decades, the widening and migration rate of both bank of Jamuna River was very high (EGIS, 1999; CEGIS, 2009; Bhuiyan et al. 2014). About 80690 hectares of land had been eroded by the Jamuna River for last few decades (Kuehl et al., 1989; Unnayan onneshon, 2012, CEGIS, 2012). Frequent flooding, fast channel shifting of Jamuna River causes vast erosion and destroyed everything in its paths, which disrupt human settlement and activities (Haque, 1988; Selim et al. 2021; mamun et al., 2022).

National Water Management Plan (NWMP) of 2001 reports that approximately 10,000 hectares of land are eroded by rivers annually. A 2005 study by the Center for environment and Geographic information Services (CEGIS) documented extensive bank erosion between 1973 and 2004, with the Padma and Jamuna rivers losing 29,390 hectares and 87,790 hectares of land, respectively. 5% of Bangladesh's total floodplain is directly impacted by erosion, affecting roughly 94 out of 489 upazilas. Currently, about 100 upazilas regularly face erosion and flood hazards, with 35 particularly affected (CEGIS, 2005, 2009; Mollah & Ferdaush, 2015; Sarker, 2018; banglapedia, 2019; Akther et al., 2020).

Bangladesh's major rivers- Padma, Jamuna and Meghna are shifting their channels, within approximately 2400 kilometers of riverbanks experiencing significant erosion annually (Islam, 2012; Pahlowan & Hossain, 2015; Akther et al., 2020; Selim et al., 2020; banglapedia, 2021). Between 1984 and 1992, rivers eroded 40,150 hectares while accreting 7,140 hectares, with erosion and accretion rate of 5,000 and 900 hectares per year, respectively. Between 1970

and 2000 the Padma and Jamuna rivers consumed 180,000 hectares of land. In 2008, riverbank erosion by Padma displaced 200,000 people, taking 1630 acres of agricultural lands and 370 settlement areas (EGIS, 1999; Zaman, 1989; Islam and Rashid, 2008; CEGIS, 2008; Rahman & Islam, 2018; Islam et al., 2019; Freihardt & frey, 2023). Since 1973, 1.6 million people have rendered homeless due to erosion along major rivers of Bangladesh (Philip et al., 2002; Sarker et al., 2014; CEGIS, 2015; banglapedia, 2018). From 1973 to 2021, erosion and accretion along the jamuna river altered 88,462 hectares and 16,315 hectares of land, respectively (MWR, 2001; Faruque, 2007; Islam & Rashid, 2011; Sarker et al., 2011; Rahman & Rahman, 2015; Sarkar et al., 2021; Saha et al., 2022). The Jamuna's channel shifting has intensified due to the narrowing of the Sirajganj- Bhuapur section, where the river width decreased from 11 km to 4.8 km (Hossain & Ferdousi, 2004; Bhuiyan et al., 2010; Rashid, 2011; Baki, 2014;; Sarker et al., 2014; Hasan et al., 2018). Map 1.02 shows the Riverbank erosion prone area in Bangladesh.



Map 1.02: Riverbank erosion prone area of Bangladesh (BWDB)

1.4. Impact of riverbank erosion

Riverbank erosion has become a common phenomenon along the rivers in Bangladesh. Bank erosion erodes away various infrastructure and destroyed communication system in the bank line area. River encroachment not only affect the rural floodplain people but also the urban people and development program has been affected (Hossain et al., 2007; Ghosh & Mahbub, 2014; banglapedia, 2015; Sarker et al., 2020). Bank erosion has been displaced people from their own land and forced people to migrate or resettle in new areas. This displacement and migration exacerbate the socio-economic condition (Elahi et al. 1991; Haque 1997; Hasan, 2015; Shahriar, 2021). The common impacts of riverbank erosion are:

- Displacement of people from their origin of place.
- Affect in public health.
- Increase landless labor.
- Effect on the transport system.
- Shortage of crop production.
- Effect on the occupation of the affected people.
- Increase unemployment problem.
- Increase poverty in society as well as nation.
- Agricultural land reduction.
- Educational structure is also negatively changed by riverbank erosion. (Haque & Hossain, 1988; Hasan, 2015; hamide & Karim, 2017; Munna, 2018, Akther et al., 2022 & Mamun et al., 2022)

1.4.1. Socio-economic impacts of riverbank erosion:

The socio-economic impact of riverbank erosion might be short term and long term. Short term socio-economic impacts are; loss of household, agricultural land, occupation, assets etc., and long-term impacts includes direct effects on livelihood condition, direct and indirect effects on human physical and mental health, effect on children education and different development projects. Livelihood standard, per capita income, access to education, healthcare service, social security and land area size is very low in erosion prone areas. As a result, the socio-economic susceptibility is increased in the erosion prone areas (Haque, 1988; Hossain 1993; Haque, 1997; Islam & Rashid, 2012; Baki, 2014; Sarker et al., 2020).

According to the regional chief of International Federation of Red cross and Red Crescent Society (2007), riverbank erosion is one of the largest concerns of Bangladesh, it may causes massive losses but very few people are concerned about this disaster (Mamun et al., 2000; Islam et al., 2007; Islam, 2010; Mollah et al., 2015). Riverbank erosion causes much more destruction to the socio-economic development and hamper our national development. Sometimes affected people lose their savings and fall into debt (Baqee, 1997; Islam, 2018; Akter et al., 2019; Ali et al., 2021). In erosion prone areas, many victims lose their occupation and remain unemployed due to lack of work opportunities. Many female-headed households displaced by riverbank erosion are particularly vulnerable. When they took shelter on embankments, roads or other places faced different types of difficulties. They felt that the shelter were either unpleasant or unsafe. Many women were unwilling to go to the shelters because of the Muslim culture of purdah which means that women should not show themselves to unrelated men would have negative

impacts on their status within their family and kinship group (Kafi, 1992; Anan, 2002; Mehta, 2007; Nasreen, 2000; Mondal, 2014; Akter et al., 2019). They also fear of violence such as stalking, kidnapping, sexual harassment, physical and mental abuse etc. For many women there were issues concerning a lack of privacy in the public shelters. They struggled with cooking, fuel shortages and safe drinking water. There were also insufficient toilets, hygienic facilities, fears of snakes and other insects, transportation problems and many other challenges (Begum, 1993; Rahid & Michaud, 2000; Nasreen, 2000; Nasreen, 2008; Hossain, 2000; Rahman, 2013). As a result, social, economic, environmental vulnerabilities among the women have been created due to riverbank erosion. (Rogge, 1991; Amin et al., 1991; Bhuiyan, 1991; Billah et al. 2022).

The impact of riverbank erosion on local livelihoods can be classified into three categories:

- The socio economic impacts: includes the loss of homestead area and its economic value, loss of agricultural and productive land, displacement, loss of income and the increase the risk of poverty.
- The environmental impact: Encompasses the degradation of drinking water quality, inadequate sanitation and poor management of soil and agricultural land.
- The other impacts include a lack of health facilities, educational attainment and crime involvement (Rahman, 2013; Ansary et al., 2001; Ali et.al, 2021).

1.5. Understanding vulnerability and disaster

To know about vulnerability, we need to know about Hazard, disaster and risk.

1.5.1. Hazard

A hazard is an agent which can cause harm or damage to a vulnerable group. It can be both natural and human induced. Hazard is a theoretical probability of harm. Natural hazard is any natural events which has an adverse impact on human being or the environment. The distribution and impact of natural hazards is unequal around the world (Nasreen, 2010; banglapedia, 2015). According to the United Nations International Strategy for Disaster Reduction (UNISDR), a hazard is a natural process or phenomenon that can negatively impact the economy, society, and ecology. This includes both natural factors and human factors associated with these natural events. Hazards are the origins of disasters and pose significant challenges to human development and the sustainability of the world (Brickmann, 2006; Disaster risk science, 2019)

"A potentially damaging physical event, phenomenon and/or human activity, which may cause loss of life or injury, property damage, social and economic disruption or environment degradation". Hazards can be single, sequential or combined in their origin and effects. (UNISDR, 2004)

"Hazard is best viewed as naturally occurring or human-induced process or event with the potential to create loss, i.e. a general source of danger" (Smith, 1996).

"A naturally occurring or man-made geologic condition or phenomenon that present a risk or is a potential danger to life or property" (Alexander, 1993).

It can be said that, a hazard is any object or situation which has the potential to cause injury or damage to human health, property and environment.

1.5.2. Disaster

A disaster is a serious disruption occurring over a short period of time that causes widespread social, economic or environmental losses which exceeds the ability of the affected community to cope using its own resources (Nasreen, 2004). According to Hyndman (2019), 'A hazard is a natural disaster when the event causes significant damage to life and property'. Some other definitions of disaster are:

- According to WHO, "A disaster is an occurrence disrupting the normal condition of existence and causing a level of suffering that exceeds the capacity of adjustment of the affected community".
- "A disaster can be defined as a significant departure from normal experience for a particular time and place" (Turner, 1978).

1.5.3. Risk

Risk is considering as the probability of harmful consequences or expected losses resulting from interaction between natural or human induced hazards and vulnerable conditions. Risk is something that creates or suggests a hazard (Dewan, 2013). Risk is:

Risk = Probability of hazards × Degree of vulnerability

- "The potential disaster losses in lives, health and livelihood status, assets and services, which could occur to a particular community or a society over some specified future time period" (UNISDR, 2009).

1.5.4. Vulnerable and Vulnerability

According to IFRC (International Federation of Red Cross and Red Crescent) vulnerable refers to capable of or susceptible to being wounded by any natural or man-made events.

Vulnerability

The term vulnerability is defined as the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (Blaikei et al, 1994; Fordham, 1998). So, vulnerability describes the characteristics and circumstances of a community system or assets that make it susceptible to the damaging effect of hazard.

- "Vulnerability is the condition determined by the physical, social, economic and environmental factors, which increase the susceptibility of a community to the impact of hazards" (UN, 2009)
- "According to IPCC (Intergovernmental panel on climate change) "vulnerability as the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change" (2001).
  IPCC describe the relation as:

  Vulnerability = f (Exposure, Sensitivity, Adaptive capacity)

So, it can be said that, vulnerability is a human condition of resulting from physical, socio-economic and environmental factors which regulate the livelihood and scale of damage from the impact of specified hazards.

1.5.5. Types of Vulnerability

There are four main types of vulnerability. These are:

1. **Physical vulnerability**

Physical vulnerability refers the population density, location of settlement, types of materials using in different infrastructure and housing construction, the degradation of environment (UNISDR, 2004).

2. **Social vulnerability:**

Social vulnerability includes the inability of people, cultural values of people, characteristics of social institutions, level of wellbeing of individuals, communities and society, education and literacy, existing peace and security, access to resource, social equity, traditional values and overall collective organizational systems (UNISDR, 2004).

3. **Economic vulnerability**

Economic vulnerability is highly dependent upon the economic status of persons, communities and nations. Poor person or community are more vulnerable to disasters due to lack of resources to build durable structures or engineering measures to protect themselves from negative impact of any disaster (UNISDR, 2004).

4. **Environmental vulnerability**

Environmental vulnerability refers the degradation of natural resources and environmental factors. All communities are not equally vulnerable because of their different environmental conditions and locations (UNISDR, 2004).

According to Blaikei et al (1994) disasters are produced by the complex mixer of social, political and economic forces that formed vulnerability of people to hazardous environment.

1.5.6. Vulnerability indicators:

Vulnerability indicators are very useful tool for understanding social vulnerability of a community. It helps to identify geographic areas, where people are vulnerable the impacts of natural hazards. The indicators are based on specific dimensions of social vulnerability. Age, Population, Household, Health, income, Social connection, Awareness of hazards, Housing, Children and elders, Culture, Security, Education etc. are the main indicators of social vulnerability (Brook, 2003; Brikmann, 2006; Balica, 2007; gall, 2007; Fakete, 2009; Balica et al., 2012; Fatemi et al., 2017).

The relationship between the indicators and vulnerability is illustrated below:

Indicators of Social Vulnerability			
Indicators	**Explanation**	**Indicators**	**Explanation**
• Income	• Higher income, Lower the vulnerability.	• Housing conditions	• More resistant house, lower vulnerability
• Gender	• Higher percentage of women, children, higher the vulnerability.	• Infrastructure	• Poor infrastructure, increase vulnerability.
• Socio-cultural norms and values	• More restriction to the women, increase vulnerability.	• Social development	• Less development, increase vulnerability.
• Age	• Older/aged person, increase vulnerability.	• Family structure,	• Higher numbers of family members increases vulnerability.
• Access to health care services (at least with MBBS doctor)	• Lower facilities, higher vulnerability	• Social networks and support	• More support reduce vulnerability
• Education	• Higher education, lower vulnerability.	• Government and NGOs support	• More sources of assistance reduce vulnerability

• Local security	• Less or no security, increase vulnerability.	• Knowledge and Experience	• Less or no knowledge, increase vulnerability.
• Physical environment	• Higher exposure, higher vulnerability	• Water	• Higher the numbers of household's unsafe drinking water, higher is the vulnerability.
• Psychological environment	• Higher mental instability, increase vulnerability.	• Sanitation facilities	• Higher the numbers of using sanitary toilet, lower the vulnerability.

Table1.1: Indicators of social vulnerability

[Burton et al. (1993); Blaikie et al. (1994); Kaplan et al. (1996); Murray et al. (1998); Brunner (2000); Cutter et al. (2003); Adger et al. (2004); Nasreen 2008] (Modified by: Author, 2022)

The vulnerabilities caused by flood and riverbank erosion can be presented as follows:

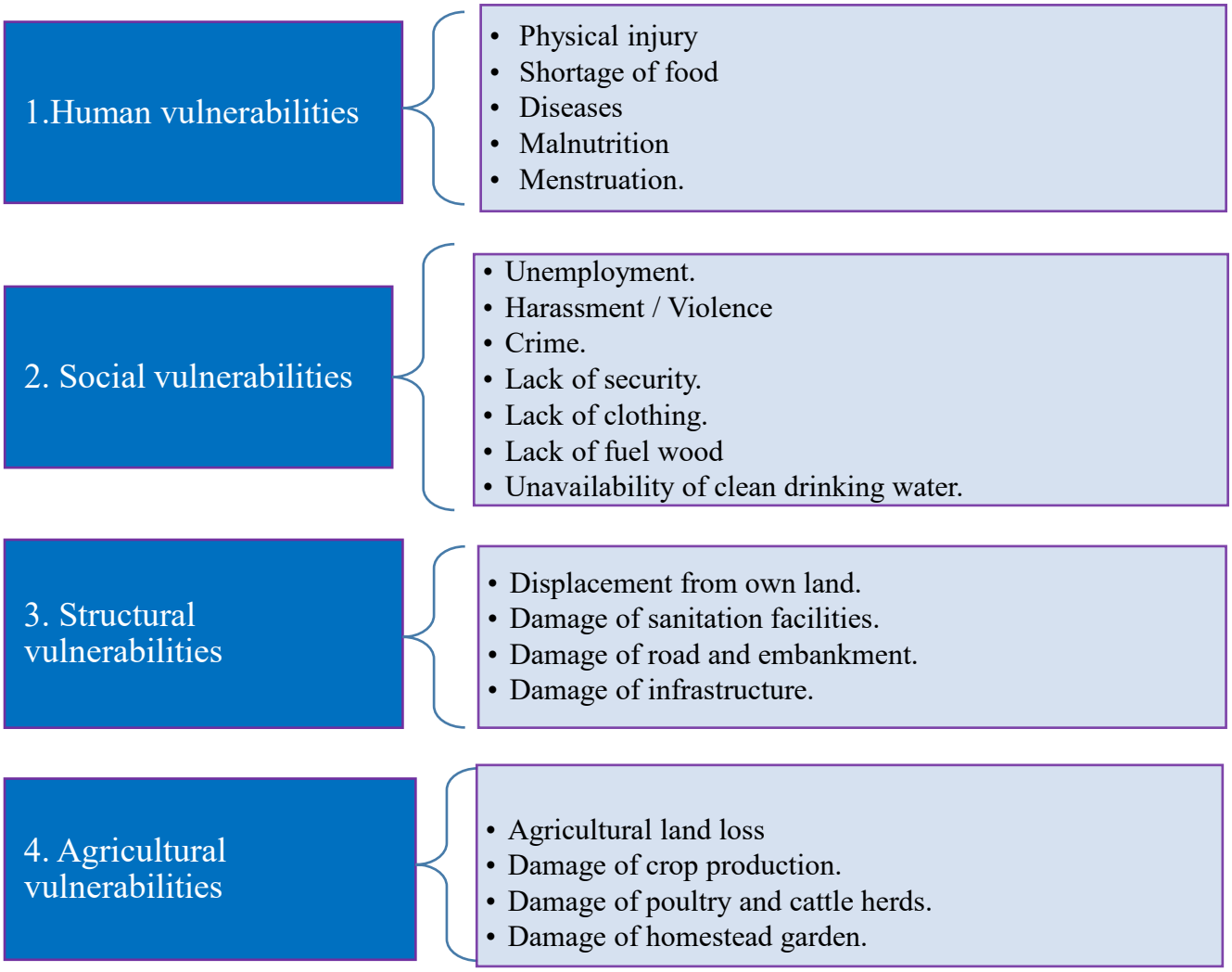


Figure 1.1: Riverbank erosion induced vulnerabilities in Bangladesh

(Modified by Author, 2022)

Riverbank erosion related vulnerability of women and children can be shown through following diagram:

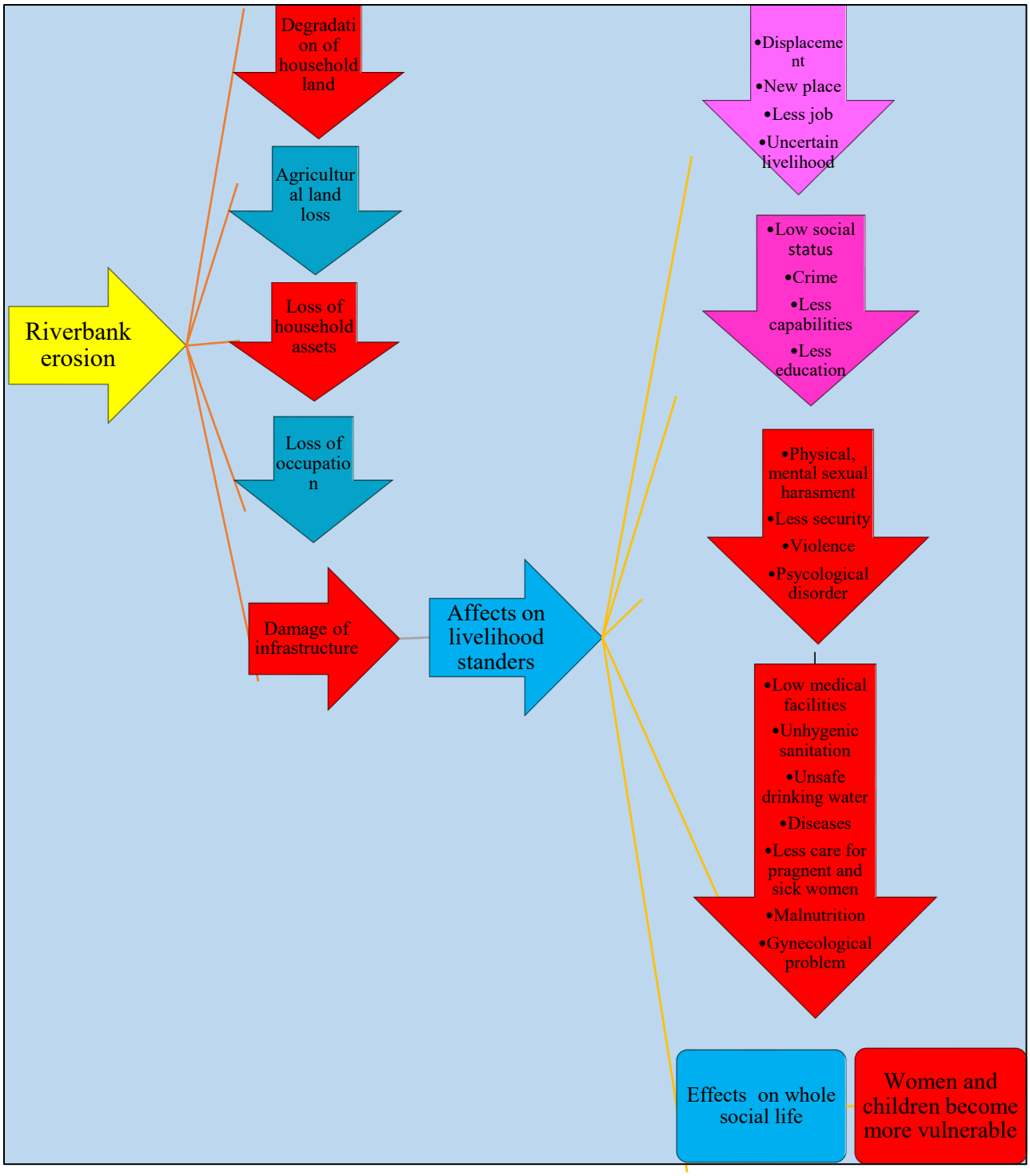


Figure 1.2: Riverbank erosion related vulnerability of women and children (Author, 2022)

1.5.7 Vulnerability assessment

Vulnerability assessment refers to the process of identifying, defining, classifying and prioritizing vulnerabilities with a systematic way. Vulnerability assessment describe the evaluation of the impact of natural hazards on the human build environment, social and economic structure, social services and the natural environment, considering the awareness of a community and its ability to response and to recover from a disastrous event (Fussel, 2009; Birkmann, 2006; Paul, 2013; Ludena & Yoon, 2015). Vulnerability assessment is the process of identifying threats and the risks they pose characteristically involves the use of automated testing tools. Vulnerability assessment usually considered as a function of a systematic ability to cope with stress and shock (Smith, 1992; Balica, 2007; Gall, 2007; Islam & Bhuiyan, 2016).

Vulnerability assessment is a vital stage to reduce the impact of natural hazard risk. Vulnerability assessment provides significant information or weakness of any society or community which is in under hazardous threats. Vulnerability assessment process offers the community or society a better understanding of its resources, facilities, setbacks, and overall risks. The assessment of vulnerability needs the ability to identifying and understanding the susceptibility of elements at risk of the society to different hazards (Fakete, 2009; Balica & Wright, 2012; Fatemi et al., 2017). There are various assessing methods have been used to describe vulnerabilities. Different vulnerability assessment methods are used to different hazards. For example, flood risk vulnerability assessment method has been developed for the flood prone areas to compare their challenges and drawbacks. By applying the vulnerability assessment methods researcher can identify and understand about the different

types disasters which may supports to decision makers for reducing damage and improving development projects (Lindenberg, 2002; Balica & Wright, 2010; Flanagan, 2011; Du et al., 2015; Nasiri et al., 2016).

1.5.8 Types of Vulnerability assessment method

There are different types of methods and models have been adopted last few decades for assessing vulnerability. These group of methods are widely used in vulnerability studies. Policy makers uses these methods to clarify and understand vulnerability which aims to lessening losses and plan for the risk response in specific regions (Lindenberg, 2002; Fussel, 2009 Ludena, & Yoon, 2015). These groups of assessment methods depend on complex indices with or without weighting. These methods also faced with significant complexities related with standardization, weighting and aggregation methods. There have been other setbacks of these methods, are the difficulties that the quantification of the number of social indicators poses to the calculation (Hahn et al., 2009; Khan, 2012). The following are some commonly employed methods for assessing vulnerability:

I. Vulnerability curve method

Vulnerability curve method has been designed to identify actual damaged caused by flood in a specific area. The data for all samples of each component class is calculated and averaged, as a result step damage carves are created. Though this method is based on actual damaged survey, so it takes a lot of time and resources. The application of this method is less than the other methods because it is designed for the specific areas (Fussel, 2009).

II. Disaster loss data method

Disaster loss data method is constructed on the basis of data collection from real flood hazard zones. It is a simple method with little accuracy because of uneven recorded data (Nasiri et al., 2016).

III. Modeling method

This is a computer-based method which can evaluate the depth, elevation and velocity of floods, using frequency, magnitude and shape of the hydrograph at selected regions. Detail topographic, hydrographic and economic data are needed to this method for accurate information (Hahn et al., 2009; Balica, 2013). This method can assess the vulnerability in local scale but it cannot describe a clear relation between predicted map and level of real flood damage. It is a geographical information system (GIS) based method where variables used as an input data which is converted to raster format for tangible analysis (Nasiri et al., 2016)

1.5.9: Vulnerability assessment method:

In recent years, index based vulnerability measurement method such as Livelihood Vulnerability Index (LVI) and the Climate Vulnerability Index (CVI) is widely employed in many parts of the world (for example: Toufique & Islam, 2014; Shah et al. 2013; Hahn et al., 2009). Livelihood Vulnerability Index (LVI) proposed by Hahn et al. (2009) and the Climate Vulnerability Index (CVI) proposed by Pandey and Jha (2012) to measure and compare livelihood vulnerability in the context of the riparian households and to assess the relative magnitude of contributing indicators within concerned vulnerability dimensions under IPCC (Intergovernmental Panel on Climate

Change) framework. According to IPCC (2007) vulnerability is the function of three dimensions as follows:

Vulnerability = (Exposure, Sensitivity and Adaptive capacity)

- Exposure refers to the environment/location of people that could be adversely affected by physical events and which, thereby, are subject to potential future harm, loss or damage (Gasper, 2010).
- Sensitivity is the degree to which the system is affected by the exposure, And
- Adaptive capacity refers to the system's ability to withstand or recover from the exposure (ebi et al., 2006).

Based on IPCC definition of vulnerability, Turner et al. developed a vulnerability framework and later Hahn et al. (2009) developed an indicator based vulnerability assessment method that has been used by many scholars in different context (For example: Etwire et al. 2013; Shah et al. 2013; Pandey & Jha 2012; Penthi et al., 2015; Aryal et al., 2014; Toufique & Islam 2014; Bhuiyan et al. 2017).

In the perspective of natural disaster of Bangladesh, different types of vulnerability assessment methods (CVI, LVI) have been used to evaluate the vulnerability of people due to disasters, which helps us to understand the susceptibilities of any disaster.

- Coastal Vulnerability Index (CVI) was formulated and later adopted by many researchers to evaluate the degree of vulnerability by using either physical parameters such as coastal geomorphology, relative sea level rise, shoreline change rate, tide and wave regime, coastal slope or population density as socio-economic parameter along with other parameters. Climate Vulnerability Index (CVI) method has also been

used to measure and compare livelihood vulnerability in the context of the riparian households and assess the relative degree of contributing indicators within the concerned vulnerability dimension. However some important variables such as institutional, governance, environmental issues have been overlooked in CVI method (Fussel & Klein, 2006; IPCC, 2007; Brikmann, 2007; Balica et al, 2012; Alam, 2016; Bhuiyan et al. 2017).

- The LVI approach is preferred over the Sustainable Livelihood Approach (SLA), developed by Chambers and Conway (1992), which only considered five types of household assets; natural, social, financial, physical and human capital. But it failed to integrate the issues of sensitivity and adaptive capacity to climate change. The LVI approach focuses on quantifying the strength of current livelihoods and health & water resource characteristics as well as the capacity of communities to alter these strategies in response to climate related exposures (Hahn et al. 2009). The IPCC approach aggregates the several major components under three dimensions: Exposure, sensitivity and adaptive capacity, for vulnerability analysis (IPCC, 2007; Hahn et al. 2009; Shah et al. 2013; Toufique & Islam 2014; Alam, 2016). Where, Exposure comprises natural disasters and climate variability. Sensitivity comprises food, water and health, and Adaptive capacity includes socio-demographic profile, livelihood strategy and social networks.

  In Bangladesh, Livelihood Vulnerability Index (LVI) has been used to measure the vulnerability of households living in the coastal region. Livelihood vulnerability index formulated based on available information in the dataset. This method have Seven major components

(Socio-demographic profile, Livelihood strategies, Social network, Health, food, Water, Natural disaster and Climate vulnerability) and several sub-components (under these three dimensions) have been used in this method to evaluate people's vulnerability.

The sub-components are chosen on the basis of respondent's weight to each major component. The sub-component dependency ratio ranged from 1 to 5. These minimum and maximum values are then used to transform this indicator into standardized index to integrate it into the major component. The minimum value is set at 0 and the maximum at 100. After standardization of each sub-components, they are averaged to calculate the value of each major components. Weights of each of the major components are determined by the number of sub-components which make up each major component. The LVI is scaled from 0 to 0.5, where 0 indicates the least vulnerability and .05 indicates most vulnerability. Now a days, Livelihood Vulnerability Index method have been used to calculate the vulnerability of the population due to disasters, but it has few limitations. One major limitation of this method is the use of equal weights. Not only the sub components but also the major components are weighted equally that might impacts on accurate results (Cutter et al., 2003; Toufique & Yunus, 2013). Livelihood Vulnerability Index (LVI) method has also been used to calculate the livelihood vulnerability of the riverbank erosion hazard and its impact on food security for rural households in Bangladesh (IPCC, 2007; Birkmann, 2006; Balica et al., 2012; Du et al., 2015).

- IPCC vulnerability assessment method has been used to calculate the livelihood vulnerability of riverbank erosion hazard along the riverine areas around the world. As IPCC suggested that vulnerability is a

function of Exposure, Sensibility and Adaptive capacity. These are the main contributing factor to vulnerability analysis. A number of indicators have been selected to represent these contributing factors and these indicators have been selected based on prevailing vulnerability studies. Here, Exposure has been determined by the location of an area which faces hazard or stress, Adaptive capacity defines the capacity of adjustment with any consequences. Education and skill, economic capacity, social network and communication are being used to describe adaptive capacity. To define sensitivity, demographic, food & agriculture, and health related data have been used in IPCC framework. To assess the vulnerability of riverbank erosion prone area, following formula has been used:

$$\textbf{IPCC-VI= (EI-AI) × SI}$$

Where, **EI** stands for Exposure Index, **AI** represents Adaptive capacity Index and **SI** refers to Sensitivity Index. In this method, equal weight has given to each indicator. The minimum and maximum value for the variables has been set at, 0-100. The range of IPCC-VI, varies from -1 to +1, where -1 indicates least vulnerability, 0 indicates moderate vulnerability and 1 indicates extreme vulnerability (Toufique & Yunus, 2013; Alam, 2016; Bhuiyan et al, 2017).

Both (LVI) and (CVI) method follows the vulnerability analysis method suggested by IPCC (2007). LVI and CVI develop with a weighted balance integrated approach to calculate the vulnerability. These methods include local and indigenous knowledge to select the indicators (Hahn et al., 2009; Birkmann, 2006; Balica et al., 2012). The value of three dimensions is calculated by selective formula suggested by IPCC framework, which is:

$$\textbf{LVI-IPCC = (Exp-Ada.Cap) × Sen.}$$

The value for LVI-IPCC has been scaled as, -1to 1, where, -1 indicates least vulnerable condition and 1 indicates most vulnerable condition (Toufique & Yunus, 2013; Alam, 2016).

Following the framework outlined by the IPCC, this study developed the Riverbank Erosion Vulnerability Index (REVI) by refining and expanding the Livelihood Vulnerability Index (LVI) introduced by Hahn et al. (2009) and the Climate Vulnerability Index (CVI) proposed by Pandey and Jha (2012). Additionally, it incorporates insights from the work of Toufique & Younus (2013), Alam (2016) and Bhuiyan et al. (2017) to evaluate the vulnerability of women and children while analyzing the significance of various indicators within specific vulnerability dimensions.

Understanding the vulnerability is essential for reducing disaster related fatalities. Conducting vulnerability assessment study enables a deeper understanding of the complex factors influencing exposure, sensitivity and adaptive capacity in specific areas. Such assessment also facilitate the examination of interactions between human and their surrounding environments. By evaluating vulnerability, insights into people's relationship with their environment, societal norms and regulations, hazard awareness and social & demographic conditions are gained. These insights play a vital role in developing and implementing strategies and initiatives aimed at reducing vulnerability for both current and future generations (Cutter et al., 2003; Adger, 2006; Khan, 2012; Bhuiyan et al., 2017).

1.6. Natural disaster and Vulnerability of Women and Children

Bangladesh is a patriarchal society where men are traditionally regarded as superior to women, leading to women occupying a subordinate or inferior

status. This situation is perpetuated by various institutions, including religious, economic, political, social, and legal systems, all of which reinforce women's disadvantaged position in society. Women in Bangladesh face vulnerabilities due to restrictions on their mobility and societal taboos. Decisions regarding safety measures, such as leaving home in emergencies, are predominantly made by men, limiting women's participation and reducing their survival chances. Women are often confined to their homes, while men gather and share information about impending disasters, leaving women uninformed and unable to make decisions (Ahsan et al., 1998; Nasreen, Akter & Hasan, 2019; 2000; Khandokar, 2000). Economically disadvantaged women often struggle with insufficient access to food, clothing and shelter. Unemployment among men frequently results in idleness or migration, leaving families behind. In such situations, women who work within their households, shoulder the responsibility of protecting their homes, children, livestock and belongings. Their challenges are compounded by low social status, illiteracy heavy domestic burdens and poverty (Rasheda, 1993; Ahsan et al., 1998; Momsen, 1999; Nasreen, 2000; Annan, 2002; Anderson & Enarson, 2004). Socio-cultural barriers often prevent many women from seeking healthcare services, while poverty, lack of education and poor health limit their opportunities to escape lives of hardship and fatigue. Women commonly face a variety of health problems, including complication from abortion, sepsis, and obstructed labor, infectious diseases like measles and diphtheria as well as chronic conditions such as asthma, diabetes, tuberculosis and malnutrition. Pregnant women often choose home delivers over hospital care. Limited nutrition and poor health also contribute to perception that women in Bangladesh are less capable of withstanding the physical demands

of disasters (Hossain, 2000; Islam, 2012; Mollah et al., 2015; Biswas, 2015; Ali et al., 2021).

Natural disaster affect individuals globally, both physically and mentally. The World Health Organization (2017) states that psychological distress affects 30% to 50% of individuals impacted by disasters, stemming from factors such as injuries, fatalities and different infrastructural damages (Bhuiyan, 2000; Norris et al., 2002; Keya & Harun, 2007; Bradshaw & Fordham, 2013; Hossain et al, 2021). Disaster severely damage local infrastructure, leading to healthcare and sanitation disruptions, food and water shortage, spread of diseases, all of which heighten vulnerability. Women and children are particularly affected, as their access to safety, food, healthcare, education and sanitation becomes drastically limited. Disasters significantly heighten the social, physical, healthcare, and economic vulnerabilities of affected populations, especially during and after such events (Rasheda, 1993; Bhuiyan, 2000; Hossain et al., 2020). In Bangladesh, a riverine country, a considerable portion of the population resides along riverbanks, making them particularly susceptible to bank erosion. This phenomenon creates stressful conditions that reduce their ability to cope with hazardous situations, often leading to mental health issues (Cannon, 2002; Dasgupta et al., 2010; Das et al., 2017; Chowdhury et al., 2021). Riverbank erosion imposes a range of difficulties on the affected individuals, with women and children being among the most impacted groups in Bangladesh. Women may adopt various coping mechanisms to manage stress, but these measures often prove inadequate for full recovery. Furthermore, the psychological impact of disasters and the capacity to cope in these situations remain critically underexplored in the country (Hutton, 2000; Keya & Harun, 2007). Women face severe challenges

during and after disasters, particularly in shelter conditions. Women may experience sexual harassment, domestic violence, mental distress, gynecological health issues, and other forms of mistreatment. Several research indicates that approximately 35% of women endured harassment during floods and related riverbank erosion events (Bhuiyan, 1991; Enarson, 2005; Nasreen, 2004 & 2012; Biswas, 2016). In erosion-prone areas, women often encounter acute physical and social insecurities. Additionally, disasters drastically alter their privacy, with inadequate sanitation facilities and fresh water hindering hygiene maintenance, leading to gynecological problems (Islam & Guchhait, 2008; CCC, 2009; Nasreen, 2012). Post-disaster periods expose poor and economically disadvantaged women to risks such as trafficking and exploitation by criminal networks under the guise of employment offers. School-going children are also heavily affected, as educational institutions are frequently damaged due to riverbank erosion (Hoque & Haque, 1989; Kafi, 1992; Islam, 2013; Khan et al., 2014; Hossain, 2015) while riverbank erosion has widespread consequences for communities, its impact is particularly severe on women and children, as identified in this study through an index-based research methodology.

CHAPTER TWO
REVIEW OF LITERATURE

CHAPTER TWO

REVIEW OF LITERATURE

2. Introduction

The literature review is an essential part of academic research, serving as a key tool to identify gaps and refine research questions. It encompasses the evaluation of diverse sources, such as books, journals, articles, and other credible materials, that relate to the research topic and study area. This process provides a structured understanding of the subject, enabling a solid foundation for addressing research objectives. In this study, the reviewed literature has played a key role in identifying knowledge gaps and refining the research questions. To maintain clarity, this chapter is structured into two main sections and three subsections, systematically addressing relevant works.

2.1. Natural disaster and riverbank erosion in Bangladesh

Due to Bangladesh's geographical location and its susceptibility to natural disasters, various types of calamities can occur at different times and locations, with varying scales and impacts. Being a riverine country with numerous large rivers, Bangladesh experiences frequent flooding and riverbank erosion, almost every year (Karim, 1995, Nizamuddin, 2001). These phenomena, triggered by both natural and human-induced factors, significantly affect the lives of those residing in floodplain areas. Riverbank erosion has adverse effects on the socio-economic, political, and cultural aspects of people's lives. Where people’s exposure and sensitivity is high due

to bank erosion and their capability is low to adapt that situation, its causes several sufferings to the inhabitants in floodplain areas (Baqee, 1997; Hossain, 2007; CEGIS, 2012; Hasan et al., 2017; Islam et al., 2019; Ali et al., 2021;). This section has been divided into three subsections to improve clarity as outlined below:

2.1.1: Extent of riverbank erosion in Bangladesh

A complex fluvial system and peak monsoon discharge intensify riverbank erosion, which is further influenced by factors like bank line evacuation, water discharge magnitude, soil particle weakness and bank morphology. Several research indicates that climate change has contributed to channel instability in the Brahmaputra-Jamuna River, altering its morphological and hydrological behavior, thereby accelerating erosion (Khan & Islam, 2003; Sarker et al., 2017; Rashid & Habib, 2022). Situated within one of the world's largest river deltas, Bangladesh forms the most extensive deltaic plain. It is traversed by the Ganges, Brahmaputra, and Meghna river systems, along with their various tributaries and distributaries (Islam et al., 2014; Misachi, 2017; Rahman, 2022). These rivers continuous erosion throughout the year, with approximately 10,000 hectares land lost annually (Kuehl, Hariu, & Moore, 1989; Ahmed et al., 2001; MWR, 2007; Rahman & Islam, 2016; Rahman, 2022). As reported by the Bangladesh Water Development Board (BWDB), several districts are highly prone to erosion such as Bogra, Kurigram, Sirajganj, Lalmonirhat, Rangpur, Gaibandha, Faridpur, Manikganj, Shariatpur, Tangail and Jamalpur. BWDB estimates that approximately 1,200 km of riverbank eroded annually in Bangladesh (CEGIS, 2009; BBS, 2011; Basar et al., 2012; Tuhin et al., 2014; Ahmed, 2019; Akter et al., 2019; Rahman, 2022). BWDB also estimated that the Padma River's erosion rate

was 1,400 hectares annually in the early 1970s, which increased to 2,200 hectares annually by the 1990s. Additionally the average annual erosion of both banks of the Jamuna River was approximately 3,300 hectares between the 1970s and the early 1990s. (IRIN, 2008; Tariqul, 2009; Rahman & Islam, 2018). Recent estimation by Islam (2021) indicate that riverbank erosion affects an average of 100 km² of land annually. Over the next 50 years, the rate of riverbank erosion is expected to increase by 9% per year (Uddin and Basak, 2012; Islam and Rashid, 2012; Hasnat et al., 2020; Paul et al., 2021). In 2007, 140 km of riverbanks were completely eroded, while an additional 1345 km were partially eroded due to flood and riverbank erosion (IRIN, 2008; Tariqul, 2009; BWDB, 2009). Over past three decades, the Padma, Meghna and Jamuna rivers are believed to have eroded nearly 0.1 million hectares of land, rendering over 0.8 million people landless. Annually, river erosion impacts around 2,000-3,000 km of riverbanks (Chowdhury, 1988; EGIS, 1999; CEGIS, 2005 & 2009; BWDB, 2009). Between 1973 and 2004, approximately 877.90 km² of land along the Jamuna and 293.90 km² along the Padma River were eroded (Kuehl, Hariu, & Moore, 1989; Hutton & Haque, 2003; Islam & Rashid, 2011; Das et al., 2014; Rahman, 2022). Using satellite images and GIS software, Alam et al. analyzed the erosion rate of the upstream and downstream sides of the Padma River from 1980 to 2019. Over this period, the downstream side experienced a cumulative erosion of 2,823 meters, with the most severe loss of 2,159 meters recorded between 1988 and 1990. Likewise, the upstream side of the Padma underwent a total erosion of 1,995 meters, with the peak erosion of 1,090 meters occurring between 1990 and 1995 (CEGIS, 2009; BWDB, 2017; Alam, Rahman & Rahman, 2020). In 2017, about 1,425 hectares of land along the Padma's bank were eroded, including 114 hectares containing settlements (CEGIS, 2009; Basar et al.,

2012; Sarker et al., 2014; BWDB, 2017; Rahman, 2022; Saha et al., 2022). A satellite-based study of the Ganges-Brahmaputra-Meghna Rivers revealed a net loss of 106,300 hectares of land between 1982 and 1992, with only 19,300 hectares of land gained, resulting in an annual net loss of 8,700 hectares (CEGIS, 2010; Islam & Rashid, 2011; Mahmud, 2015; Sarker et al., 2018; Islam et al., 2019; banglapedia, 2019; Freihardt & Frey, 2023). Since 1973, the Padma Meghna and Jamuna Rivers in Bangladesh have eroded approximately 159,000 hectares of floodplains (Alam, 1991; Aktar, 2013; CEGIS, 2012; Chowdhury et al., 2021).

The Jamuna river is recognized as one of the most dynamic river system globally, eroding several square kilometers of land annually (Sarker et al., 2014; Pahlowan & Hossain, 2015; Hassan et al., 2017; Khan et al., 2022). Large scale erosion events, where several hundred square meters of land can collapse into the river rapidly (Ashworth et al., 2002; Basar et al., 2012; Mollah & Ferdaush, 2015; Ali et al., 2021). Such events are concentrate in specific hotspot areas along the Jamuna Ganges and Meghna rivers. Since 1970s, the Jamuna's bank-line had shifted by approximately 20 km, persistently eroding riverbanks while forming new land, mainly as islands (Islam & Rashid, 2011; Mount et al., 2013; Alam, 2017; Dixon et al., 2018; banglapedia, 2021). The widening rate of the Brahmaputra-Jamuna river in Bangladesh between 1830 and 1992 increased from 6.2 km to 10.6 km. between 1983-1857 and 2018, approximately 766.7 km² and 1,624.2 km² of land were extensively eroded along the east and west bank of Jamuna River, respectively, at rates of 4.8 km²/year. However, from 1977 to 2018, the erosion rates increased to 14.4 km²/year on the east bank and 12.5 km²/year on the west bank (Ashworth, 1996; Khan & Islam, 2003; Bhuiyan et al., 2010;

Pahlowan & Hossain, 2014; Tariqul, 2009; Rashid & Habib, 2022). Coleman (1969) was the first to study the Jamuna River's bank erosion rate using historical maps, revealing average erosion-accretion rates of 5 to 8 km during two periods: 1944-1952 and 1985-1963 (Theme et al., 1993; WARPO, 2021). Later, Theme et al. conducted similar analysis using satellite images from 1973 to 1992, estimating erosion rates on the Jamuna's right bank at 500-meter intervals averaged over 10km. the annual bank erosion rate during this period varied between 10 and 160 meters per year (Coleman, 1969; EGIS, 1999; Bhuiyan, 2002). Between 1973 and 2000, the Jamuna river widened at an average rate of 128 meters per year, with 68 meters occurring on the left banks and 60 meters on the right bank. In this period, the river's average width increased from 9.7 km to 11.2 km, with the most significant bank erosion occurring on the left bank. Over past three decades (1970-2000), the Padma and Jamuna rivers have eroded approximately 180,000 hectares of land (Hossain, 1993; Islam and Rashid, 2011; Tuhin et al., 2014; Hasan et al., 2018; banglapedia, 2019; Chowdhury et al., 2021). A study FAP 24 (Flood Action Plan) based on satellite image analysis estimated a total maximum bank erosion of Jamuna River approximately 1.4 km between 1973 and 2001. Another FAP 24 study found that since 1975, the Jamuna's bank line has shifted westward by about 1.6 km. the Jamuna River area expanded by approximately 48%, leading to erosion of 822 km² of croplands and 390 km² of settlements between 1973 and 2001 (FAP 24, 1996; Klaassen & Masselink, 1992; Thorne et al., 1993; Islam, 2009; Sarker et al., 2014; Maminul et al., 2014; Islam et al., 2017; Rana & Nessa, 2017; Rahman, 2019; banglapedia, 2019; Alam et al., 2020; Hasan et al., 2024).

Using Landsat images from 1977 to 2014, Pahlowan and Hossain analyzed the erosion and accretion rates of Jamuna River between Bahadurabad Ghat and Bhuapur, highlighting that the highest erosion rate of 21.15 km²/year occurred between 1989 and 1992, while the highest accretion rate of 13.57 km²/year was recorded between 1980 and 1989. In the 1980s, the Jamuna River eroded around 5000 hectares of land annually (Nazneen, 2013; Pahlowan & Hossain, 2015). Between 1995 and 2000, the Jamuna River experienced erosion rates of 1,500 hectares on its left bank and 1,200 hectares on tis right bank (Islam et al., 2017; banglapedia, 2020). Between 2000 and 2018, about 254 hectares of land along the left bank of jamuna River in the Tangail district were eroded (Tuhin et al., 2014; Akter et al., 2019). The most erosion prone districts along the Jamuna River from 1973-2017 include:

District	Eroded Area (ha)
Bogra	11456
Gaibandha	10215
Jamalpur	10864
Kurigram	19584
Manikgonj	6568
Sirajgonj	23697
Tangail	8180

Table 2.1: Erosion prone districts along the Jamuna River (CEGIS)

Takagi et al. (2007) analyzed the spatial and temporal changes in the Brahamputra-Jamuna channels and found that the Jamuna River widened at approximately 150 m/year between 1970 and 1980 (Basar et al., 2012; Khan

et al., 2014). Between 1973 and 1980, the average bank erosion was 314.12 km², with similar siltation on both banks, averaging 243.9 km². In several areas, erosion rates ranged between 1,500 and 2000 m/year (CEGIS, 2009; Uddin et al., 2011; Nazneen, 2013; Khan, 2015; Mahmud, 2015; Rashid & Habib, 2022). A study by Islam and Matin estimated that the maximum bank erosion rates of the Jamuna range from 51.95 m/year to 69.82 m/year, while the average erosion rates fall between 38.65 m/year and 40.57 m/year (Sarker et al., 2003; Jakia & Ruknul, 2011; Rahman, 2019; Basar et al., 2012; banglapedia, 2019; Islam & Matin, 2022). Uddin, Shrestha and Alam (2011) assessed the Jamuna River bank erosion using Remote sensing (RS) and Geographic Information System (GIS) and revealed notably annual bank erosion and siltation rates, with erosion at 1235.25 km²/year and siltation at 29.82 km²/year. The river exhibited its greatest movement, 35,847 meters, in 2003, while the least movement 16,415 meters, occurred in 2010 (Uddin et al., 2011; Rashid & Habib, 2022). Pahlowan & Hossain (2015) studied the erosion hazards of Jamuna River and found a net land loss of 107 km². CEGIS (2012) analyzed the erosion patterns of Jamuna River, reporting that 2,408 hectares of land were eroded in 2012. Erosion along the right bank amounted to 900 hectares, including 86 hectares of settlement, with 7 km of embankments. During 1995 and 2015, the west bank of Jamuna River experienced the most erosion, with 3.81 km² and 2.61 km² on the east bank (Pahlowan, 2015; Mahmud, 2015; Hassan et al., 2017; CEGIS, 2022). Between 1973 and 2014, approximately 88,000 hectares of arable floodplains were lost to the river (MWE, 2015). Sarker et al. observed that the Jamuna River experienced significant erosion and accretion between 1973 and 2021, with respective land area changes of 88,315 hectares (Uddin, 2012; Pahlowan

& Hossain, 2015; Akhter et al., 2020). The Accretion and erosion rates of Jamuna riverbank at 1977 to 2014 are as follows:

Period	Accretion (km^2 $year^{-1}$)	Total accretion (km^2)	Erosion (km^2 $year^{-1}$)	Total erosion (km^2)	Difference (km^2)
1977-1980	7.64	22.94	16.64	49.92	-26.98
1980-1989	13.57	122.13	14.11	127	-4.87
1989-1992	5.91	17.73	21.15	63.47	-45.73
1992-2000	13.24	105.96	17.54	140.38	-34.42
2000-2004	9.74	38.98	10.48	41.95	-2.97
2004-2011	3.65	25.6	11.25	78.78	-53.18
2011-2014	6.04	18.13	8.61	25.85	-7.72
Total	9.49	351.47	14.25	527.35	-175.87
1977-2014	4.29	158.96	7.18	266	-1.7.04

Table 2.2: Accretion and erosion rates of Jamuna riverbank (Pahlowan & Hossain, 2015)

2.1.2: Impacts of riverbank erosion on human life

Riverbank erosion poses a serious threat to approximately 20 of Bangladesh's 64 riverine districts, leading to the loss of nearly 8,700 hectares of land annually (MWR, 2015). According to the Ministry of Water Resources (MWR), this phenomenon occurs every year in 283 locations, including 85 cities across the country. The erosion causes extensive damage, engulfing homes, trees, farmland, marketplaces, educational institutions and various other establishments (BWDB, 2014; MWR, 2015; Mollah & Ferdous, 2015; Shahana et al., 2021; Mamun et al., 2022). Each year, erosion leads to the loss

of around one million acres of land and housing. The impacts on affected individuals are severe, including reduced access to education, health issues and diminished social and economic status. In total, riverbank erosion affects around 200,000 people annually by destroying their homes or agricultural land (CEGIS, 2009; Afreen, 2009; Rahman, 2012; Alam, 2017; Hassan et al., 2017; banglapedia, 2019; Hossain & Fahad, 2023). This erosion significantly disrupts village agriculture by sweeping away homesteads, farmland, infrastructure and communication networks. The most immediate consequence of riverbank erosion is the displacement of affected communities. Approximately 300,000 displaced individuals often find refuge on roads, embankments or government-designated lands (CEGIS, 2009; Hassan at al., 2017; Alam et al., 2020, Akhter et al., 2020).

Between 1981 and 1993, the ISPAN conducted an analysis combining satellite imagery and population data, revealing the extensive impact of riverbank erosion. The study indicated that 728,439 individuals were displaced from their original homes during this period. Additionally, the findings estimated that an average of 63,722 people faced displacement annually as a result of this phenomenon (Chowdhury, 1985; Islam & Rashid, 2011; Ghosh & Mahbub, 2014; Das et al., 2014; banglapedia, 2019). Between 1981 and 1993, over 728,000 individuals were displaced as a result of riverbank erosion along the Jamuna, Ganges, Padma and Meghna rivers (Elahi, 1989; Baki and Bhuiyan, 2007; Ahmed et al., 2019; Shahriar, 2021). Each year, large numbers of people lose their homes and livelihoods, prompting them to migrate to nearby regions or major cities, often causing instability in the areas they move to (Islam & Rashid, 2012; Baki, 2014; ghosh & mahbub, 2014; Uddin et al., 2015; Akter et al., 2017; Hossain et al., 2017; Islam et al., 2017).

Riverbank erosion leads to significant challenges, including employment crises and population displacement. Many victims, having lost everything to the river, find themselves trapped in poverty, unable to secure work (Tuhin et al., 2014; Ghosh & Mahbub, 2014; Mosharof, 2015; Hossain et al., 2021). Displaced individuals often endure severe economic hardships, such as losing their homes, farmland and jobs, which frequently pushes them into poverty or, at times, criminal activities (Iqbal, 2010; Hossain, 2015; Saha, 2016; Islam et al., 2017; Rana and Ilina, 2021). In response to riverbank erosion, people are forced to relocate to new areas, often finding shelter on river embankments or road, in neighboring villages, towns or urban centers (Hossain, 1993; Hutton & Haque, 2003; Gain et al., 2012; Naher & Soron, 2019; Kaiser, 2023). Many of these displaced families lack basic healthcare and sanitation facilities, with some relying on pond or river water for drinking (Rahman, 2010; Hossain & Mosharof, 2015; Ghosh & Mahbub, 2014; Islam et al., 2017; Rahman, 2022). Landless and unemployed heads of households to abandon their families, leaving women to shoulder the burden of maintaining their households in extremely difficult circumstances (Bhuiyan, 1991; Islam & Rashid, 2012, Ali et al., 2021). Security was another significant challenge for those affected by erosion. Affected people identified five major areas of concern in their new settlements, including fears of theft of valuable items, loss of household belongings, harassment of women and girls, attacks by animals or snake bites, and the risk of infants or children going missing (Bhuiyan, 1991; Khondokar, 1996; Nasreen, 2008; Akter et al., 2019; MWR, 2015, Alam et al., 2020).

Riverbank erosion has significantly increased health-related threats for affected populations. Common illnesses among them include diarrhea, skin

diseases, dysentery, asthma, tuberculosis and typhoid (CCC, 2009; Blaikie et al., 2014; Biswas, 2015; Chowdhury et al., 2022). Those impacted often suffer from anxiety, stress, intense fear, disbelief and depression. Insomnia frequently results from frustration over the loss of livelihood, homes, possessions and the uncertainty of their future (Hutton & Haque, 2003; Islam & Rashid, 2012; Das and Saraf, 2007; Keya & harun, 2007; Dasgupta et al., 2010; Saha, 2016; Alam et al., 2020). Riverbank erosion significantly disrupts the educational system, leaving long-lasting effects on students and their communities. When educational institutions are swept away by erosion, students lose access to schools and vital learning materials, such as books and stationery. This loss not only interrupts their education but also leads to a lack of motivation to continue studying in the aftermath of such devastation. Additionally, the financial strain caused by erosion limits families' ability to invest in their children's education as they did before the disaster. As poverty deepens among affected households, many students are compelled to take on work to support their basic needs and that of their families, abandoning their education in the process (Felderman, 2012; Rahman, 2013; Bhuiyan et al., 2017 Ghosh & Mahbub, 2017; Khan et al., 2018; Hasan, 2019). Consequently, school dropout rates rise sharply among displaced populations each year, creating long-term barriers to opportunities for these young individuals. This ongoing cycle of disruption and poverty highlights the critical challenges that riverbank erosion poses to the education sector (Rahman, 2022; Hossain & Mosharof, 2015; Ghosh & Mahbub, 2017). Riverbank erosion along the Jamuna River displaces at least 20,000 families annually and results in the loss of 10,000 hectares of land each year. In 2000 alone, approximately 88,750 hectares of land and 416,000 people were affected, leading to an estimated financial loss of around USD 3.3 billion (Siddique, 2008; Basar et al., 2012;

Hassan et al., 2017). The consequences extend beyond human displacement, as continuous erosion damages roads and other communication networks, delaying the delivery of relief efforts. Displaced individuals often attempt to adapt locally but with limited options, many are forced to migrate to nearby cities in search of livelihoods. They end up living in slums, open spaces near rail lines, or on government-owned Khash lands within urban areas (Rahman & Gain, 2002; Hassan et al., Rahman, 2012; Hossain et al., 2021).

2.1.3: Integrated plan and program to reduce riverbank erosion

Although erosion control is costly and sometimes environmentally unsuitable, it is necessary to protect lives, infrastructure, agricultural land and property. Sustainable plans and strategies are required to safeguard riverbanks (Islam, 2010). Efforts to minimize losses should include strategies at both community and national levels, supported by individual knowledge, institutional backing and appropriate measures (Haque, 1988; Biswajit et. al, 2013). However, large infrastructure projects like bridges or dams may contribute channel shifting and exacerbate erosion, as demonstrated by the Jamuna Multipurpose Bridge, which reduce river width in the Bhuapur-Sirajganj section. The regulation of water flow between this two sections increased erosion along the riverbanks (Haque & Zaman, 1989; Bhuiyan et al., 2010; Islam and Rashid, 2011; Hossain, 2015; Rahman et al., 2016). Unlike other disasters, where resources may not be lost or people displaced temporarily while land remains intact, riverbank erosion results in the permanent loss of land. Despite its severity, there are no dedicated policies or programs to address the needs of riverbank erosion victims in either government or non-government sectors in Bangladesh (Hoque & Haque, 2013; Van, 2020). Previously, riverbank

erosion was not recognized as a distinct disaster in Bangladesh and was instead considered a secondary consequence of flooding. However, not all floods necessarily qualify as disasters. Following persistent advocacy from concerned agencies and stakeholders, in 1993, the Government of Bangladesh officially classified riverbank erosion as a disaster (Van, 2020). Even so, the issue remains integrated with other disasters and affected individuals are supported under existing disaster management policies and programs. Neither formal nor informal training on disaster education regarding riverbank erosion has been organized by local NGOs or the Governments (Mosharof, 2015; ISPMC, 2021; Kaiser, 2023). NGOs such as BRAC, ASA, Grameen Bank, Proshika, CARE, Grameen Unnayan angstha and SDO (Society for Environment & Development Observer) actively contribute to socio-economic development across Bangladesh. Their efforts are primarily focused on areas like education, health, sanitation, and women's empowerment, income generating activities through small or microcredit and socio-economic programs. However, these organizations seldom address issues related to riverbank erosion and other disasters (Islam & Rashid, 2012; Mosharof, 2015; Rahman, 2022).

Food aid programs in areas affected by riverbank erosion are quite limited. Most of the individuals impacted by erosion rely on government safety net initiatives, such as meal-for-work and profit-for-work programs. These programs are implemented by various government organizations but are insufficient to address the needs of those affected (Keya & Harun, 2007; Iqbal, 2010; Islam & Rashid, 2011; Islam et al., 2012; Rahman & Rahman, 2015; Rahman, 2018). People affected by the riverbank erosion in Bangladesh receive less governmental attention compared to victims of other disasters. In

early 2018, the government approved a budget of 255 million USD for flood and riverbank erosion management investment program. This initiative was intended to enable the Bangladesh Water Development Board to construct at least 50 kilometers of riverbank protection structure and rehabilitate approximately 89 kilometers of flood embankments. However, the project never commenced and currently stalled (Iqbal, 2010; Islam & Rashid, 2011; Rahman & Rahman, 2015; Roy et al., 2017; Rahman, 2018; Rahman, 2022).

Bangladesh Water Development Board (BWDB) has implemented some measures to mitigate riverbank erosion in the areas most at risk. Geo bags (geo-synthetic materials made from polyester, polypropylene, designed to protect hydraulic structures and riverbanks from severe erosion and scouring) have been used to cover certain section of embankments in the affected regions. However, in many parts of the riverbanks, these measures have failed and remain unrepaired (Elahi & Rogge, 1991; EGIS, 1999; Das et al., 2014; Hamide & karim, 2017). The government of Bangladesh has initiated several projects, including the use of geotextile sandbags and concrete cement blocks, to protect the right bank of Jamuna River, while these efforts are still underway, local communities remain skeptical about the long term sustainability of these measures(Rahman & Gain, 2002; Islam, 2009; Global Voices, 2018; Billah, 2023; Kaiser, 2023). The ministry of Water Resource (MWR) and the Ministry of Food and Disaster Management (MFDM) are two principal ministries working in the disaster management sector in Bangladesh. The MWR is tasked with riverbank protection and management, while the MFDM oversees the coordination of government disaster management efforts. This coordination is carried out through two associate's agencies: the

Directorate of Relief and Rehabilitation (DRR) and the Disaster Management Bureau (DMB).

The Government of Bangladesh has promulgated The National Water Policy (NWP) in 1999 proving policy direction for water sector. Planning and Management of water resources under the policy provides directive to undertake survey and investigation of the problem of riverbank erosion and develop and implement master plans for river training and erosion control works for preservation of scarce and prevention of landlessness (NWP-1999; article- 4.2 q, MFDM, 2010). Few NGOs like CARE-Bangladesh, OXFAM, BDPC and RDRS are working with displacees (displaced by riverbank erosion or other disasters) in certain areas of Bangladesh (MFDM, 2015).

In May 2007, the Ministry of Food and Disaster Management issued four significant Government circulars outlining guidelines for the distribution of CI Sheets (corrugated iron sheet, General Relief (cash), allotments (cash) for house construction and general relief (cash) to assist victims of cyclones, fires, floods, riverbank erosion, tidal waves and earthquakes. However, riverbank erosion displacees do not qualify for the first two forms of assistance due to eligibility criteria. For example, receiving CI sheet requires victims to own land, but those displaced by riverbank erosion lose their land, making them ineligible for this essential material needed to build temporary shelters. They are also excluded from receiving general relief in cash. Cash assistance is typically provided only when a person dies as a result of disaster. Fortunately, fatalities are uncommon among victims of riverbank erosion. As general relief, twenty kilograms of rice are distributed to each affected family, but only once (Van, 2020).

The Bangladesh water Development Board (BWDB), in collaboration with the Asian Development bank, prepared the Flood and Riverbank Erosion Risk Management Investment Program (2014). The primary objective of this program is to mitigate riverbank erosion and flood risks in adjacent floodplains while promoting sustainable and environmentally sound economic activities (BWDB, 2014).

In 2015, the Ministry of water Resources, Government of Bangladesh, launched the River Management Improvement Program (Phase I) to safeguard the riverbank along the Brahmaputra -Jamuna right embankment, historically known as the Brahmaputra Right Embankment (BRE), was constructed in the mid-1960s. Spanning approximately 180 kilometers along the bank of Jamuna River, it was designed to protect around 240,000 kilometers of floodplain from annual flooding and to promote agricultural development (MWR, 2015; BWDB, 2015; banglapedia, 2019).

The Jamuna River Sustainable Management Project-I, in Bangladesh aims to pilot nature-based solutions alongside innovative river structures and navigation techniques at two channels of Jamuna River. The project also includes monitoring the flooding discharge and bank erosion (World Bank, 2020). This initiative is being implemented by the Bangladesh Inland Water Transport Authority (BIWTA), Ministry of Shipping (MoS), Ministry of Water Resources (MWR), Bangladesh Water Development Board (BWDB), Insurance Development and Regulatory Authority (IDRA) and Ministry of Finance (MoF). Additionally, the project seeks to reduce disaster risks and displacement for vulnerable populations residing along Jamuna River (BWDB, 2020).

The Jamuna-Meghna River Erosion Mitigation Project (2020) in Bangladesh, supported by Asian Development Bank (ADB), was designed to promote economic growth, reduce poverty and ensure livelihood security in the areas vulnerable to riverbank erosion. The project aimed to address progressive riverbank erosion by constructing protective structures to counter the dynamic behavior and morphological changes of the Jamuna and Meghna rivers. It introduced an adaptive approach using geotextile bags to reinforce riverbanks in a phased manner, offering a novel technical solution for Bangladesh (ADB, 2020). Additionally, the project formulated policies related to irrigation, flood control, waterlogging mitigation, drainage system improvement and the prevention of river erosion. It also provided technical assistant and supported the construction of water conservation reservoir, embankments, barrages and river dredging to prevent erosion.

Despise the presence of various policies and programs, there is no specific policy dedicated exclusively to addressing women's needs and concerns, while existing initiatives may include some general provisions that affect women, they do not comprehensively focus on their unique challenges or priorities.

2.2. Riverbank erosion related vulnerabilities of women and children in Bangladesh

Women and children are particularly susceptible to riverbank erosion due to challenges in physical, mental and social well-being. Displacement caused by erosion often forces them into unsafe and inadequate shelter, where basic necessities like food, water, fuel, medical care and proper sanitation are scarce (Nasreen, 1995; Mehta, 2007; Nasreen, 2008; Mondal, 2013; Akter et al.,

2019; Alam et al., 2020). These conditions amplify their vulnerability. In temporary shelters, the lack of safety exposes them to violence and harassment, further hindering their coping mechanisms and ability to manage risks effectively (Nasreen, 2012; Monirul et al., 2017). In Bangladesh, women face significant exposure to various disaster, with limited capacity to cope effectively (Islam, 2010; Nasreen, 2012). Displacement caused by riverbank erosion severely disrupts their livelihoods, forcing them into difficult situations (Khondoker, 1996; Akter et al., 2019). Riverbank erosion imposes both direct and indirect impacts on women's lives. Direct consequences include malnutrition, poverty and food scarcity, lack of secure shelter, unemployment and illiteracy. Indirect impacts encompass social insecurity, violence, harassment, child marriage, trafficking, physical injury and mental distress. These long-term effects emphasize the need for gender-sensitive policies and safety net programs to bolster resilience (Ansary et al., 2001; Annan, 2002; Norris, 2009; Hasan, 2010; Soron, 2019). Access to resources and decision making remains limited for women in society, leaving their livelihoods disproportionately affected during disasters and heightening their vulnerabilities. Improved access, education, healthcare and disaster preparedness programs is crucial for reducing risks (Begum, 1993; Sharmin & Islam, 2013; Biswas 2015). While disasters themselves are impartial, societal norms and practices intensify vulnerabilities for women. Illiteracy, financial constraints and limited technological knowledge worsen their challenges. Empowering women through education, training and economic support can enhance their adaptability and reduce risks. Women in rural Bangladesh are among the most affected by riverbank erosion. Addressing their needs calls for effective strategies at both community and national levels. Though affected women often adopt survival strategies independently, these

efforts are insufficient without organizational support (Bhuiyan, 1991; Anderson & Enarson, 2004; Ariyabandu & Foenseka, 2006; Islam, 2010; Biswas et al., 2016).

2.3. Scope of the study

The reviewed literature highlight that riverbank erosion poses a severe challenge in Bangladesh, significantly impacting the lives of those residing near riverbanks. Erosion disrupt various aspect of their lives, including livelihood standers, income, employment, education, social relationship and security. Numerous studies have been conducted to assess people's socio-economic vulnerability caused by riverbank erosion in Bangladesh. Some have explored the displacement and migration of affected individuals due to bank erosion (Elahi & Rogge, 1991; Hossain, 1993; Bapery, 2011; Rabbi et al., 2013; Baki, 2014; Akther et al., 2020; Alam et al., 2020; Ali et al., 2021). Research on elderly victims of riverbank erosion and other natural disaster has been minimal. Similarly, only a limited number of studies have examined the psychological impact of riverbank erosion on women and other populations in Bangladesh (Bhuiyan, 2000; Keya & Harun, 2007; Hassan, 2015; Hossain et al., 2021). Displacement and resettlement issue resulting from riverbank erosion have been reviewed in several studies, along with evaluations of people's awareness, preparedness and capacity to adapt in erosion prone areas (Haque & Zaman, 1989; Elahi & Rogge, 1990; Hutton & Haque, 2004; Iqbal, 2010; Islam & Rashid, 2012; Das et al 2014; Ghosh & Mahbub, 2014; Hossain, 2015; Rana & Nessa, 2017; Islam et al., 2019, Akter et al., 2019). Most research has focused on morphological evaluations, river dynamics, erosion patterns and trends of bank erosion. Advanced technologies such as GIS and remote sensing have been widely utilized to determine the erosion

rates of river channels. Many studies have incorporated satellite images and historical maps to analyze river morphology and dynamics, socio-economic impacts of riverbank erosion in erosion prone regions have been extensively covered (CEGIS, 2005; Uddin & Rahman, 2011; Uddin et al., 2011; CEGIS, 2012; Biswajit et al., 2013; Rob & Billah, 2013; Pahlowan & Hossain 2015; Rahman & Islam, 2017; Rashid, 2022). Few studies emphasizing the vulnerabilities of women affected by disasters, particularly in cyclone and flood prone areas. Limited research has revealed people's vulnerability and coping strategies related to disasters, especially in coastal and flood prone regions of the country. Women's vulnerability due to climate change has also been studied within the context of Bangladesh (Sullivan, 2006; Sharmin & Islam, 2013; Rahman, 2013; Alam, 2016; Tanny & Rahman, 2016; Toufique & Yunus, 2013; Siddik et al., 2017; Sarker et al., 2020). But research addressing the specific impacts of riverbank erosion on women remains scarce. Existing studies on this topic primarily highlight the overall socio-economic effects of riverbank erosion on human populations.

Recently, index-based vulnerability measurement methods have gained popularity worldwide for analyzing people's vulnerability in the face of various disasters. Tools such as the Livelihood Vulnerability Index (LVI), Climate Vulnerability Index (CVI), Resilience Capacity Index (RCI), Coastal Resilience Index (CRI) and Flood Security Index (FSI) have been utilized to better understand vulnerability, resilience, and food security among affected populations (Hahn et al., 2009; Shah et al., 2013; Toufique & Islam, 2014; Alam, 2016; Bhuiyan et al., 2017; and Ahmed, 2019).

Bangladesh, with its numerous disaster prone regions and vulnerable communities faces significant challenges in addressing livelihood

vulnerabilities. While some global studies have evaluated such vulnerabilities, no research has specifically used an index based livelihood vulnerability method to analyze the plight of women and children in this erosion prone region. This study seeks to bridge that gap by focusing on the vulnerabilities of women and children impacted by Jamuna riverbank erosion in Kastapara village of Tangail district. To address this issue, the study introduces an indicator based Riverbank Erosion Vulnerability Index (REVI), developed in line with IPCC vulnerability framework and incorporating methodologies such as Livelihood Vulnerability Index (LVI) and Climate Vulnerability Index (CVI), as previously utilized by researchers like Toufique & Islam (2014), Alam (2016), Bhuiyan et al. (2017), and Asib Ahmed (2019). The study sheds light on the severe consequences of Jamuna riverbank erosion, which annually occurred in this area and the erosion rate steadily increases. By emphasizing the challenge faced by women in Kastapara village, this research aims to enhance understanding and provide solution for mitigating their vulnerability.

This village remains unprotected by a dam or embankment, leaving it exposed to the Jamuna River. During the monsoon season, floods are a regular occurrence, and the river relentlessly erodes its banks, submerging enormous part of the village. While individuals from all social strata are affected, women, children and the elderly bear the brunt of the consequences. Studies and literature consistently highlight women as the susceptible group in the face of natural disasters. Women in this village endure heightened challenges due to riverbank erosion but receive less support. Each year, they encounter a range of socio-economic, physical and psychological hardships. Despite this, no prior research has focused on assessing their vulnerability in this village.

This study, therefore seeks to examine the effects of riverbank erosion on women and children in this area, investigating their socio-economic, physical and mental conditions, their awareness of riverbank erosion, as well as their adaptation and coping mechanism. Additionally, it evaluates policies and programs implemented by government and non-governmental organizations from the perspective of the affected individuals.

2.4. Aim and objective of the study

Women and children face significant challenges due to riverbank erosion, with societal norms and customs amplifying their vulnerability to such disasters and heightening the risks they endure. This study emphasizes a comprehensive approach to tackling the vulnerabilities experienced by women and children affected by riverbank erosion in the study area. The aim of this study is:

- **To identify the vulnerability of the women and children due to Jamuna riverbank erosion in the study area.**

And objectives are:

- To find out women and children's exposure regarding riverbank erosion in study area.
- To find out women and children's sensitivity to food, agriculture, health and socio structural issues due to riverbank erosion.
- And to find out their adaptive capacity during and after riverbank erosion in this study area.

The harmful impacts of riverbank erosion over women's physical and mental health have also been discussed in this study.

Women in this region experience significant exposure to the impact of riverbank erosion, with limited capacity to adapt to this recurring disaster. Despite the need for a systematic approach to address their vulnerability, no research has been conducted on this issue in this area. This study focuses on analyzing the livelihood vulnerability of women affected by Jamuna riverbank erosion, introducing the Riverbank Erosion Vulnerability Index (REVI) as an evaluative tool. The conceptual framework developed in this study serve as a critical resource for addressing vulnerabilities in erosion prone areas. By examining socio-economic conditions, physical and psychological impacts, and adaptive capacities, it provides a detailed understanding of riverbank erosions effects on women and children. Furthermore, this framework can be applied to other regions, facilitating the identification of vulnerabilities, the formulation of effective mitigation strategies, and the development of inclusive disaster management policies.

CHAPTER THREE
MATERIALS AND METHODS OF THE STUDY

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MATERIALS AND METHODS OF THE STUDY

3. Selection of Study Area

Kastapara village, situated in Bhuapur upazila of Tangail district, lies on the right bank of the Jamuna River. With the river just about half kilometer away, the area faces recurring flooding and bank erosion during the monsoon season. Every year thousands of people have been affected by riverbank erosion and floods in this area. It is a common phenomenon to the people of this area particularly who lived along with the riverbank. Location is an important factor for vulnerability to any disaster. People who lived adjacent to riverbank are prone to erosion and it causes numerous miseries to them. This village has been selected as the study area by considering its location, number of erosions affecting circumstances and people's miseries respectively. Following criteria have been considered to select this village as study area:

- Kastapara village situated along the Jamuna River, where the lives of its residents have been deeply influenced by its proximity. For decades, they have faced the persistent of bank erosion, which has had a lasting impact on their lives.
- Riverbank erosion engulfs peoples cultivated lands, homesteads and other resources. Both men and women are affected by this disaster, but its impact on women and children are different due to their physical, social, economic and cultural setbacks and difficulties. Women faces different types of difficulties during and after bank erosion. To find out

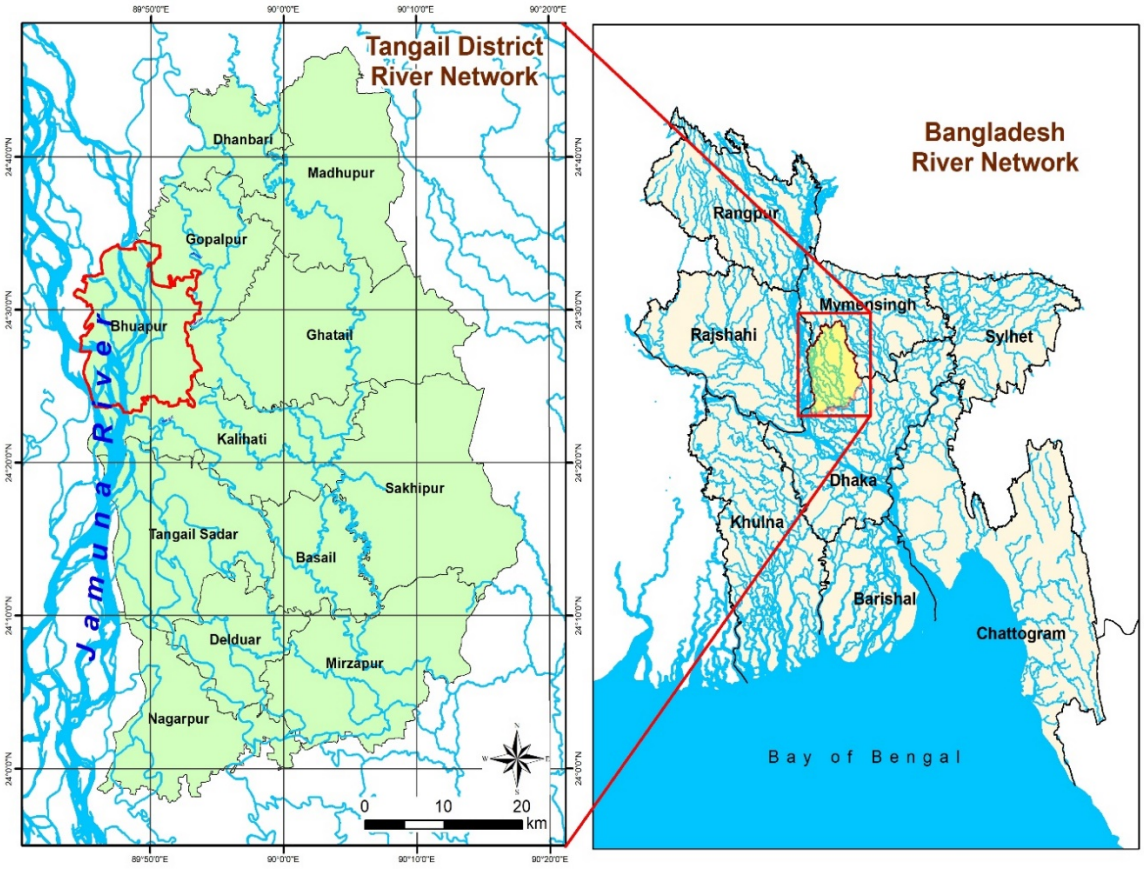
their vulnerabilities due to riverbank erosion, Kastapara village has been chosen as my study area.

3.1. Overview of study area

My study area is Kastapara Village, located in Bhuapur upazila of Tangail district within the Dhaka division. The village sits on the right bank of the Jamuna River.

- **Tangail**

The total area of Tangail district is 3414.35 sq. km. Tangail district lies between 24º01' and 24º47' north latitudes and 89º44' and 90º18' east longitudes. The district is bounded by Manikganj and Dhaka district on the south, Mymensingh and Gazipur district on the east, Jamalpur district on the north, Sirajganj district and Jamuna River on the west (banglapedia, 2015). There are 12 upazilas, 109 unions and 2443 villages under this district (Map: 3.01). The main rivers of this district are: Jamuna, Jhenai, Dhaleshwari, Bangshi, Lohajang, Turag (banglapedia, 2015; BBS, 2015)

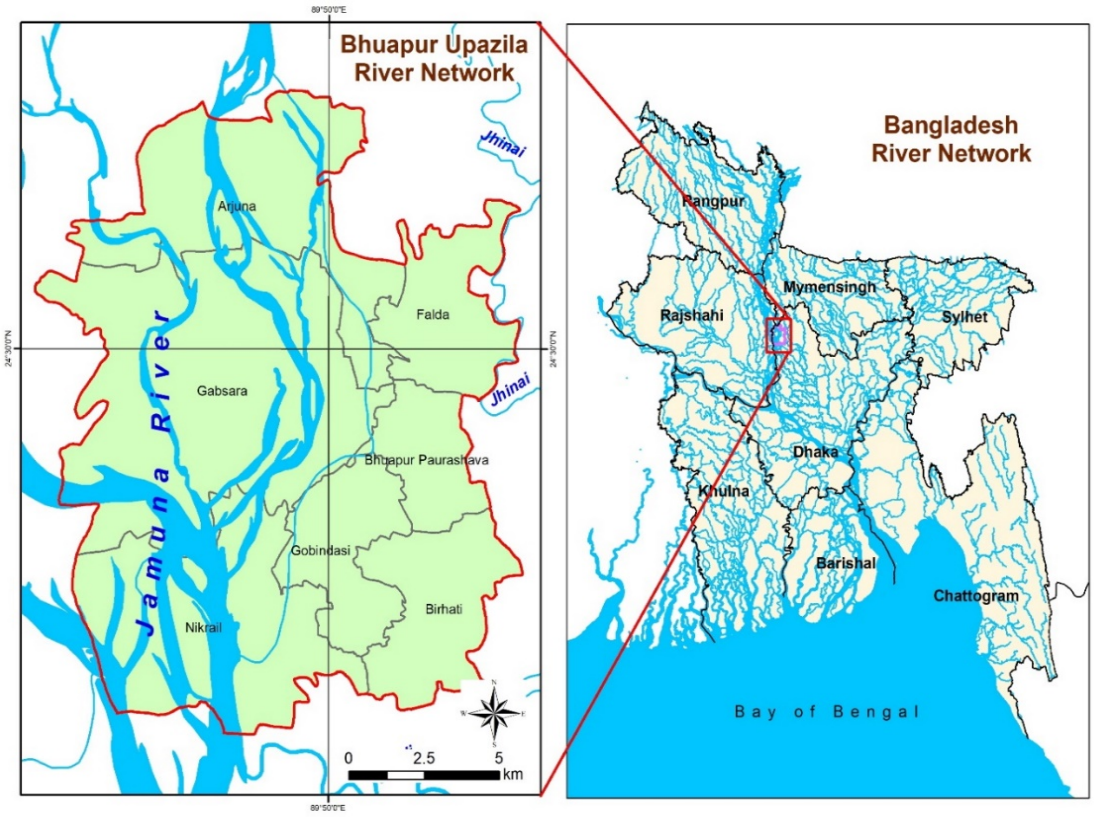


Map 3.01: Tangail District with River Network [CEGIS. (Modified by: Author 2022)]

Upazilas of Tangail district			
Bhuapur	Dhanbari	Madhupur	Nagorpur
Basail	Ghatail	Mirzapur	Kalihati
Delduar	Gopalpur	Shakhipur	Tangail Sadar

- **Bhuapur Upazila:**

The area of Bhuapur upazila is about 225 square kilometers. Bhuapur upazila is bounded by Jamalpur district and Gopalpur upazila on the north, Kalihati upazila on the south, Ghatail and Gopalpur upazila on the east, Jamuna River and Sirajganj district on the west (Map: 3.02). There are 6 unions (Arjuna, Gabsara, Aloa, Gobindashi, Falda, Nikrail), 146 village and 115 mauzas under this upazila (BBS, 2015).

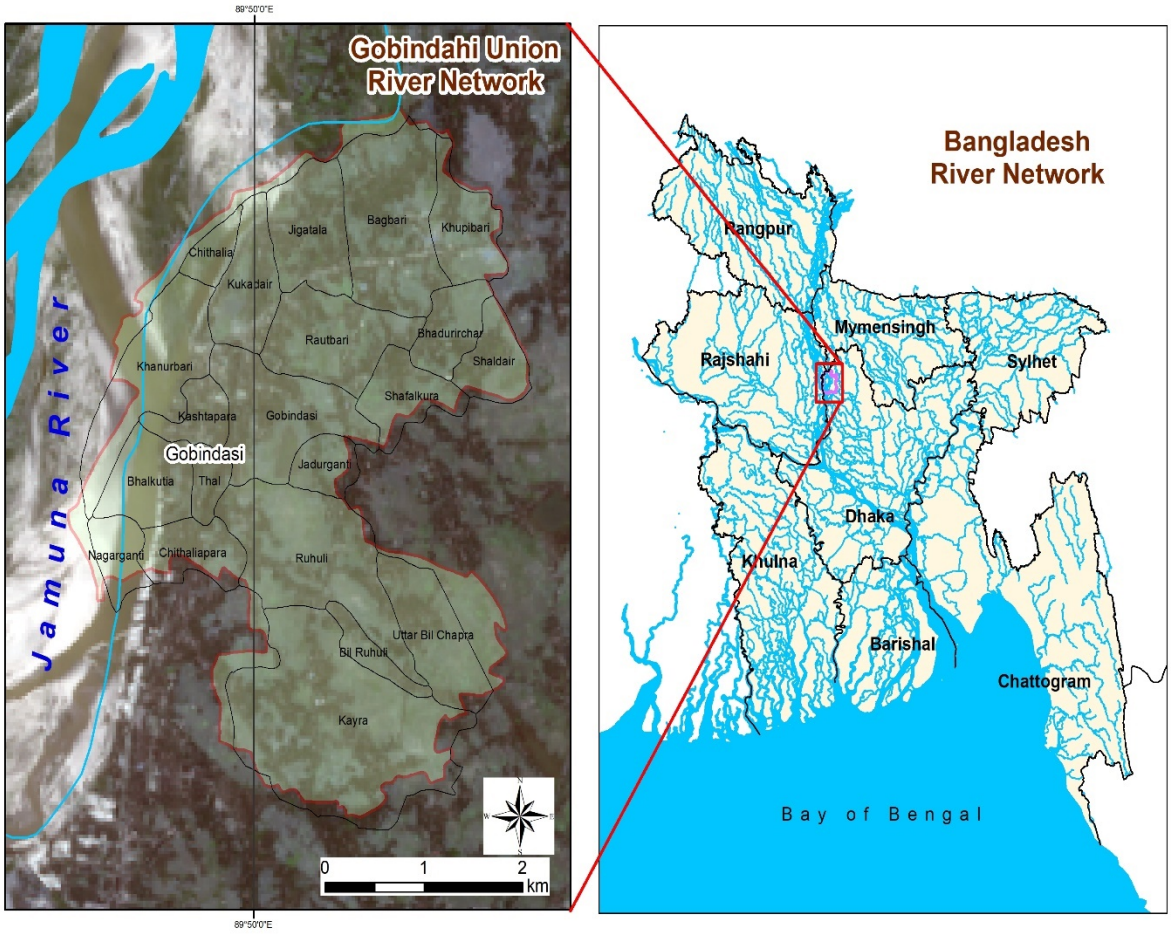


Map 3.02: Bhuapur Upazila with River Network
[CEGIS, (Modified by: Author 2022)]

- **Gobindashi Union:**

Gobindashi union is situated 35 kilometer north from Tangail sadar and 7 kilometer west from Bhuapur upazila. This union bordered by the Jamuna

River on the west (Map: 3.03). It has about 33439 populations where 16435 male and 17004 female (BBS, 2011)

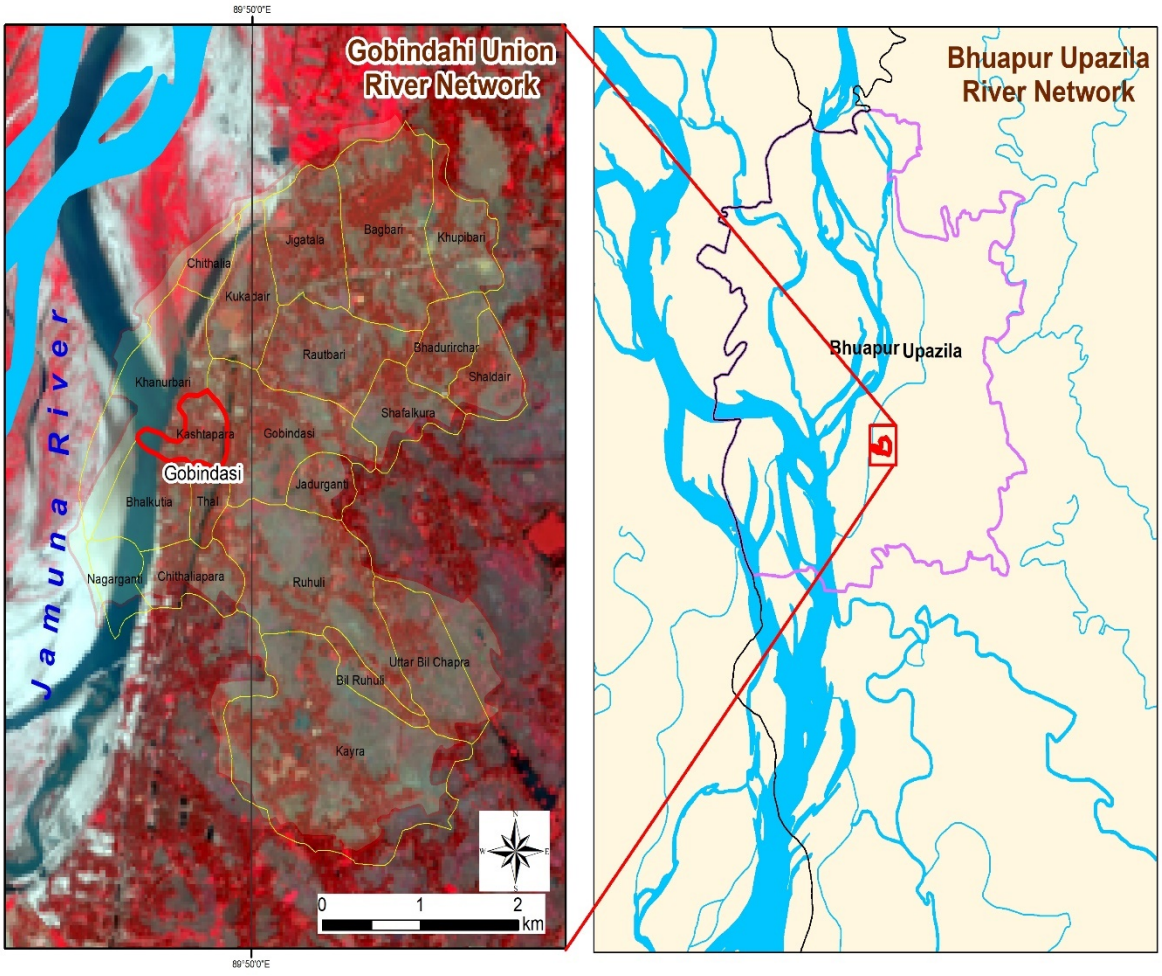


Map 3.03: Gobindashi Union with River Network

[CEGIS, (Modified by: Author 2022)]

- **Kastapar village (Study area):**

Kastapara village is located in Gobindashi union, with a population of 2,405 and a total of 568 households (BBS, 2011). The Jamuna River is approximately half a kilometer from the village (Map: 3.04)



Map 3.04: Study area

[CEGIS, (Modified by: Author 2022)]

3.2. Methodology of the study

In this study, primary data was gathered through a questionnaire survey, with the sample size determined using a statistical formula. A structured household questionnaire was developed to obtain essential information for the research. To assess the vulnerability of women and children affected by riverbank erosion in the study area, the survey incorporated variables related to exposure, sensitivity, and adaptive capacity. These variables include women's experiences with riverbank erosion, its impact on their lives, their livelihoods, and the strategies they employ to cope with the situation.

3.2.1. Data collection methods

In this study primary data has been collected through questionnaire survey to determine the vulnerability. The questionnaire has been developed in five-point rating scale, where each question has been ranked between 1 and 5, which indicates the level of vulnerability. Sample size has been calculated using Cochran's modified formula for known population (Cochran, 1977). Sample size has been determined by the following formula:

$$\frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Given:

Z = 1.96 (for 95% confidence level)

e = 0.05 (margin of error)

p = 0.5 (Population Proportion) to maximize the sample size when there is no previous literature on population proportion of the study area.

N = 568 (population size)

A total of 230 surveys were conducted using purposive sampling techniques, with all respondents being women. The primary data was collected through a questionnaire survey conducted via face-to-face interviews. All these women were residing in this village, had directly experienced and been affected by flood and riverbank erosion for over a decade. Moreover, information concerning children was also collected through their responses. Oral consent from the head of the household was secured prior to each interview, ensuring adherence to ethical guidelines. The qualitative data for this research, comprising interview transcript, narrative notes, images, text documents and other unstructured statements was collected during questionnaire survey, informal community discussions, photographs and the researcher's observations. It focused on women's experiences related to riverbank erosion, other disasters, mental health and access to safety nets, and was analyzed descriptively to highlight insights across multiple dimensions.

The respondent's (women) exhibit diverse characteristics, with 10% aged 16-30, 34.34% aged 46-60, and the majority (37.39%) aged 60 or older. Marital status distribution shows that 73.47 % are married, 19.56% are unmarried, 6.08% are widow and .86% is divorced. Education levels vary significantly, with 57.82% being illiterate, 29.96% having completed primary education, 13.91% attaining secondary education and only 1.31% reaching higher secondary, while none pursued higher education. In terms of occupation, 87.39% are housewives, 3.04% work in agriculture, 9.13% are involved in livestock rearing and 0.44% are employed in service roles. Only 8.26% households are led by women. Regarding family structure, 55.23% live in nuclear families, 42.17% in joint families and 2.60% in extended families.

Children are present in 65.78% of households, while 35.22% households have no children.

Riverbank erosion predominantly takes place during the monsoon season in our country. Therefore, data collection was carried out during this period (June 2020 and November 2020). The questionnaire survey was conducted in Bengali to ensure effective communication and a deeper understanding of local experiences, as respondents were more comfortable expressing themselves in their native language. The questionnaire included the following aspects:

- Fundamental details about households.
- Women's perceptions of riverbank erosion, both past and present.
- Socio-economic conditions of the women.
- Experiences and knowledge of women regarding riverbank erosion.
- Physical and psychological well-being of women after enduring riverbank erosion.
- Support systems and networks available to assist the affected individuals.

Many secondary information have also been used to complete this research work. Secondary information have been collected from various books, documents, journals, published and unpublished research and reports, newspapers, websites and recorded documents from various Government and non-government organizations such as UNO office, union parishad office, agricultural office, Local government and engineering office, Bangladesh Bureau of Statistics, Bangladesh water development board, Tangail office and

local NGOs (BRAC, SSS, ASA etc.). Source of secondary information for this research have been showed the table below:

Information	Organization
▪ Location, transport, communication, institutional infrastructure	▪ UNO office Bhuapur, Tangail. Local Government and Engineering Department (LGED) office, Tangail
▪ Area, population, household, Education	▪ Union parishad office, Gobindashi, Bhuapur. BBS.
▪ Crop, livestock, forestry, fishery	▪ Agricultural office at Bhuapur, Tangail. BBS.
▪ River and flooding data, Riverbank erosion data, Riverbank protection information, shelter information.	▪ Bangladesh Water Development Board (BWDB)
▪ Women empowerment, microcredit, training	▪ BRAC, ASA,SSS (Non-Government organizations)

Table 3.1: Source of secondary information

After collecting the household data by questionnaire survey, Riverbank Erosion Vulnerability Index method have been formulated and used to calculate women's and children's vulnerability.

3.2.2. Data analysis methods

The initial step of data analysis involved the systematic organization of survey responses to ensure clarity and ease of interpretation. These responses were meticulously arranged and entered into a Microsoft Excel Spreadsheet (Excel 13), forming the basis for subsequent analysis processes. Statistical analysis software SPSS (16.0) was then employed to process the data. The findings were documented and compiled using Microsoft World (2013), facilitating the preparation of comprehensive written reports. Additionally, GIS software (10.1) was utilized to create detailed maps, enhancing the visualization of geographical aspects relevant to the study. Descriptive statistics, including calculation of percentage and frequencies were applied to analyze the socio-economic profile of the surveyed households.

3.2.3. Methods of vulnerability assessment

To assess disaster vulnerability, various methods have been proposed and implemented worldwide. According to the IPCC (2007), vulnerability is defined as a function of exposure, sensitivity, and adaptive capacity: f (E, S, A). This relationship is influenced by factors such as the research area's location, population size, and the socio-economic and demographic characteristics of its inhabitants. IPCC describes exposure as the extent to which a community or area is subject to a disaster, sensitivity as the degree to which it is positively or negatively affected by the disaster, and adaptive capacity as the ability of individuals or communities to adjust to significant disasters. When disaster risk exposure and sensitivity are high, and adaptive capacity is low, vulnerability is correspondingly elevated (IPCC, 2007). Hence, vulnerability can be considered a positive function of exposure and a

negative function of adaptive capacity (Hahn et al., 2009; Toufique & Islam, 2014; Bellal, 2016; Alam, 2016; Bhuiyan et al., 2017).

Expanding on the vulnerability framework, Turner et al. (2003), Hahn et al. (2009) and pandey & jha (2012) devised an indicator based approach such as Livelihood vulnerability Index (LVI), Climate Vulnerability Index (CVI), to evaluate vulnerability. To assess community resilience in the face of climate change, Joerin and Shaw (2011) developed the Climate Disaster Resilience Index (CDRI), which is grounded in an erosion event focused method. To identify the relevant parameters and variables for selected communities, surveys and in-depth literature reviews are essential (Ahmed, 2019). These methodologies integrate parameters and variables across the key dimensions of exposure, sensitivity, and adaptive capacity. These methodologies have been extensively utilized by researchers to examine various types of disasters (Alam, 2016; Bhuiyan et al. 2017; and Ahmed, 2019).

This study introduces an indicator based Riverbank Erosion Vulnerability Index (REVI), developed in line with IPCC vulnerability framework and incorporating methodologies such as Livelihood Vulnerability Index (LVI) and Climate Vulnerability Index (CVI), as previously utilized by researchers like Hahn et al. (2009), Pandey and Jha (2012), Toufique & Islam (2014), Alam (2016), Bhuiyan et al. (2017), and Ahmed (2019). In this study, a range of indicators were utilized to evaluate the vulnerability. These indicators were organized under three key dimensions: exposure, sensitivity, and adaptive capacity. These three dimensions composed of eight major parameters and several variables. These Dimensions includes following parameters:

Parameters
1. Natural disaster
2. Riverbank erosion related vulnerability
3. Health and water
4. Food and Agriculture
5. Socio structural profile
6. Socio-demographic profile
7. Livelihood strategies
8. National and social networks

Each parameter comprises several variables which are related to riverbank erosion vulnerability and they are chosen on the basis of their relevance to each dimension. Few variables have been selected on the basis of existing vulnerability studies. Several components have been considered to identify the vulnerability of this study area. These components are, information about natural disaster, socio economic status, education, skills, infrastructure, social and national network, and access to resource. To explore the nature of vulnerability and impacts of disasters on the women in the study area, field survey with a set of questionnaire and physical observation have been used. Table 3.2 presents the dimensions, parameter and variables which have been used for vulnerability assessment in this study:

Table 3.2: Vulnerability assessment indicators

Dimension	Parameter	Variable
Exposure	Natural Disaster	▪ Average number of natural calamities last 10 years.
		▪ Riverbank erosion in last 10 years.
		▪ Distance from the river.
	Riverbank Erosion related vulnerability	▪ Information of land property
		▪ Damage occurring due to riverbank erosion
		▪ Shelter places
		▪ Damage of cultivated land and crop
	Health and Water	▪ Source of drinking water
		▪ Facilities and distance of healthcare center.
		▪ Experiencing mental distress due to riverbank erosion
		▪ Types of injury or diseases suffered by women and children
		▪ Pregnant women treatment facilities.
		▪ Sanitation facilities in the study area.
		▪ Gynecological problem suffered by women.
	Food and agriculture	▪ Source of food supply
		▪ Cropping intensity
		▪ Household food security.
		▪ Agricultural land size.
	Socio structural profile	▪ Security status of women and children in the shelter places.

		▪ Having the right to participate in the decision making process for family and society.
		▪ Sold of household accessories
		▪ Perception and coping strategies with Riverbank erosion.
		▪ Number of family members.
		▪ Seeks assistance provided by various organizations.
		▪ Household materials.
		▪ Loan status for buying food/land or making house.
		▪ Knowledge about riverbank erosion.
Adaptive capacity	Socio Demographic profile	▪ Education of the respondents.
		▪ training and awareness program held in study area about natural disaster
		▪ Occupation of the respondents.
	Livelihood strategies	▪ Occupation of household head.
		▪ Monthly income.
		▪ Monthly expenditure.
		▪ Saving status.
		▪ Loan status.
	National and social network	▪ Obtain financial support through loans from the government or other sources.
		▪ condition of road network or communication
		▪ Adaptation technique to prevent Riverbank erosion.
		▪ Condition of community aid and support

		▪ Receive assistance provided by Government institutions.
		▪ Aid given by NGO.
		▪ Support from relative.
		▪ Support from neighbor
		▪ Loan from money lenders.

Quantitative data was gathered through a household-level questionnaire survey. The questionnaire was designed using a five-point rating scale, with each question rated between 1 and 5 to reflect varying degrees of vulnerability. This scale is defined as follows:

1 = very low vulnerability

2 = low vulnerability

3 = moderate vulnerability

4 = high vulnerability

5 = very high vulnerability

Following this rating scale, the weights of individual variables, parameters and dimensions are given by the respondents during questionnaire survey. Respondents assigned this weight as the reflection of their local situations, socio-economic status and previous experiences. The score of each variable and parameters under three dimensions (exposure, sensitivity and adaptive capacity) are as the degree of stimulus of the variables distinguished by the respondents according to their susceptibility to riverbank erosion. The Researchers observations have also been taken into account in the final calculation.

To calculate the score of variables and parameters weighted mean index and aggregate weighted index method have been used following the work of Alam, (2016) and Ahmed, (2019).

The following equations have been used to calculate weighted scores of individual variables, parameters and dimensions for the study:

1. **Score of each variable:**

$$\frac{w1v1 + w2v2 + \ldots\ldots\ldots\ldots\ldots wnvn}{w1 + w2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots wn}$$

Here,
V1= is the score of variables which are found from field survey
w1= is the weight of variables.

2. **Score of each parameter:**

$$\frac{w1p1 + w2p2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots wnpn}{w1 + w2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots wn}$$

Here,

W1= is the weight of parameter.
P1= is the score of each parameter.

3. **Weighted mean score:**

$$\textbf{Exposure} = \frac{Wexp1ND + Wexp2RE}{wexp1 + wexp2}$$

Here,

(*Wexp1ND* and *Wexp2RE* represent the weight for Natural disaster and Riverbank erosion vulnerability, respectively)

$$\textbf{Sensitivity} = \frac{Wsen1HW + Wsen2FA + Wsen3SS}{Wsen1 + Wsen2 + Wsen3}$$

Here,

(*Wsen1HW*, *Wsen2FA* and *Wsen3SS* represent the weight of Health and Water, Food & agriculture and Socio structural condition, respectively)

$$\textbf{Adaptive capacity} = \frac{Wadp1SD + Wadp2LS + Wasp3NS}{Wadp1 + Wadp2 + Wadp3}$$

Here,

(*Wadp1SD*, *Wadp2LS* and *Wadp3NS*, represent the weight of Socio demographic profile, Livelihood strategies, National and social network respectively).

Then, the index value of exposure, sensitivity and adaptive capacity have been combined and Riverbank Erosion Vulnerability Index (REVI) has been developed following Alam, (2016) and Ahmed, (2019).

4. **The Riverbank Erosion Vulnerability Index is**

$$(\textbf{REVI}) = \mathbf{1} - \left[\left\{\frac{\mathbf{N_1 Exp - N_2 Ada.cap}}{\mathbf{N_1 + N_2}}\right\}\right] * \left\{\frac{\mathbf{1}}{\mathbf{Sen}}\right\}$$

Here,

Ni = Number of parameters in the ith dimension of vulnerability.

The value is attained maximum 1 and minimum 0. Where: 1 indicates most vulnerability and 0 indicates least vulnerability.

Vulnerability assessment has been conducted to identify the people's vulnerability due to disasters. By using vulnerability assessment method Government, planners, researchers can develop different strategies to reduce damage and losses. By assessing vulnerability, Government, community, planners can take proper measurement for the affected people to improve affected people's livelihood standers.

CHAPTER FOUR

RESULTS OF THE STUDY

CHAPTER FOUR

RESULTS OF THE STUDY

4. Introduction:

The study area was selected due to the low socio-economic status of women and its susceptibility to riverbank erosion. Based on the survey results; variables, parameters and dimensions representing vulnerability have been presented in this chapter. The selected variables, categorized under eight parameters (Natural Disaster, Riverbank Erosion Related Vulnerability, Health and water, Food and Agriculture, Socio-structural profile, Socio-Demographic profile, Livelihood Strategies and National & Social Network) are discussed within three dimensions: Exposure, Sensitivity and Adaptive capacity. Collected data through questionnaire survey have been presented in tabular form. The values of each variable, along with those of the parameter and dimensions, are summarized in the following table 4.1:

Dimension	Index value	Parameter	Index value	Variable	Index value
Exposure	0.623	Natural Disaster	0.741	▪ Average number of natural calamities last 10 years.	0.781
				▪ RE in last 10 years.	0.913
				▪ Distance from the river.	0.579
				▪ Information of land property	0.729
				▪ Damage occurs due to RE	0.484

		Riverbank Erosion related Vulnerability	0.539	▪ Shelter place types	0.439
				▪ Damage of cultivated land and crop	0.59
Sensitivity	0.561	Health and Water	0.616	▪ Source of drinking water	0.459
				▪ Facilities and distance of healthcare center.	0.576
				▪ Experiencing mental distress due to riverbank erosion	0.575
				▪ Types of injury or diseases suffered by women and children	0.562
				▪ Pregnant women treatment facilities.	0.447
				▪ Sanitation facilities in the study area.	0.383
				▪ Gynecological problem suffered by women	0.657
		Food and agriculture	0.560	▪ Source of food supply.	0.580
				▪ Cropping intensity	0.701
				▪ Household food security.	0.511
				▪ Agricultural land size	0.500
				▪ Security status of women and children in the shelter places.	0.451
				▪ Having the right to participate in the decision making process for family and society.	0.416
				▪ Sold of household accessories	0.369

		Socio structural profile	0.472	▪ Number of family members.	0.486
				▪ Seeks assistance provided by various organizations.	0.504
				▪ Household materials	0.452
				▪ Loan status for buying food/land or making house.	0.478
				▪ Knowledge about riverbank erosion.	0.566
Adaptive capacity	0.599	Socio Demographic profile	0.791	▪ Education and occupation of the respondents.	0.725
				▪ training and awareness program held in study area about natural disaster	0.940
				▪ Occupation of the respondents	0.754
		Livelihood strategies	0.479	▪ Occupation of household head.	0.604
				▪ Monthly income	0.608
				▪ Monthly expenditure	0.544
				▪ Saving status	0.599
				▪ Loan status	0.256
		National and social network	0.581	▪ Received relief from govt. or other sources	0.600
				▪ condition of road network or communication	0.634
				▪ Adaptation technique to prevent Riverbank erosion.	0.544
				▪ Condition of community aid and support	0.660
				▪ Receive assistance provided by Government institutions.	0.559
				▪ Aid given by NGO	0.600

				▪ Support received from relatives	0.520
				▪ Support received from neighbors	0.644
				▪ Loan received from money lenders	0.432

Table 4.1: Index Value of vulnerability indicators

4.1. Index value of Exposure

The value of Natural disaster and Riverbank erosion related vulnerability are being diverse because of their location, land property, growing crop damage due to bank erosion. The index value of exposure also calculated from the result of parameters. The index value of each individual parameter under exposure are displayed in the following figure (4.1):

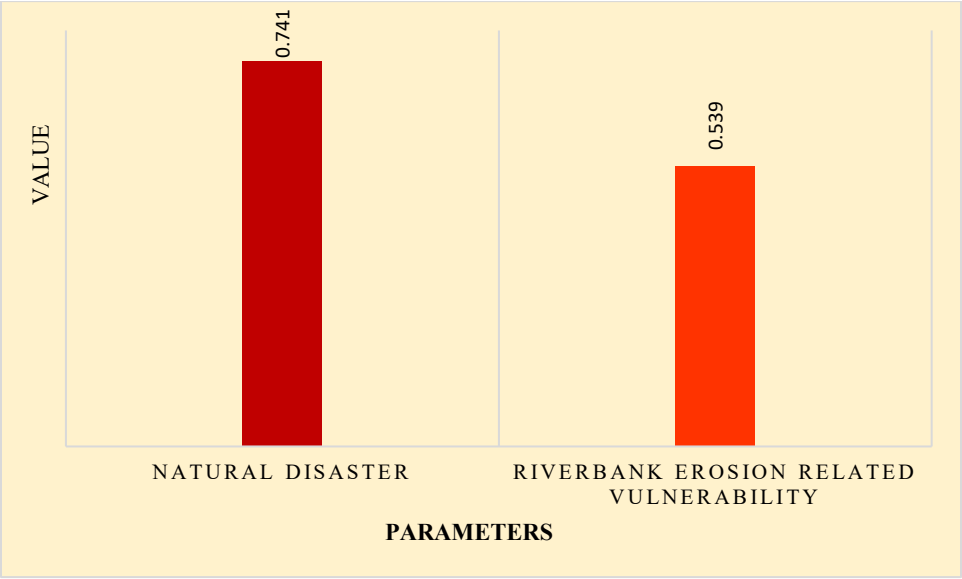


Figure 4.1: Exposure

The diagram below illustrate riverbank erosion related vulnerability within this dimension (Figure 4.2):

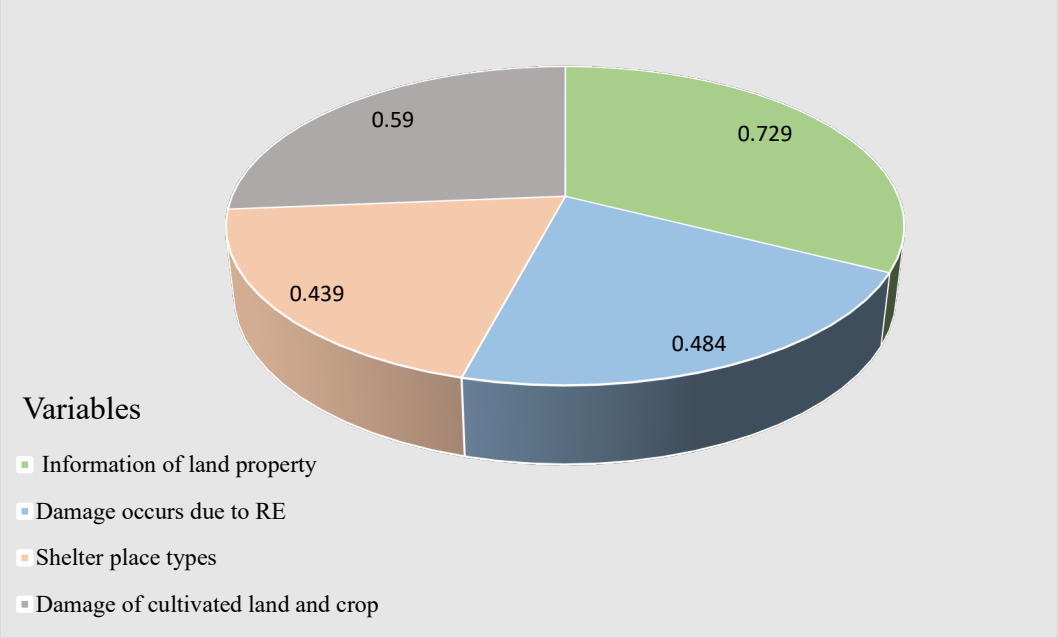


Figure 4.2: Riverbank erosion related vulnerability

4.2. Index value of Sensitivity:

To assess the vulnerability of households, agriculture, food-water, and women related issues, data are collected by the questionnaire survey. The index value of the individual variable along with respective parameter indicates the vulnerability of this dimension. The calculated value shows the variation of sensitivity level. The value of individual parameters under sensitivity dimension have been shown in the diagram below (Figure 4.3):

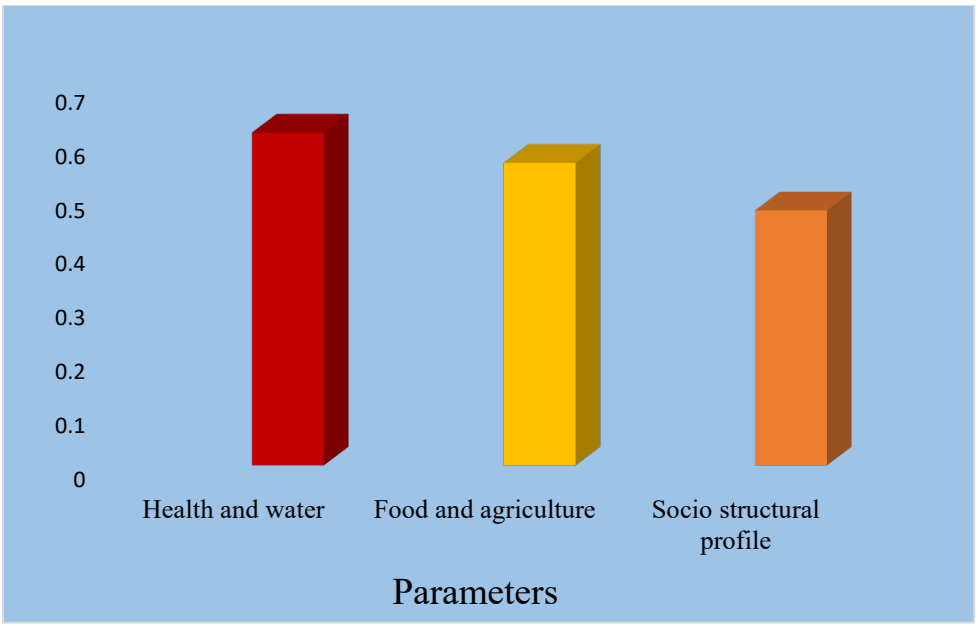


Figure 4.3: Sensitivity

4.3. Index value of Adaptive Capacity

The study result shows much differences among the socio-demographic profile, Livelihood strategies, National and social network parameters under this dimension. Peoples Livelihood strategies, National and social network vulnerability are moderate to near high in this study area. But their socio-demographic vulnerability is very high due to riverbank erosion. Survey results shows that women education level is very low in this area. Most of the women does not engage with any economic activities and they have very limited access to resources, there are no training and awareness program have been held in this village regarding riverbank erosion and other disaster. The diagrams below (Figure 4.4) present the values of parameters associated with Adaptive Capacity:

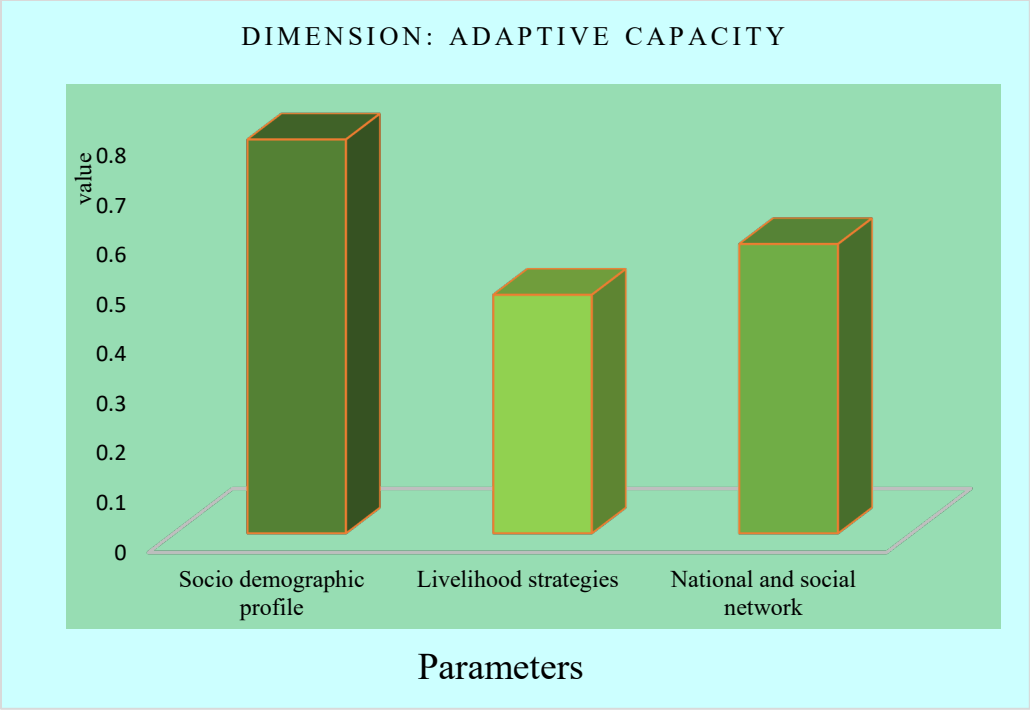


Figure 4.4: Value of Adaptive capacity

4.4. Riverbank Erosion Vulnerability Index

The Value of Riverbank Erosion Vulnerability Index (REVI) has been calculated by using following formula which indicates the total vulnerability.

$$(\text{REVI}) = 1 - \left[\left\{\frac{N_1 \text{Exp} - N_2 \text{Ada. cap}}{N_1 + N_2}\right\}\right] * \left\{\frac{1}{\text{Sen}}\right\}$$

$$= 0.20$$

The values range from 0 (minimum) to 1 (maximum), where 0 signifies very low vulnerability, and 1 indicates very high vulnerability. The following scale has been employed to interpret these values within the range of 0 to 1.

Scale Range	Intensity
0-.19	Very low vulnerability
.20-.39	Low vulnerability
.40-.59	Moderate vulnerability
.60-.79	High vulnerability
.80-1.00	Very high vulnerability

The composite result of the Riverbank Erosion Vulnerability Index in 0.20, indicating a low overall vulnerability for the selected area. However, individual values for specific parameters and variables reveal moderate to very high levels of vulnerability in several instances. These variations in vulnerability across different factors are analyzed and discussed in greater detail in the subsequent chapter.

4.5. Mean and Standard deviation across dimensions

The mean and standard deviation also helps to analyze riverbank erosion vulnerability of this study, as they provide insights into how erosion impacts individuals. By examining both measures, a clear understanding of whether residents in this area experience similar level of vulnerability or if there are notable differences have been found. An overview of index values across three dimensions: adaptive capacity, exposure and sensitivity are presented in the table 4.2 below:

Dimension	N	Mean	Standard deviation
Adaptive capacity	17	0.601	0.1420
Exposure	9	0.645	0.1699
Sensitivity	19	0.509	0.0874

Table 4.2: Mean and standard deviation value

The mean and standard deviation values across three dimensions: adaptive capacity, exposure and sensitivity denotes that the exposure dimension has the highest average index value of 0.645 (with standard deviation of 0.1699), suggesting that individuals of this region are highly exposed to riverbank erosion related risk.

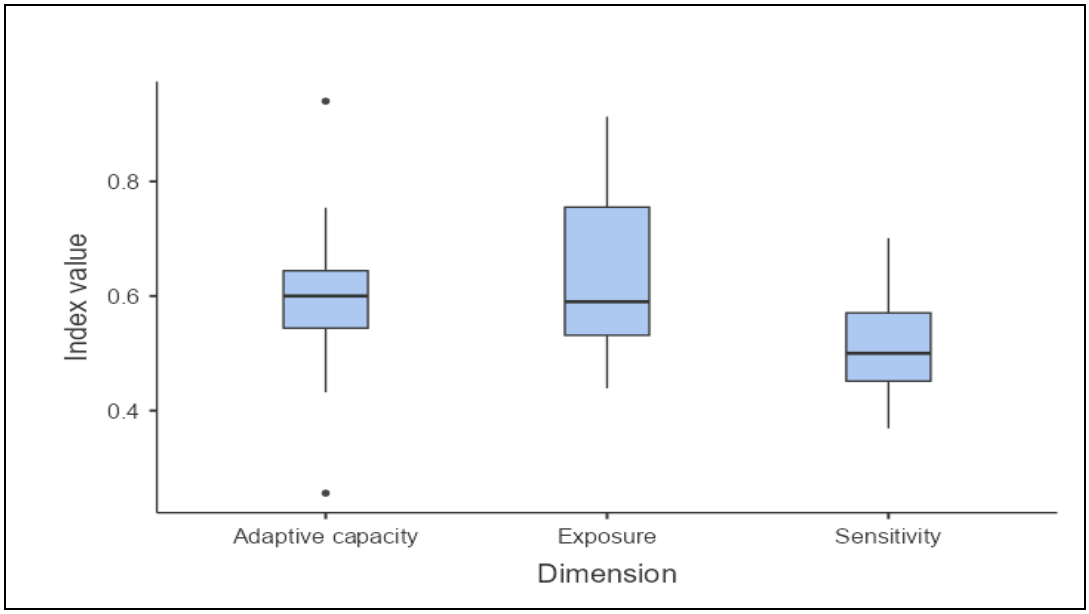


Figure 4.5: Mean value of Dimensions

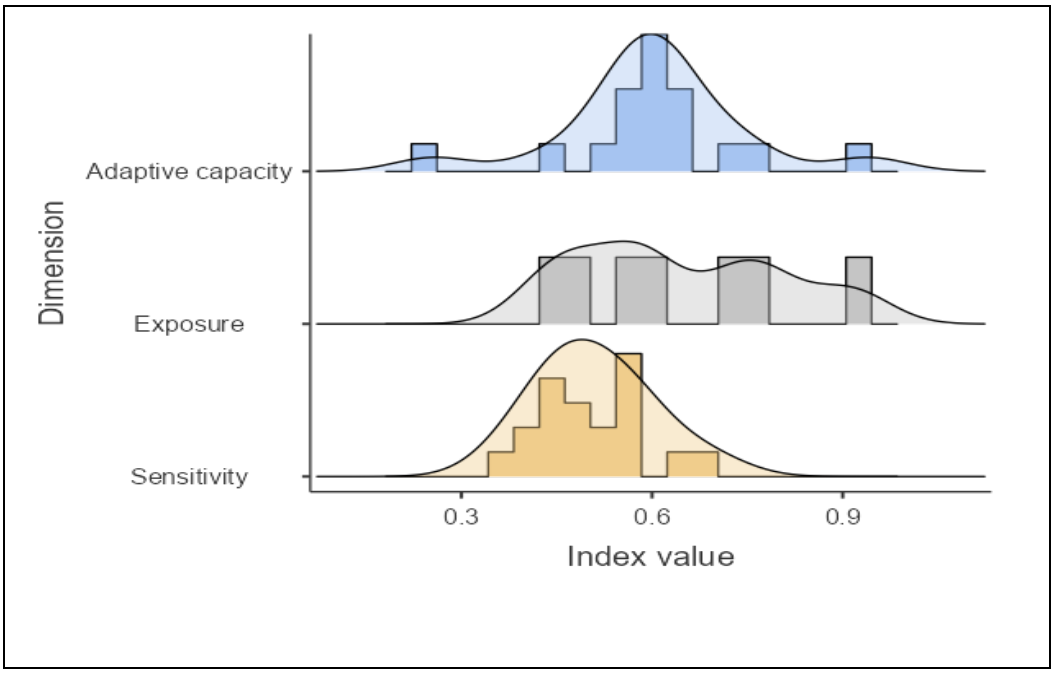


Figure 4.6: Standard deviation of Dimensions

The adaptive capacity dimension follows, with a mean of 0.601 and standard deviation of 0.1420, indicating a moderate level of ability to cope with or adjust to riverbank erosion. On the other hand, the sensitivity with a mean of 0.509 and relatively small standard deviation of 0.0874, representing that the vulnerability associated with sensitivity is comparatively lower (Figure: 4.5) and (Figure: 4.6). Overall, these findings indicate that while riverbank erosion poses a substantial threat due to high level of exposure, their ability to adapt is moderate and their sensitivity to impacts although presents-is relatively less pronounced compared to exposure and adaptive capacity. This indicates that prioritizing the enhancement of adaptive capacity could play a crucial role in mitigating long term vulnerabilities in this erosion prone area.

CHAPTER FIVE
DISCUSSION OF THE SURVEY RESULT

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5. Introduction

This study examines how various selected variables influence the experiences of women in the study area, with a focus on vulnerability through three key dimensions: exposure, sensitivity and adaptive capacity. Since all respondents are women, the findings indicate that they experience significant exposure to riverbank erosion as demonstrated by the index values. Exposure plays a critical role in shaping both sensitivity and adaptive capacity, affecting how women navigate and respond to riverbank erosion. Each parameter and its associated variables provide crucial insights into the vulnerabilities present in this region. This chapter examines the parameters and variables that define the area's vulnerability, explaining their individual and collective impacts. The distribution of variables across different parameters allows for a thorough understanding of the challenges confronting the women, revealing the extent of vulnerability. The index value of these variables present an overall depiction of the region, offering a clear assessment of exposure, sensitivity and adaptive capacity. This broader perspective enhance the understanding of women's and children's vulnerability while providing valuable insights into the riverbank erosion risk affecting the study area.

The questionnaire has been devised in five points rating scale, each question has been ranked between 1 and 5, according to their vulnerability, where 1 denotes very low. 2 = low, 3 =moderate, 4 = high and 5 = very high vulnerability. It is important to note that the value of each variable, parameters and dimensions has been divided by 100 on behalf of better understanding.

So, the index value of 0- 1 presents the vulnerability of the study area. Here the scale (0-1) represents: 0-.19 = very low, .20-.39 = low, .40-.59 = moderate, .60-.79 = high and .80-1 = very high vulnerability respectively. The vulnerabilities of each variable, parameter and dimensions are described below according to their index value.

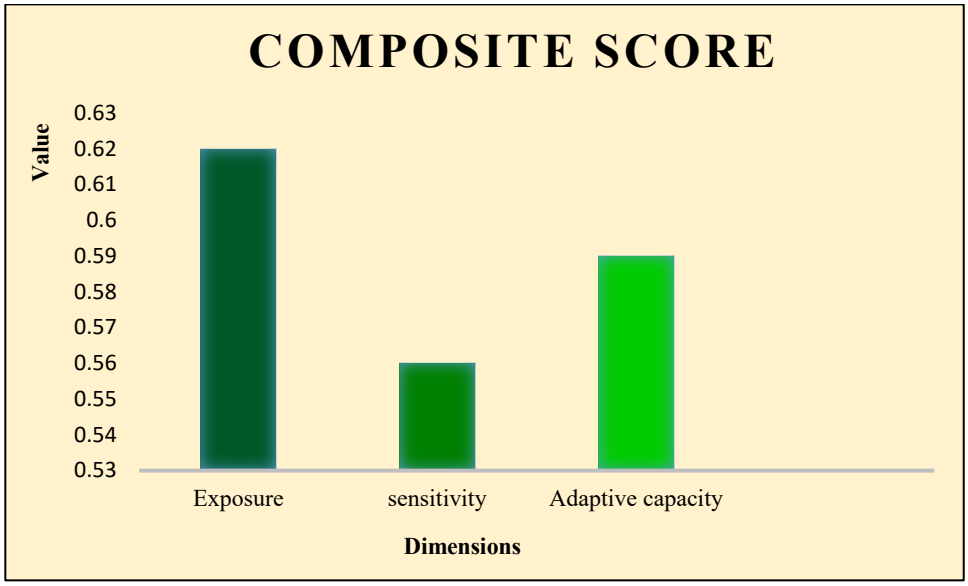

Figure 5.1: Composite score of riverbank erosion vulnerability

The composite scores for the study area's current vulnerabilities are as follows: 0.62 for exposure, 0.56 for sensitivity and 0.59 for adaptive capacity, as illustrated in the figure (5.1) above. According to IPCC framework, high vulnerability occurs when there is significant exposure to disaster risk, combined with high sensitivity and low adaptive capacity (IPCC, 2007). The composite result for each dimension indicate that the study area has a high level of exposure, while sensitivity and adaptive capacity range from medium to low. These findings highlight the vulnerability of women in this region, primarily due to the impacts of Jamuna riverbank erosion.

5.1. Discussion of Exposure

The composite score of Exposure is 0.623, considered as high vulnerability of this area (Figure 5.1). The results of different parameters under this dimension are discussed below.

5.1.1. Natural disaster

The mean score of natural disaster under the dimension of exposure is 0.741, indicates the higher vulnerability of the study area. The residents of this area face significant exposure to riverbank erosion and associated flooding. The variables under the natural disaster parameter further highlight their vulnerability, as illustrated in Figure 5.2. A detailed discussion of these variables follows below:

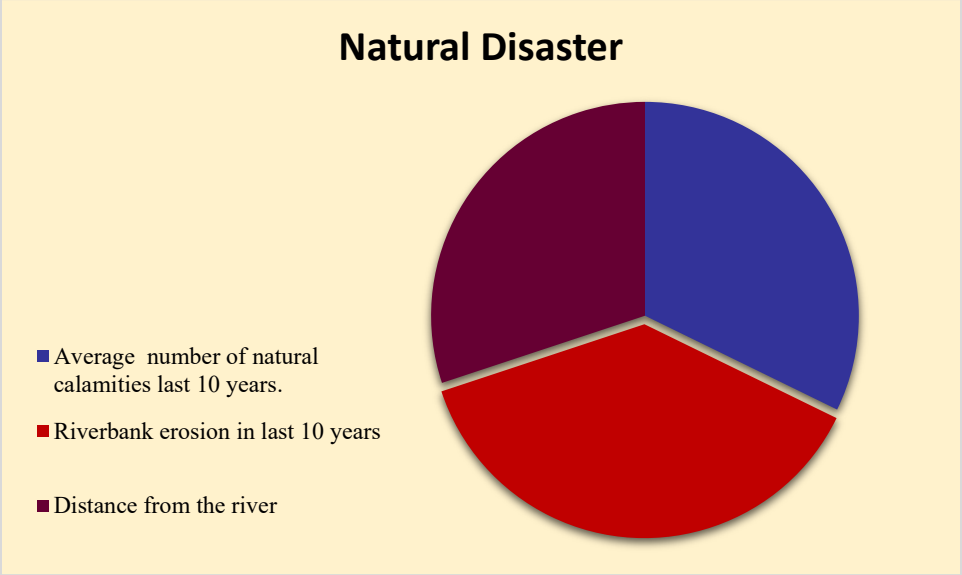

Figure 5.2: Variables of Natural Disaster

5.1.1.1. Average number of natural calamities

A significant number of respondents reported experiencing multiple disasters over the past decade, including storms, nor'westers, droughts, floods and riverbank erosion. They claimed that these calamities occurred over five times within this period, demonstrating the recurring nature of the natural disaster in the study area. The severity of their impacts is reflected in the index value highlights the significant vulnerability of this area, indicating that women as well as other residents face frequent exposure to natural disasters.

5.1.1.2. Riverbank erosion in last 10 years

Respondents stated that they had experienced riverbank erosion more than seven times over past ten years. The index value for riverbank erosion during this period stands 0.913, signifying an extremely high level of vulnerability within the study area. The gradual increase in erosion over the decade is highly concerning for the residents, as it continues to pose significant risks to their homes, livelihoods and overall well-being. Over the last ten years, riverbank erosion has progressively worsened, posing a serious threat to livelihood and infrastructure.

5.1.1.3. Distance from river

Geographical location plays a crucial role in determining a population's susceptibility to disasters. Those living in low-lying areas or near riverbanks are exposed to flood and erosional hazard. The gradual shifting of the river and continuous wearing away of the banks pose significant risks and leading to land loss, damage to homes and displacement. This community faces ongoing challenges as erosion affects their safety, livelihood and access to essential resources. A significant portion of the respondents, approximately

70% reported that their homes are situated less than 300 meters from the river. This close proximity places them vulnerable to erosion and flooding. The index value of this variable is 0.579, indicates near critical vulnerability of this area regarding distance from the river. Because of their adjacent location to the river most of the households confronted by bank erosion almost every year.

5.1.2. Riverbank erosion related vulnerabilities

Mean score of riverbank erosion related vulnerability is .539, refers the moderate vulnerability of the residents in the study area. Score of the variables under these parameters are discussed below:

5.1.2.1. Information of land properties

From the study it is found that most of the people in this area are landless or have very little land. According to survey, about 76% people possess less than 20 decimal (1 decimal = .6198 Acre) land. Only .43% possess more than 80 decimal land (Figure 5.3). Less land increased vulnerability. Limited land ownership significantly contributes to their economic instability, making it challenging for them to maintain sustainable livelihoods. The land property index value has been determined to be 0.729, highlighting the high vulnerability of residents in this area.

Figure 5.3: Land ownership

5.1.2.2. Damage occurs due to riverbank erosion

Study results revealed that most of the respondents (61.29%) have lost their households, agricultural land and other accessories either totally or partially due to bank erosion in their life time period. The destruction of these resources disrupts livelihoods, forcing families to relocate and rebuild under challenging conditions. As the extent of asset loss increases, the vulnerability of affected communities also rises, making recovery efforts more difficult and long-term resilience harder to achieve. The index value of this variable is 0.484, which indicates the moderate vulnerability of the residents in this area.

5.1.2.3. Damage of crop land and crop production

Riverbank erosion has significantly impacted crop production, increasing the vulnerability of the local population. A decrease or complete loss in crop land and crop production aggravates the situation, exposing residents to economic instability and food insecurity. Women, in particular, bear the brunt of these challenges, as they often struggle more access essential resources and

maintain their livelihoods in such adverse conditions. Survey results reveal that approximately 68.69% respondents have experienced partial or complete loss of their farmland and crop yields, while only 4.37% reported no losses. The index value for this variable is calculated to be 0.591, indicating nearly high level of vulnerability associated with cultivated land and crop damage.

5.1.2.4. Shelter place after damage of households

Riverbank erosion causes displacement of the residents. At the time of bank erosion and displacement affected people are eagerly searched for shelter places for their family members and for other household accessories. In this study area, there are no designated shelter spaces for people affected by riverbank erosion or other disaster. During the bank erosion period displaced people take shelter at various places like neighborhood village or relatives houses, on the roads, other villages or nearest city or towns. It is found that their first choice for taking shelter is at the house or vacant land of neighbors or relatives who are not at erosion risk. The index value of this criterion is 0.439, indicating a moderate level of vulnerability in finding shelter due to riverbank erosion.

5.2. Discussion of Sensitivity

The composite score for the sensitivity dimension is 0.561, indicating that the people in this area are close to being highly vulnerable, as illustrated in figure 5.4. According to IPCC (2007), a highly sensitive population is more susceptible to harm. The parameters and variables related to sensitivity are outlined below:

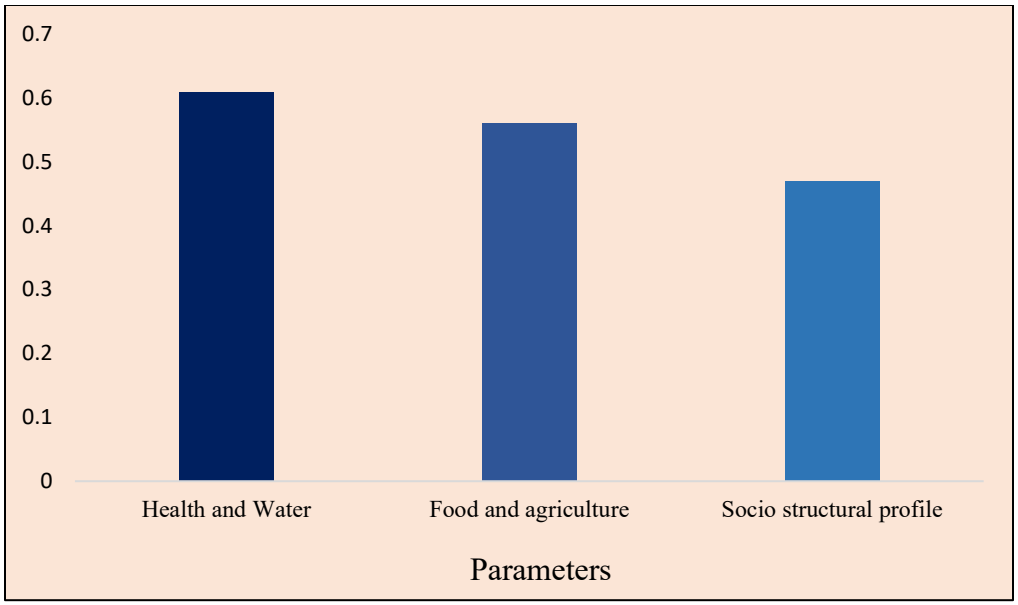

Figure 5.4: Sensitivity parameters

5.2.1. Health and water

This is one of the most important parameter under the dimension of sensitivity. Limited access to healthcare services, clean water and proper sanitation heightens vulnerability. Inadequate medical facilities contribute to the spread of diseases such as cholera dysentery, diarrhea, infections and malnutrition, further endangering affected populations. The mean score of this parameter is 0.616, indicates the higher vulnerability of the respondents. The index value of the variables under this parameter are discussed below.

5.2.1.1. Source of drinking water

Proper water supply facility indicates a good socio-economic status. The study shows that households in this area use tube-well as well as river water for drinking and other household activities (Figure 5.5). This area once had multiple tube-wells but many have been lost due to riverbank erosion.

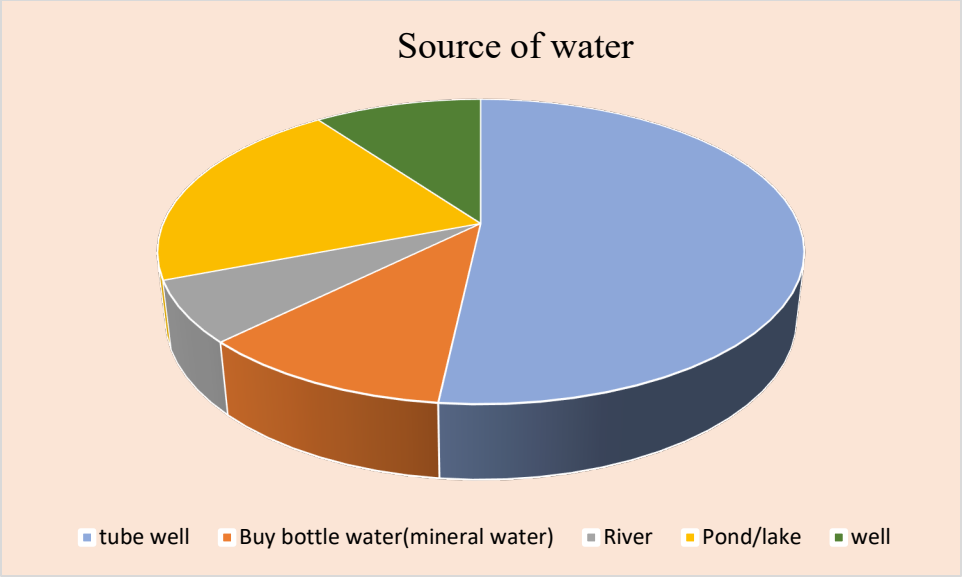

Figure 5.5: Source of drinking water

People also use bottle and the supply water during bank erosion which is provided by various aid supply organizations and relatives. Approximately 51.73% of the population relies on tube well water, while the remaining individuals use river, pond, well, or bottled water for drinking and household needs during riverbank erosion. The index value of this variable is 0.459, indicates the moderate vulnerability of the people is the study area.

5.2.1.2. Facilities and distance of Health Care Centre

The value for this criterion is 0.576, suggesting that the residents of this area are in a state of near-high vulnerability due to riverbank erosion. Respondents reported having minimal or no access to adequate medical facilities. The limited ability of female doctors and examiners, dependence on traditional healthcare practices, and the significant distance between home and healthcare center create barriers for women in accessing medical care, further increasing their vulnerability in this area.

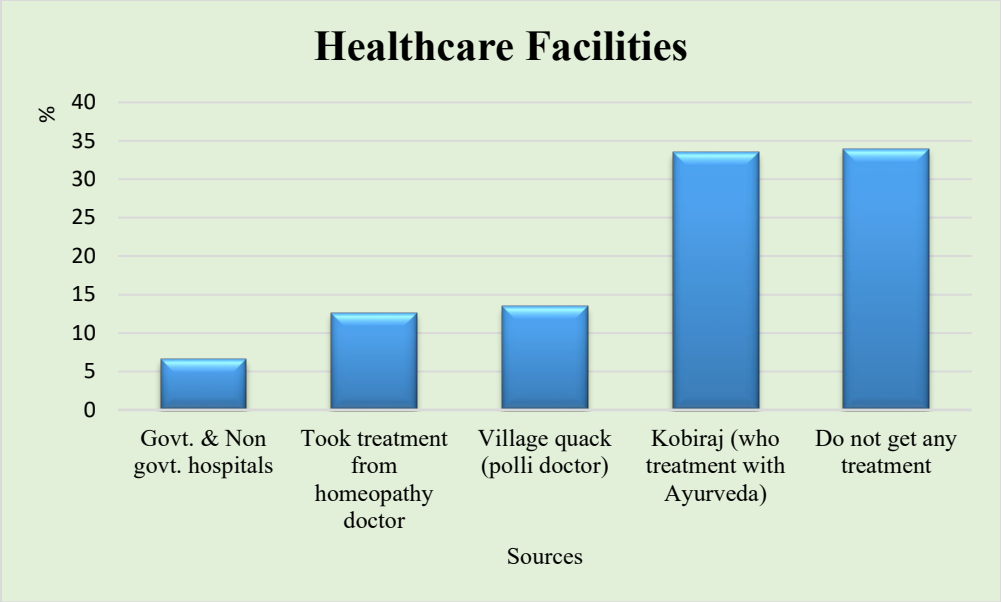

Figure 5.6: Healthcare facilities

A significant portion of women seeks treatment from village quacks (13.47%), while only a small percentage (6.55%) have accessed healthcare services provided by government or non-government medical centers. Additionally, 33.47% rely on kobiraj for treatment, where 33.91% reported not receiving any medical care for their illnesses (Figure: 5.6).

5.2.1.3. Face of mental disturbance due to riverbank erosion

Disaster affected people have experienced physical, emotional and psychological distress which put them into a traumatic situation. It is also true for the riverbank erosion affected people. Erosion affected people specially women, children and older persons suffered from physical as well as psychological distress due to sudden engulfment of their homestead and other belongings by the river, that lead them to force migration from their own place (Keya & Harun, 2007; Hossain & Haque, 2021). Respondents expressed feelings of disappointment, fear, anxiety and psychological distress due to the

ongoing threat of riverbank erosion, which could suddenly engulf their homes, leaving them homeless and without property in a short time. They also felt a deep sense of helplessness regarding both their current and future living conditions. Among them, 25.65% reported experiencing severe psychological distress, while 45.65% stated the impact was minor. Additionally, 13.04% indicated they faced moderate effects, which slightly influenced their livelihood (Figure: 5.7). A small portion (6.08%) mentioned that they did not experience any mental disturbances. The index value of 0.576 for this variable underscores their heightened vulnerability in this situation.

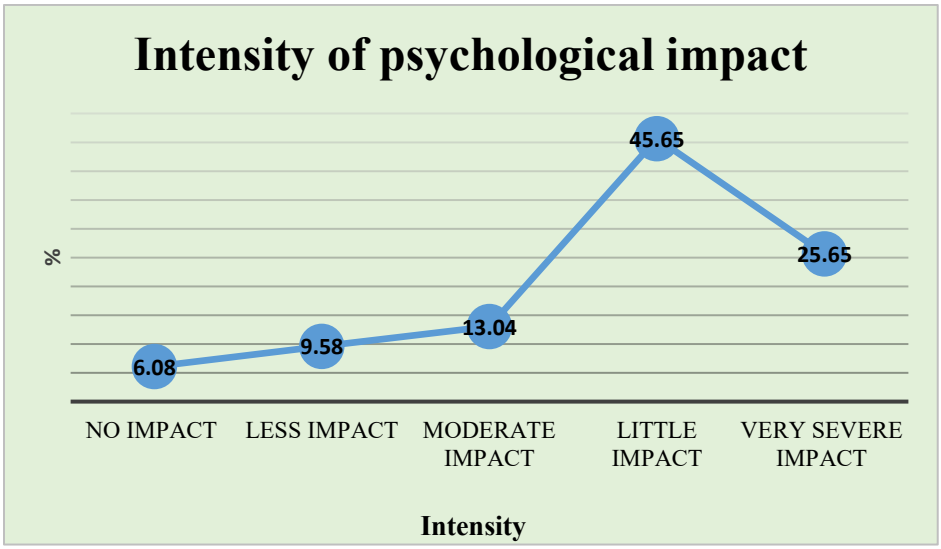

Figure 5.7: Psychological impacts

5.2.1.4. Types of injury and illness affecting women and children

As the severity of physical injuries and illness increases, vulnerability escalates, creating a cycle of hardship for affected individuals and communities. Severe injuries such as fractures, amputations, hemorrhages and infections significantly impair people's ability to work, earn a livelihood, and sustain themselves, further deepening their vulnerability. The index value of

0.565 indicates that the women and children in this area face moderate vulnerability to injuries due to riverbank erosion. The study found that a high percentage of respondents experienced illness and injuries-including amputations, hemorrhages, swelling, respiratory issues, waterborne diseases, skin infections and malnutrition both during and after erosion events. Among them, 41.30% reported suffering physical injuries and illness, particularly during erosion events when they attempted to relocate quickly. Additionally, 23.49% stated they frequently sustained injures during and after erosion, while 15.65% mentioned occasional occurrences. Meanwhile, 10.43% of respondents reported not facing any physical health problems due to riverbank erosion.

5.2.1.5. Treatment status of pregnant women

Respondents indicates that pregnant women seek medical care at nearby hospitals or clinics during childbirth; however, many are either reluctant or not permitted to consult male doctors. Pregnant women faces significant challenges during disasters, and riverbank erosion further exacerbates their difficulties. The sudden disasters, and displacement caused by erosion disrupt access to healthcare, making medical attention during pregnancy and childbirth more difficult to obtain. Additionally, the lack of female doctors and skilled birth attendants forces many to rely on traditional methods, which heightened their vulnerability. Among the respondents, 31.3% reported relying on older female family or community members for support during childbirth and related complications, which poses health risks. Additionally, 16.98% reported that no treatment was available for pregnant women, while 21.3% mentioned that they seek advice and assistance from midwives. Furthermore, 13.47% receive treatment from private clinics and 16.95% seek

care at government hospitals (Figure 5.8). The index value of 0.447 suggests that pregnant women in this area experience moderate vulnerability due to riverbank erosion

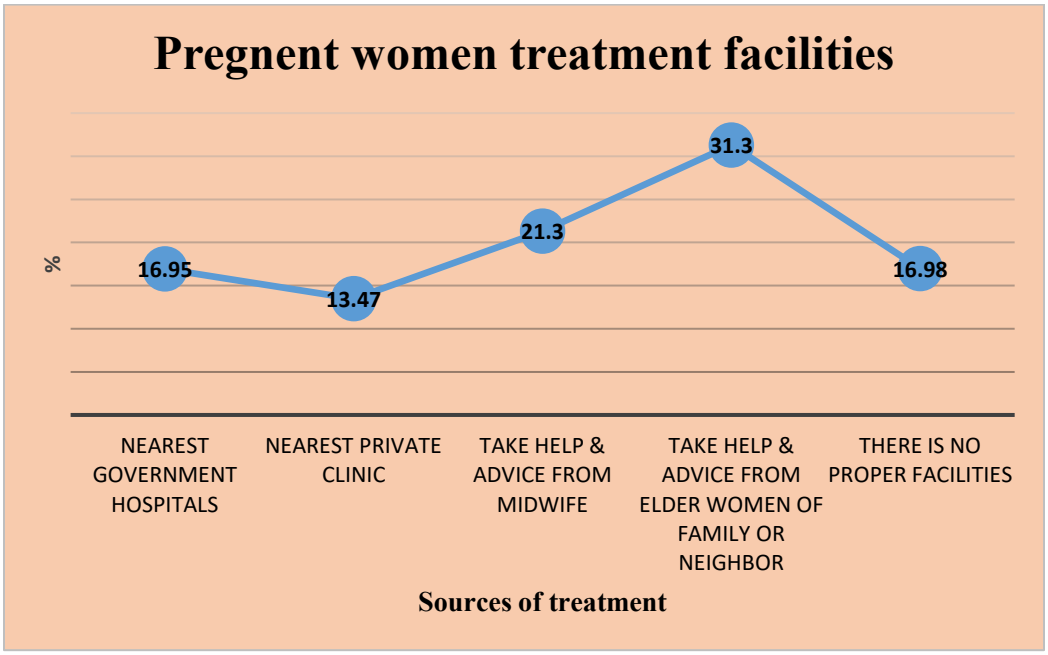

Figure 5.8: Treatment facilities of pregnant women

5.2.1.6. Sanitation facilities

Poor sanitation increases vulnerability by exposing individuals to infectious diseases, contaminated water, and inadequate hygiene practices. Insufficient sanitation can lead to spread of illness such as cholera, dysentery and diarrhea which weaken the immune system and contribute to cycle of poverty due to medical expenses and reduced productivity. Women and girls face heightened risks due to inadequate sanitation facilities, affecting their hygiene, and overall well-being. Conversely, improved sanitation helps reduce vulnerability by preventing diseases outbreaks and creating a healthier

environment. The study found that respondents use various types of toilets made from different materials including bricks, cement, tin, bamboo, sack, slab etc., among the respondents, 33.04% use pacca toilets, constructed with brick, cement and slabs, 38.69% use semi pacca toilets, made with brick, tin and slabs; 15.24% use semi-pacca toilets built with bamboo, tin and slabs and 9.56% use kacha toilet made with slabs and thatch. The remaining respondents rely on open or hanging toilets surrounded by sacks (figure 5.9). In terms of sanitation facilities, the index value of 0.383 suggests a relatively low level of vulnerability among the respondents.

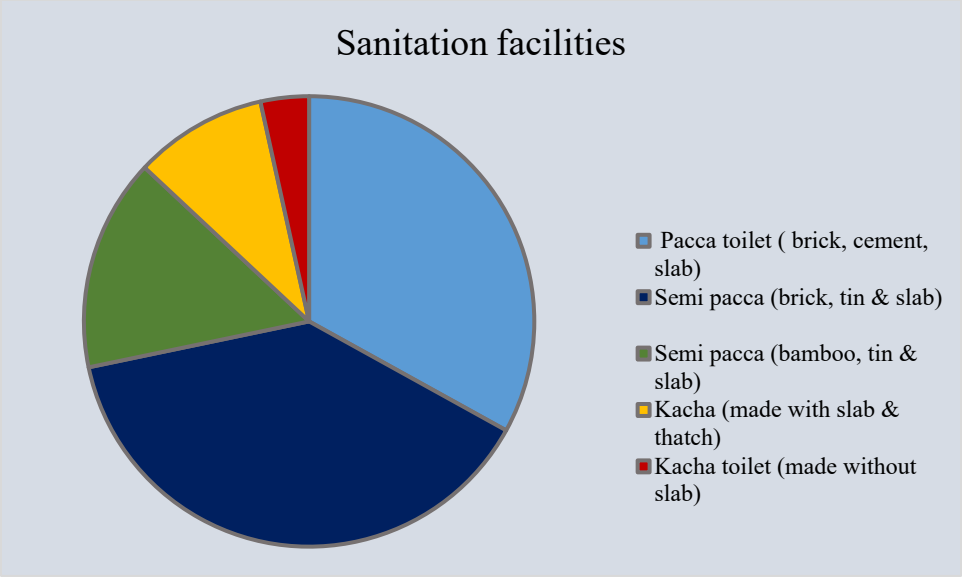

Figure 5.9: Sanitation facilities

5.2.1.7. Gynecological problem

A higher prevalence of gynecological problems increases vulnerability. Women's reproductive health is closely linked to vulnerability, as various social, economic and environmental factors heighten the risk of complications. Women in precarious situations, such as those displacement or

living poverty, often lack access to proper menstrual hygiene products, making them susceptible to infections and discomfort. Poor sanitation and hygiene contribute to infections like urinary tract infections and reproductive tract infections, which, if left untreated, can lead to long term health consequences. The study found that women in this area experience gynecological issues such as vaginitis, improper feminine hygiene, abortion, menstrual irregularities, pelvic pain and endometritis. Among the respondents, 60% reported always suffering from these conditions, while 22.17% frequently experienced gynecological problems during riverbank erosion and continued to face its effects afterward. Additionally, 7.39% sometimes and 6.52% rarely experienced such issues, whereas only 3.91% reported never having any gynecological problems. Riverbank erosion often forces women to abandon their homes and seek shelter or roads, embankments or other overcrowded areas with poor or nonexistent sanitation facilities and inadequate water supply. This lack of proper facilities makes bathing and washing clothes difficult, preventing women from maintaining their gynecological hygiene and contributing to further health challenges. The index value of 0.657 indicates a high level of vulnerability in this regard.

5.2.2. Food and Agriculture

Mean score of this parameter is 0.560, which indicates the moderate vulnerability of the respondents in this area regarding food and agriculture status. Variables under this parameter are described below.

5.2.2.1. Source of food supply during erosion hazard

Respondents stated that during times of scarcity and emergency, some NGOs and government organizations (5.65% and 16.96%, respectively) provide relief, but the assistance is insufficient to meet their needs. Riverbank erosion

often forces many people to relocate, displacing them from their homes and causing food shortages. In such situation, various government and non-government institutions, as well as relatives and neighbors, offer support. Some individuals reported relying on their previous food storage (21.30%) during crises, while the majority (53.49) depended on food provided by relatives. However, according to respondents, these sources are inadequate and not sustainable in the long term, forcing them to endure ongoing food insecurity following riverbank erosion. The index value of 0.580 suggests that the affected population is nearing a highly vulnerable state regarding food security in these circumstances.

5.2.2.2. Cropping intensity

Higher crop intensity can reduce vulnerability by maximizing food production and income, higher crop intensity can help reduce vulnerability by maximizing food production and income, enabling people to better withstand economic shocks during disasters. However, riverbank erosion negatively affects crop growth by eroding landmass, increasing water stress, and reducing yields from cropping systems. In the study area, the loss of agricultural land has led to a significant decline in cropping intensity. Among respondents, 75.22% reported harvesting crops only once per year, while 20.87% stated that their land no longer produces any yield. Additionally, 3.91% mentioned harvesting twice per year, with no respondents reporting a three-time annual harvest. The index value of 0.701 reflects a high level of vulnerability regarding agricultural productivity in the affected region.

5.2.2.3. Household food security

Food security and vulnerability are deeply interconnected, especially in regions affected by riverbank erosion. The destruction of agricultural land and disruption of livelihoods due to erosion significantly impact food availability, accessibility, and stability, increasing the risk of food insecurity among affected communities. As farmland diminishes and traditional income sources become unstable, households struggle to secure sufficient food, often relying on external aid which make them vulnerable. Food security can reduce vulnerability. The study found that due to limited land and reduced crop production, many people are unable to cultivate and store food. Households without food storage face greater challenges during and after riverbank erosion, often having to purchase food at higher prices or borrow from neighbors and relatives to manage food shortages. In some cases, they resort to taking high-interest loans from lenders or selling their livestock and household assets at low prices, further increasing their vulnerability. The findings indicate that only 3.48% of respondents have sufficient food reserves for any disaster, including remaining respondents stated that their food reserves last between one to six months (Figure: 5.10). The household food security index value of 0.511 reflects their moderate level of vulnerability.

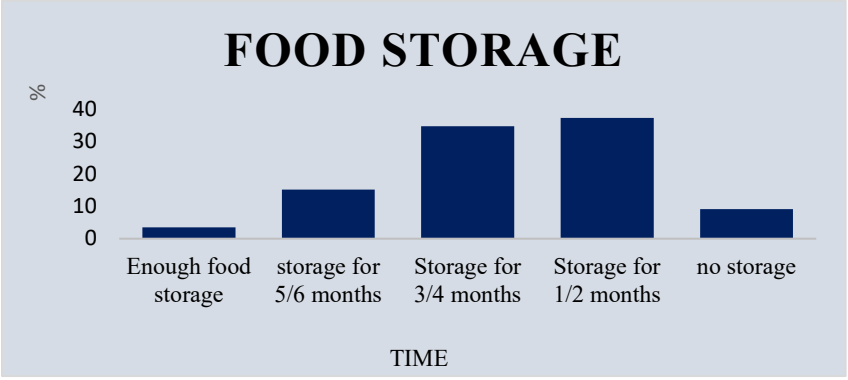

Figure 5.10: Household food security

5.2.2.4. Agricultural land size

Riverbank erosion greatly impacts agricultural land size, increasing the vulnerability of farming communities. As erosion reduces cultivable land, farmers struggle to sustain crop production, resulting in food insecurity and economic instability. The higher cultivated land under cultivation increase food security. Studies indicate that riverbank erosion has caused significant farmland loss in this area, disrupting cropping patterns and forcing people to relocate, worsening their hardships. The study reveals that most farmers here are either small to medium-scale or landless. Due to erosion, many have lost their cultivated land, either entirely or partially. According to respondents, 33.04% own only 20-50 decimals of cultivable land, which is insufficient for producing adequate crops. Only 20% possess 80 or more decimals of land, while the remaining have between 21 and 80 decimals. The loss of land and decreased crop production have heightened their vulnerability, as reflected in the index value of 0.761 for this criterion.

5.2.3. Socio structural profile

The socio-structural profile of a community plays a crucial role in vulnerability assessment, directly influencing its ability to withstand disasters. Communities with strong social structures tend to be more resilient, while those with weaker social frameworks face heightened vulnerability. Marginalized groups-including women, children, the elderly, and persons with disabilities-are particularly at risk due to systemic inequalities and limited access to essential resource. The mean score of 0.472 indicates a moderate level of vulnerability in the study area. The variables related to this parameter are discussed below:

5.2.3.1. Security status of women and children in the shelter place

Riverbank erosion forces people from their homes, displacing them to various shelter locations. Respondents expressed concerns about the lack of security in these shelters, stating that security measures are either very weak or nonexistent. Due to this insecurity, women often feel unsafe and are vulnerable to various forms of violence, including sexual harassment, forced marriage, and other gender-related issues. Additionally, respondents reported a lack of privacy in shelter areas, where women must share common toilets with men, with these facilities often located outside the living spaces. Consequently, women and girls face significant difficulties and harassment, particularly when using toilets at night. Concerns were also raised about the safety of young girls in shelters. According to the findings, 16.96% of respondents stated that there was no security in their shelter locations, while 20% described security as very weak. Meanwhile, 24.78% and 16.96% reported low to moderate security measures, and the remaining respondents indicated that they or their children had not faced security-related issues. The security index value for women and children in shelter locations is 0.451, reflecting a moderate level of vulnerability.

5.2.3.2. Women right to participate of decision-making process

In our patriarchal society men are the households head and main decision maker for their family. Women have limited access to resource and any household decision making process. From the study result it is found that women do not have own property and economic abilities. They have less right to take any decision for their family members in any difficult situations which put them into a vulnerable situation. The index value of this variable is 0.416

represent their moderate opportunity to take any decision about family matters or any difficult situations.

5.2.3.3. Sold off household accessories

Selling assets, particularly livestock and poultry, and other accessories serves as a critical coping mechanism for households during riverbank erosion, providing immediate financial relief. However, while selling livestock and poultry may temporarily ease financial strain, it can lead to long-term food insecurity and increased vulnerability. When families are forced to sell these resources at low prices during emergencies, they lose an important source of sustenance and income, making future recovery difficult. This cycle of asset depletion exacerbates vulnerability, making affected households more dependent on external aid or borrowing, which may come with high-interest rates. The index value of 0.369 for sold household accessories reflects a low level of vulnerability in this context.

5.2.3.4. Number of family member

The study reveals that the majority of respondents have 5-8 family members (53.93%), while 32.16% have 1-4 members, and the remaining families consist of 9-12 members. A larger household size combined with limited income can significantly increase vulnerability, as financial resources must be stretched to cover basic needs. In this context, the index value of 0.486 indicates a moderate level of vulnerability among the surveyed households.

5.2.3.5. Received aid from various organization

The study found that women face several challenges when seeking aid from various relief organizations. 8.26% of respondents reported that they do not go for aid due to family restrictions, as their husbands or heads of the

household do not allow them to do so. Additionally, 32.04% stated that they experience physical or mental harassment by men at relief distribution centers. They also claimed that men receive greater priority from aid organizations, forcing women to wait extended periods for assistance. Furthermore, 26.96% mentioned that they do not receive sufficient relief, while 18.26% stated that they avoid seeking aid altogether. On the other hand, 23.48% of respondents reported that they had no choice but seek aid after losing their belongings to riverbank erosion. The index value of 0.504 reflects moderate vulnerability in this regard.

5.2.3.6. Household types

Stronger housing structures are less vulnerable to disasters, including riverbank erosion. The study reveals that inhabitants in this area construct their homes using various materials such as brick, cement, tin wood, bamboo, straw, and other raw materials. 53% of respondents reported building their houses with brick, tin wood, and bamboo, while 21% constructed theirs using brick, cement and tin. Only 6.52% stated that their houses were made entirely of brick and cement. The remaining respondents indicated that their homes were built with mud, thatch, straw, sacks, and other fragile materials, making them more susceptible to erosion and disaster-related damage (Figure5.11). The index value of 0.452 reflects a moderate level of vulnerability in relation to household type due to riverbank erosion.

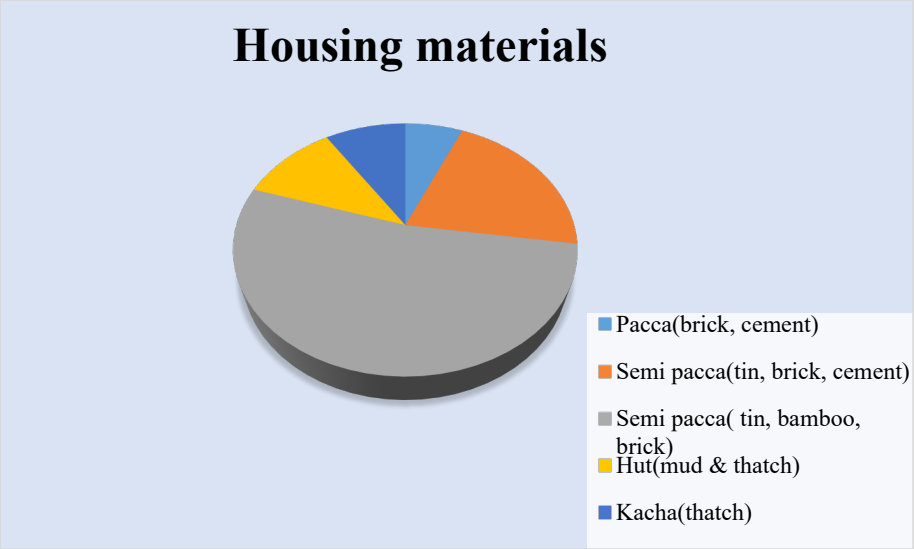

Figure 5.11: Housing materials

5.2.3.7. Get loan for buying food and accessories

Due to low income and the loss of agricultural land or livelihood caused by riverbank erosion, many affected individuals struggle to meet their basic needs and are forced to take loans from various sources, increasing their vulnerability. Only 12.14% of respondents reported never having taken a loan, while the remaining erosion-affected women stated that they rely on financial assistance from neighbors, relatives, NGOs, government organizations, or money lenders to cover household expenses. The index value of 0.478 reflects a moderate level of vulnerability in this context.

5.2.3.8. Knowledge about the reason of river bank erosion

Having proper knowledge about disasters, including riverbank erosion, can help minimize losses and reduce vulnerability. Awareness of erosion risks allows individuals to take appropriate safety measures to protect themselves and their property. During the field investigation, respondents were asked about the primary causes of riverbank erosion in their area, the majority of

respondents, 50.87% and 16.52% respectively, identified extreme flooding and the absence of embankments along the riverbank as the primary causes of erosion. Additionally, 10.87% pointed to deforestation, 10.44% cited riverbed siltation, and 11.3% mentioned excessive sand upheaval from the riverbed as contributing factors (Figure: 5.12). The index value of 0.566 reflects a moderate level of vulnerability in this context.

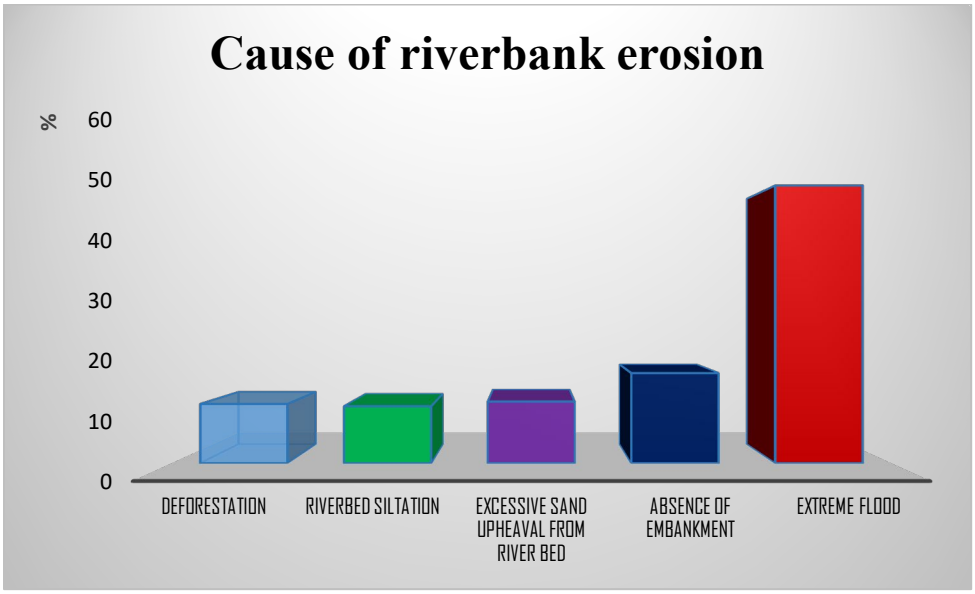

Figure 5.12: Cause of riverbank erosion

5.3. Discussion of Adaptive capacity

A high adaptive capacity reduces vulnerability by enabling communities to implement effective preparedness measures, diversify livelihoods, and utilize available resources efficiently. Factors that enhance adaptive capacity include access to education, economic stability, infrastructure, and income, strong social and national network & supports. When communities have these advantages, they are better equipped to withstand and recover from disasters,

minimizing long-term impacts. Conversely, low adaptive capacity leads to heightened vulnerability, as communities struggle to cope with disasters due to limited financial resources, weak governance, poor infrastructure, and lack of network & supports. According to the scale of this study, **(0-.19 = very low, .20-.39 = low, .40-.59 = moderate, .60-.79 = high and .80-1 = very high vulnerability)** the composite value of adaptive capacity is 0.601, which define that the people of this area are highly vulnerable due to riverbank erosion. The parameters and variables under this dimension have been discussed below.

5.3.1. Socio demographic profile

Socio-demographic profiles provide valuable insights into the characteristics of a population, helping to assess societal structure and potential risks. They play a crucial role in evaluating vulnerability, which refers to the degree to which individuals or communities are susceptible to disasters and other external threats. A higher vulnerability index suggests that certain groups face greater challenges in coping with crises due to limited access to resources, weaker support networks, or systemic disadvantages. In the study area under consideration, the mean score of 0.791 indicates a relatively high level of vulnerability among respondents. Additionally, the index values of different socio-demographic variables further emphasize the heightened risk faced by individuals in this region, highlighting the need for targeted interventions and policy measures to reduce social and economic vulnerabilities. The variables under this parameters are as follows:

5.3.1.1. Educational status of the respondents

Education serves as a key instrument in mitigating disaster vulnerability among women by equipping them with essential knowledge, skills, and resources to effectively prepare for and respond to crises. Women with higher education levels are more likely to comprehend early warning systems, access emergency service, and actively engage in disaster risk reduction efforts. On the other hand, limited education significantly amplifies vulnerability, as women with lower literacy levels may struggle with evacuation procedures, disaster preparedness awareness, and economic insecurity. Findings from a study conducted in and affected region reveal alarming trends: 57.82% of respondents were illiterate, 26.96% had competed primary education, 13.91% had attained SSC, and only 1.31% had finished HSC, with no respondents pursuing honors or master's degrees. Due to the erosion-prone nature of the village, access to schools and educational institutions remains severely constrained. This limitation is reflected in the index value of 0.725, underscoring the heightened vulnerability associated with educational levels.

5.3.1.2. Training and awareness program

Training and awareness programs play a crucial role in reducing disaster vulnerability by equipping individuals and communities with the knowledge, skills and strategies needed to effectively manage crises. Proper training enhances a community's ability to anticipate risks, take preventive measures and minimize casualties and losses during disasters. Through training, individuals gain the ability to identify hazards, interpret early warning systems, and implement proactive protective measures. Awareness programs also promote collective responsibility, encouraging community cooperation

in disaster response and recovery efforts. However, findings from the study indicate that no training or awareness programs have been conducted in this village regarding natural disaster or riverbank erosion. The index value of .940 further underscores the high vulnerability of the populations in this regions.

5.3.1.3. Occupation of the respondents

A field visit to the study area revealed that the majority of women are unemployed, primarily engaged in household chores. A small percentages are involved in income generating activities, with 3.04% of respondents engaged as agricultural laborers and working as laborers in the village tobacco factory and 9.13% are participating in livestock rearing. However, a significant 87.39% of women are not engaged in any formal income generating work, instead fulfilling roles as housewives. Additionally, only 0.44% respondents are employed in NGOs. The index value of 0.754 further highlights the high vulnerability of women in this context.

5.3.2. Livelihood strategies

Livelihood strategies are key determinants of disaster vulnerability, influencing a community's ability to manage risks, recover from crises and maintain economic stability. A diversified approach to livelihoods significantly reduces vulnerability, as communities with multiple sources of income tend to be more resilient during disasters such as riverbank erosions. Conversely, those reliant on a single livelihood source face greater risks, as disruptions can lead to severe economic hardship. Limited employment opportunities further increase vulnerability, especially in regions where livelihood options are scarce. In this study, the index value of .479 indicates moderate vulnerability in livelihood categories. However, an analysis of

individual variables within this parameter reveals high to very high vulnerability.

5.3.2.1. Occupation of household head

Stable and well-paying jobs help minimize vulnerability by ensuring financial security to any disaster or crisis, while low-income or unstable employment can leave individuals more exposed to economic hardship during or after any disasters as well as riverbank erosion. According to the respondents, a significant portion of population in this area in engaged in agricultural activities (33.48%), cultivating both the own land and land owned by others. A smaller percentage is involved in non-agricultural sectors, such as business (10.88%) and service-based occupations (3.47%). Day labor remains a primary source of income, with 39.13% of individuals depending on it both before and after riverbank erosion. Additionally, several other occupations contribute to local economy, including boatmen, fishermen, poultry farming, plantation or vegetation work and animal farming. In recent years, remittance income has emerged as another important livelihood sector, accounting for 13.04% in the area. However, the index value of 0.604 reflects a high level of vulnerability in this area.

5.3.2.2. Monthly income

Income plays a crucial role in determining vulnerability, as financial stability directly impacts a community's ability to manage disasters, recover from crises, and access essential resources. Those with stable earnings can afford adequate housing, healthcare, education, and disaster preparedness measures, increasing their resilience. On the other hand, individuals with low income often lack savings, insurance, and access to emergency relief, making disaster

recovery slower and more challenging. Survey findings indicate that 39.13% of respondents earn less than 6,000 BDT per month, while only 3.48% report earnings exceeding 25,000 BDT. Additionally, 33.48% earn between 7,000 and 12,000 BDT, and the remaining individuals fall within the 13,000 to 24,000 BDT income range (1 USD is approximately equal to 121 BDT). These figures highlight the prevalence of low-income households in the region. Furthermore, the effects of riverbank erosion have significantly impacted livelihoods, exacerbating financial instability. The index value of 0.604 underscores the high vulnerability associated with household income levels in this area.

5.3.2.3. Monthly expenditure

A significant portion of respondents (34.35%) said that their monthly expenditure exceeds 6,000 BDT, surpassing their income levels. Additionally, the effects have led to a rise in monthly expenses, further straining household finances. The monthly expenditure index value of 0.544 reflects moderate vulnerability, highlighting the financial challenges faced by the affected population.

5.3.2.4. Saving status

Savings play a crucial role in reducing livelihood vulnerability. The absence of savings increases the risks of financial instability, forcing individuals to rely on external aid, loans, or unsustainable coping strategies. The study reveals that financial insecurity is a major concern for the respondents, with only 5.22% having the ability to set aside savings for the future or emergency situations. In contrast, 43.91% reported being unable to save money at all, highlighting significant economic hardship in the community. The index

value of 0.599 further emphasizes the nearly high vulnerability associated with financial insecurity in this area.

5.3.2.5. Loan status

Limited income and savings often force individuals to borrow money to sustain their livelihood, increasing their vulnerability. Respondents indicated that they had to take loans from government and non-government institutions, relatives, neighbors or wealthy individuals both during and after riverbank erosion to cope with financial hardships. However, 7.39% of respondents stated that they regularly take loans, while the majority either do not rely on borrowing or require financial assistance only on rare occasions. The index value of 0.25 suggests lower vulnerability in this aspects, indicating that loan dependency is relatively minimal within the study area.

5.3.3. National and the social network

National and social networks play a vital role in minimizing vulnerability, as they provide individuals and communities with essential support systems, resources and recovery opportunities in times of crisis. When these networks are weak or disconnected, people face greater risks, struggling with delayed assistance, financial instability, and a lack of social support during emergencies. Strengthening these connections is crucial for enhancing resilience and mitigating long-term risks. In the study area, social and national networks significantly influence vulnerability levels. The calculated social network index value of 0.581 indicates nearly high degree of vulnerability among women's. A detailed breakdown of variable scores within this parameter provides further insights into their specific vulnerabilities, which are discussed below:

5.3.3.1. Receive relief from government or other source

Respondents indicates that during riverbank erosion, both government and non-government organizations provide relief assistance. However, 40% reported that the aid they receive is insufficient, while 27.83% stated that they hardly receive any support during and after riverbank erosion. Riverbank erosion has led to significant losses, including crops, assets, livestock and essential belongings, leaving affected individuals in a precarious situation. Although relief efforts include food, medicine, cloths and drinking water, respondents noted that these provisions last for only a few days and are inadequate to meet their long-term needs. The index value of 0.60 reflects high vulnerability, underscoring the challenges faced by women in securing adequate relief and recovery support.

5.3.3.2. Condition of roads network

This area experience severe road damage due to riverbank erosion and associated flooding. According to respondents, 56.98% reported that the entire road network in the area was completely destroyed. Additionally, 13.47% stated that half of the total road network in this village sustained damage (Figure: 5.13). The remaining respondents mentioned that the impact was minimal in certain locations. With index value of 0.634, the findings highlight high vulnerability among residents, as road infrastructure degradation severely affects mobility, accessibility, and overall disaster resilience in the region.

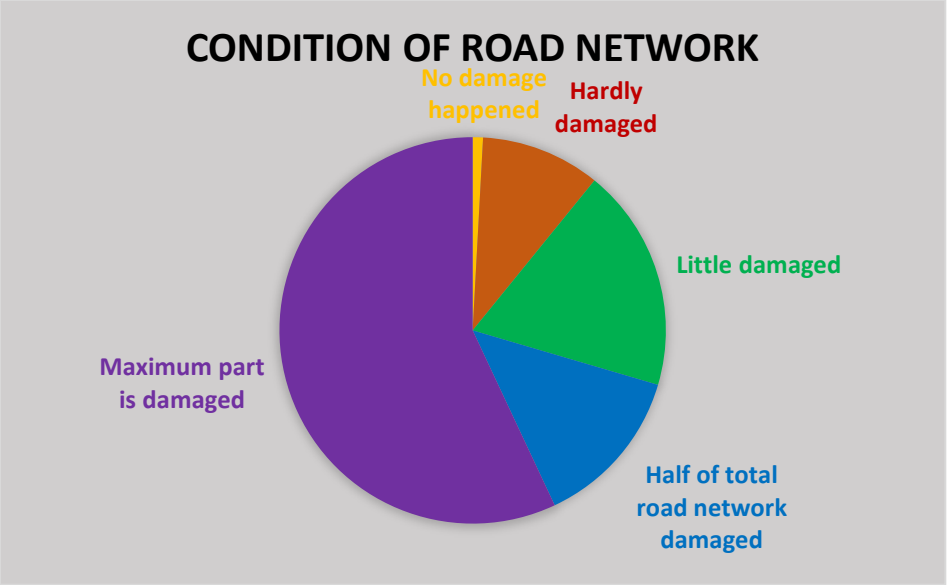

Figure 5.13: Road Network

5.3.3.3 Adaptation technique to prevent riverbank erosion

Strengthening resilience through adaptation techniques is essential for mitigating vulnerabilities associated with riverbank erosion. . The index value of 0.544 reflects moderate vulnerability, highlighting the need for improved adaptation strategies and greater community engagement in erosion prevention efforts. According to the study, 14.37% of respondents reported taking self-initiated measures to protect against erosion. However, 38.69% indicated that they struggled to take action due to financial or technical constraints, while 36.08% stated that they lacked awareness about available mitigation strategies. Additionally, 1.30% of respondents mentioned that they did not take any measures to address erosion. Respondents emphasized that the construction of embankments and regular deepening of the riverbed could help reduce the impact of riverbank erosion

5.3.3.4 Condition of community aid and support

During riverbank erosion, many affected individuals are forced to leave their homes and seek refuge on roads, or other temporary shelters. The study reveal that community support is limited, with only 6.52% of respondents stating that the community plays a role in assisting displaced individuals during and after erosion. While 7.96% of respondents acknowledged that the community sometimes intervenes by helping to protect assets and houses, secure roads provide clean drinking water, safeguard lives and livestock, and manage relief distribution, these efforts remain insufficient to significantly alleviate their hardships. Additionally, a majority (71.71%) reported that the local community does not participate in any meaningful way to support victims of erosion (Figure: 5.14). The index value of 0.660 highlights high vulnerability in terms of community support, emphasizing the need for stronger collective action and coordinated efforts to mitigate the impact of riverbank erosion and assist affected populations.

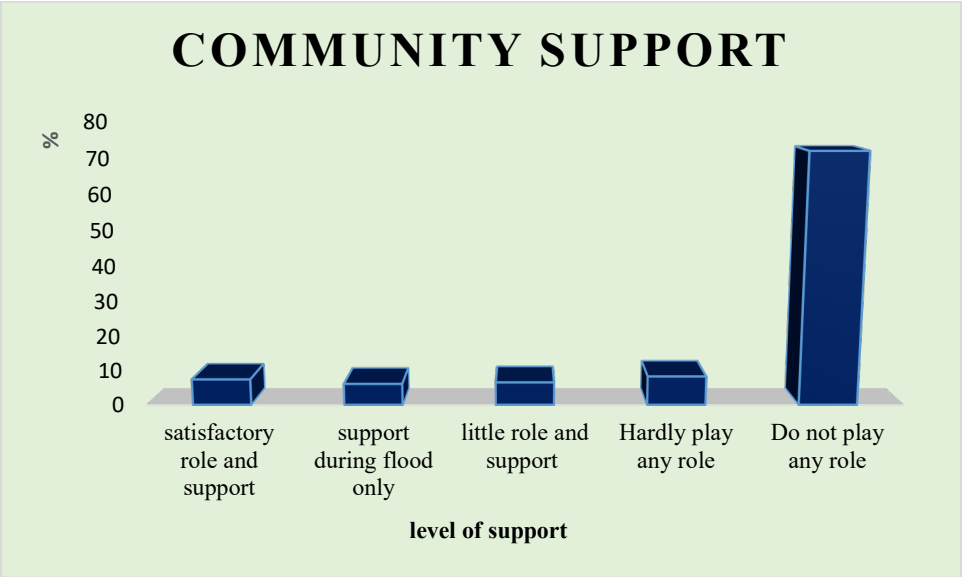

Figure 5.14: Community support

5.3.3.5. Aid given by Government organizations

According to respondents, the government provides relief assistance for affected communities. However, 50% of the respondents reported that they do not receive relief, despite their urgent needs. Only 1.30% expressed satisfaction with government assistance, while the remaining individuals claimed they receive little to no aid. The index value of 0.559 highlights the vulnerability of the affected population in this regard. Strengthening social networks and government intervention in the region could play a crucial role in reducing vulnerability and ensuring better access to essential resources and support.

5.3.3.6 Aid given by NGO

A strong presence of NGOs can help reduce vulnerability levels, providing essential aid and support to affected communities. However, in areas where NGO assistance is minimal or inconsistent, vulnerability remains high, further worsening the impact of disasters. According to respondents, they receive some aid from NGOs, but 52.17% stated that the support is insufficient to meet their needs. The index value of 0.600 highlights the limited effectiveness of NGO interventions in the region, contributing to the heightened vulnerability of the local population.

5.3.3.7. Support from relatives

Relatives are often among the first responders during and after riverbank erosion, providing essential support to affected individuals. However, most respondents noted that their relatives live in distant locations, which delays their ability to assist promptly. The index value of 0.520 reflects moderate vulnerability.

5.3.3.8. Support from neighbors

According to respondents, neighbors tend to respond more quickly compared to other sources of assistance during crises. They readily share resources and support within their capacity. However, since neighbors are also affected by riverbank erosion, their ability to provide aid is often limited, preventing them from consistently helping others in need. The index value of 0.644 reflects high vulnerability, highlighting the challenges faced by residents due to the limited support network within the community. Strengthening local resilience and coordinated disaster response efforts could help mitigate this issue.

5.3.3.9. Loan from money lenders

Respondents indicated that, at times, they are forced to borrow money from money lenders at high interest rates to sustain their livelihoods. However, when they struggle to repay the loans on time, their financial burden increases, further exacerbating their vulnerability. The index value of 0.432 signifies moderate vulnerability, highlighting the economic risks associated with reliance on high-interest loans.

5.4. Riverbank Erosion Vulnerability Index (REVI):

This study aims to assess the vulnerability of women and children in the area affected by riverbank erosion. Using the Riverbank Erosion Vulnerability Index (REVI) formula, the calculated index value of 0.201 indicates a low overall vulnerability. However, respondents expressed that in many cases, they experience high levels of vulnerability. The scores of individual variables and parameters further support these concerns, highlighting specific areas of heightened risk.

CHAPTER SIX
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6. Concluding remarks

Riverbank erosion is a great threat to the study area and it has been badly impacted on human life. From the physical survey in the study area shows that many of the riverbank erosion affected people lost their household lands, cultivated lands and other resources and now living in relatives houses or lands, on roads or Governments 'khash' lands. Respondents said that their homestead or agricultural land eroded by river almost every year and most of the people are unable to regain their eroded land. According to the result of individual variable and parameter, vulnerability of women is in the highest order. This study has been focused on the vulnerability and risk of women and children due to Jamuna River bank erosion. Related physical, mental, social and economic condition such as health, diseases, education, sanitation, occupation, security etc. also discussed to fulfill the study objectives. Study result shows that most of the women are illiterate and unemployed, they have little or no knowledge about socio economic, health care or security related facilities to secure their family members and themselves. Their social, physical, economic and political status are very low, which put them to complex vulnerable conditions. Due to bank erosion flood occurred very frequently in this area. As a result, people's as well as women's vulnerability increased gradually. During and after bank erosion and flood occurrence, the scarcity of shelter place, food, safe drinking water, proper sanitation and medical facilities have been increased. Prevalence of water borne and other skin infectious diseases are very common during this period. Women and girls

who take shelter in other places have been faced several difficulties. Proper privacy and security, separate toilet for female, separate room for pregnant women are absent in their shelter places. As a result, women's right to safety, to food and drinking water, to medical and other facilities persists on intense threat due to riverbank erosion. This also effects on women and children's physical and mental behavior terribly. During and after riverbank erosion, women face numerous difficulties and challenges. They are experiencing social, economic, psychological, health related problems and also faced insecurity and sexual harassment. Government, NGOs have taken very few or no special care and program for women's and children's the above-mentioned issues. Government and other organization should have emphasized on socio-economic, physical and mental health condition of women's and children. Protection of women and children form violence should be ensured by community level organizations as well as Government. From the study, it is found that women have little or no idea about the consequence of riverbank erosion and they have very little knowledge about survival and coping strategies. Though embankment had been built by the Government of Bangladesh but now this is eroded by river erosion. Building of new embankment along the riverbank in this area is very vital needs. Building of durable roads and maintain them regularly are also important to reduce vulnerability. Most of the affected people received help and support from their relatives, friends or neighbors who lived in safe places. Few respondents said that they received supports from the Government and other organizations only help at the time of riverbank erosion. Although this study has been conducted at a micro scale, the study found a significant relationship between riverbank erosion and women vulnerability.

6.1. Recommendations

It is true that both men and women are being affected and vulnerable to any kind of disasters. But the severity of helplessness is not same to these two groups. Due to socio-cultural norms, educational status, economic conditions and gender based division of labor and responsibility, women face heightened vulnerability. In our country, Government and some other national and international organizations have been trying to lessen women's vulnerability but it's very insufficient. Government and non-government authorities have taken numerous policies and programs to reduce women, children and other people's vulnerability. In this regard, some recommendations can be made for erosion affected women as well as other people of this village.

This is an erosion prone area, every year many people lost their homestead and agricultural land, but in this critical period, they do not get proper and secured shelter places. So adequate number of shelters need to be built for the affected people. Most of the respondents said they faced shelter crisis during and after riverbank erosion. It is needed to identify land to nearby safer zones where erosion affected people can take shelter at the time of emergency. Women amicable shelter should be constructed where women's privacy, security and other facilities would be easy during and after riverbank erosion. There was an embankment between this village and Jamuna River, but it had been eroded, so at present this village has no embankment protection. According to respondents the most important step that will help them at present and in future, is the construction embankment and riverbank management. A well-constructed embankment will obviously reduce their uncertainty as well as vulnerability. The length and height of the embankment should be constructed above erosion level and the length of embankment

should be extended that it can protect this village and also other vulnerable villages from bank erosion. Road and transport network should be developed to rapid and emergency movement of affected as well as other people due to erosion related difficulties. Effective erosion proactive plan and policies also needed for this village as well as other erosion prone areas. Women and children's safety and needs should be given higher priority in all plans and programs. Educational institutions have been found damaged in this village, Government and local community should have emphasized to protect or rebuilt educational institutions. Government, NGOs and other local authorities can take various development and income generating initiatives for women. The rights and security of the women, girls and children in shelter places should be ensured. Communities and local authorities should take strong initiatives to prevent unexpected events like torturing and harassment of women, hijacking and other violence's. To ensure women and children's security and safety, community-based awareness programs should be implemented. Laws and regulations should be implemented to prevent violence against women. Women's access to education and training programs should be implemented so that they can adapt and cope with erosion related difficulties. According to respondents, a satisfactory amount of relief came in this affected area from various sources like Government, NGOs etc. but the distribution system is not satisfactory, as a result vulnerable people do not get proper relief. Its government and local authority's duty to insure proper distribution of relief among the affected groups. So, appropriate steps for relief and rehabilitation to the erosion affected people needs to be taken during and after bank erosion. Both Government and non-government organizations should be worked together to reduce the vulnerability of women and children.

Many erosions affected people suffers from income erosion, they lose their occupation and most of the time they cannot occupy any jobs. Sometimes they have to lend money from money lenders with very high interest and most of the cases are unable to pay off that money which make them further vulnerable. In this situation, Government and non-government organizations can give them loan or create employment opportunities. NGOs should provide flexible credit schemes for riverbank erosion affected people especially for women. A handsome amount of loans can be provided for the affected women to create their employment opportunity.

Establishment of health camps in the neighborhood and creating facility for free medical support for the erosion affected people is needed for this area. The Government should provide them appropriate housing structure and materials with sanitary latrine and pure drinking water facilities. Households should be re located at the non-erosion prone areas. The construction of embankment, reforestation program along the river bank can reduce bank erosion. So, Government as well as community should emphasize on these strategies. Riverbank erosion engulf graveyard, roads, schools, fields, mosques, temples and other infrastructure as along with homesteads. To reduce the vulnerability all these things need to reconstruct and protect. Government should take suitable steps for the development of this erosion prone area. There are few initiatives have been taken to protect this area but these are not sufficient. So, Government has to ensure that the number of initiatives are adequate and implemented accurately.

6.2. Importance of the study

The study results help us to find valuable information about women, children and other vulnerable communities who lived in erosion prone areas in our

country. In this study, the analytical framework has been used for assessing vulnerability. This framework might be applied in other regions having similar characteristics in our country as well as in the world. Various modified flood, erosion and disaster related models and approaches have been used in this study to find a suitable index for this area. People who live in riverine areas are being affected by bank erosion and become vulnerable. Riverbank erosion affect all surrounding riverine people, mostly women, children and elder people are significantly being in vulnerable condition which may impacts on our national development. The development of Riverbank Erosion Vulnerability Index (REVI) may contribute to understand the most vulnerable groups and it may help policy makers to formulate and improve need-based policies. This study may also be helpful for the policy makers to formulate different socio economic and environmental policies to reduce riverbank erosion related vulnerabilities of women and children. How women and children's social, economic, physical and mental status impacts on whole society as well as national level, have been revealed in this study. The study methods can be applied in other regions or communities around the world for assessing and comparing vulnerabilities which might be very helpful to development new strategies. This is a flexible method and it allows to change or replace parameters and variables as per the local conditions. So, it can be applied simply on different communities.

6.3. Limitation of the Study

This is academic research with limited time, little money and small study area. So, few limitations have been faced during completing this research. During field survey some difficulties have to face in collecting primary data and other secondary documents. Having secondary documents from various officials are

very difficult. Unavailability of documented information another setback of this study. Many information considered as confidential so getting information from the public office is quite impossible. On the other hand, the responsible offices have very few data about women related records sometimes women simply decline to provide any data. Data about cultivable lands, household land and other assets are calculated on the basis of respondent's assumption, which might impact on data accuracy. The study has been conducted in a small area which may not be represent the whole country. Besides these limitations, it is significant research which may help us to identify the riverbank erosion related vulnerabilities in the erosion prone areas.

6.4. Conclusion:

Disasters do not discriminate, but our society created many roles that makes women as the vulnerable group during any disasters. Women and children are the most vulnerable group in our society with limited access to resources, education, economic capabilities. Most of the women do only household or domestic work. Various research shows women's vulnerabilities in different circumstances. In our country women experienced different types of physical, sexual and domestic violence and it might be increased at any kind of disasters as well as riverbank erosion. Riverbank erosion can generate different types of vulnerabilities such as displacement, social status degradation, insecurity, mental stress and many other violence and risks. Women consists half of the total population of our country and they are the most vulnerable group. We need to take effective initiatives for this vulnerable group so that they can be able to cope with erosion related vulnerabilities. It is very difficult to forecast

where will be erosion occurred but it is not impossible. So, Government should take necessary actions to stop riverbank erosion and to ensure women and children's security and other basic facilities. This study has been conducted to understand the vulnerability of women and children due to riverbank erosion and also find out their coping strategies regarding bank erosion.

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APPENDICES

Appendix- 1: Questionnaire for Household Survey (English version)

Vulnerability Assessment of women and Children due to the Jamuna riverbank erosion: A study of kastapara village of Bhuapur Upazila, Tangail

ID: Name of respondent:	Village: Kastapara Union: Gobindashi Upazila: Bhuapur District: tangail

1. General information of respondents:

a.

Age of respondents		Marital status of respondents	
Age group	Number	Marital status	Number
< 15		Married	
16-30		Unmarried	
31-45		Widow	
46-60		Divorced	
60+		Separated	

b. Family type:

Types	Number
Extended (multiple generations)	
Joint (grandparents, parents, children)	
Nuclear (parents, children)	

c. Are you the household head?

☐ Yes:

☐ No:

d. Are there any children in your family?

☐ Yes:

☐ No:

2. Education level of respondents

Education level	Status	Number
Higher education (Honors & Masters)	1	
Higher secondary(XI-X)	2	
Secondary(XI-XII)	3	
Primary(I-VIII)	4	
Not educated/ Illiterate	5	

3. Occupation of the respondents

Categories	Status	Number
Govt. & non Govt. service	1	
Business	2	
Agriculture/ labor	3	
Rearing livestock	4	
Housewife	5	

4. Are there any natural disaster (storm, nor'wester, drought, flood, tornedo, riverbank erosion and earthquake) occurred in your area in last 10 year3s?

State of disaster	Status	Number
No disasters occurred	1	
Hardly occurred	2	
Only 1/2 times occurred last 10 years	3	
Frequently occurred (3/4 times)	4	
annually occurred (5+ times)	5	

5. How many times riverbank erosion occurred in your locality last 10 years?

Intensity	Status	Number
1-2 times	1	
3-4 times	2	

5-6 times	3	
6-7times	4	
7+times	5	

6. How far is your homestead from the river??

Distance	Status	Number
>500 meters	1	
400 meters	2	
300 meters	3	
200 meters	4	
<100 meters	5	

7. How much land property do you have?

Land unit	Status	Number
>80 decimal	1	
61-80 decimal	2	
41-60 decimal	3	
40-21 decimal	4	
<20 decimal	5	

*1 decimal = .6198 Acre

8. Did any damage occurred due to riverbank erosion (homestead land, agricultural land, fisheries, livestock, home accessories etc.)

volume of damage	Status	Number
No damaged occurred	1	
Rarely damaged	2	
Little damaged	3	
Partially damaged	4	
Fully damaged	5	

9. Did your crop land & crop production damaged due to riverbank erosion?

Volume of damage	Status	Number
No damaged occurred	1	
Rarely damaged	2	

Little damaged	3	
Partially damaged	4	
Fully damaged	5	

10. Where did you take shelter after damaged your homestead due to river bank erosion?

Places of shelter	Status	Number
Migrate another town or cities	1	
On existing embankment of road	2	
Nearby village	3	
Another place of own	4	
Relatives house	5	

11. Where did you get pure drinking water during or after riverbank erosion?

Source of water	status	Number
tube well	1	
Buy bottle water(mineral water)	2	
River	3	
Pond/lake	4	
well	5	

12. Where did you get healthcare facilities (including children and other family members) during and after riverbank erosion?

Categories	Status	Number
Govt. & Non govt. hospitals	1	
Took treatment from homeopathy doctor	2	
Village quack (polli doctor)	3	
Kobiraj (who treatment with Ayurveda)	4	
Do not get any treatment	5	

13. Do you believe that riverbank erosion affects your or your children's mental health, causing feelings such as disappointment, depression, loneliness, anxiety, anger, or fear?

Level of impacts	Status	Number
No impact	1	
Less impact	2	
Moderate impact	3	
Little impact	4	
Very severe impact	5	

14. Have any physical injuries, particularly among women and children- such as amputations, fractures, hemorrhages, swelling, respiratory issues, waterborne diseases, skin infections, or malnutrition, been caused by riverbank erosion?

Level of occurring time	Status	Number
Never happened	1	
Seldom happened	2	
Sometimes happened	3	
Often happened	4	
Always happen	5	

15. Where did pregnant women get treatment during and after bank erosion?

Sources	status	Number
Nearest government hospitals	1	
Nearest private clinic	2	
Take help & advice from midwife	3	
Take help & advice from elder women of family or neighbor	4	
There is no proper facilities	5	

16. What is the condition of your sanitation facilities?

Types	status	Number
Pacca toilet (brick, cement, slab)	1	
Semi pacca (brick, tin & slab)	2	
Semi pacca (bamboo, tin & slab)	3	
Kacha (made with slab & thatch)	4	
Kacha toilet (made without slab)	5	

17. Did you suffer from any gynecological (vaginitis, Improper feminine hygiene, abortion, menstrual problem, pelvic pain, Endometritis etc.) problem due to bank erosion?

Level of suffered	Status	Number
Do not suffer	1	
Hardly suffer	2	
Sometime	3	
Frequently	4	
Always suffer	5	

18. What are the sources of your food supply during and after bank erosion?

Sources	Status	Number
Own storage	1	
Get from neighbor	2	
Non govt. organizations	3	
Govt. organizations	4	
From relatives	5	

19. What is the cropping intensity of your farmland?

Intensity	Status	Number
3+ times/year	1	
3 times/year	2	
2times/year	3	
1time/year	4	
No cultivation	5	

20. Do you have enough food storage regarding riverbank erosion?(food security of your family during or after riverbank erosion)

Storage extent	Status	Number
Enough food storage	1	
storage for 5/6 months	2	
Storage for 3/4 months	3	
Storage for 1/2 months	4	
no storage	5	

21. How much cultivated land do you have?

Land unit	Status	Number
80+ decimal	1	
61-80 decimal	2	
41-60 decimal	3	
21-40 decimal	4	
Less than 20 decimal/land less	5	

*1 decimal= .01 acre

22. Security status of women and children in the shelter places:

State of security	Status	Number
Highly secured	1	
Moderate security	2	
Low security	3	
Very low security	4	
No security at al	5	

23. Do you have any right to participate of taking decisions for your family?

State of participation	Status	Number
Almost always	1	
Often	2	
sometimes	3	
Seldom	4	
Do not have any right	5	

24. Did you have to sell your household assets (gold, animal or other valuable assets) for bearing livelihood due to riverbank erosion?

State	Status	Number
Do not have to sell	1	
Seldom	2	
In time of crisis	3	

Often	4	
Yes, have to sell assets	5	

25. Housing materials

Types	Status	Number
Pacca(brick, cement)	1	
Semi pacca(tin, brick, cement)	2	
Semi pacca(tin, bamboo, brick)	3	
Hut(mud & thatch)	4	
Kacha(thatch)	5	

26. Do you have to take loan for buy food/ children food or other accessories due to riverbank erosion?

State of taking loan	Status	Number
Never	1	
Hardly ever	2	
Sometimes	3	
Frequently	4	
Always	5	

27. Dou you know the cause of riverbank erosion?

Causes	Status	Number
Deforestation	1	
Riverbed siltation	2	
Excessive Sand upheaval from river bed	3	
Absence of embankment	4	
Extreme flood	5	

28. How many member do you have in your family?

Number	Status	Number
<2 members	1	
3-4 members	2	
5-6 members	3	

7-8 members	4	
>9 members	5	

29. Did you go for aid given by different Govt. & non Govt. organizations?

State of going	Status	Number
Do not go for aid	1	
Go, if household head allowed	2	
Go, if there have been proper security	3	
Go, do not get adequate aid	4	
Yes, I do go	5	

30. Is there any training program executed in your village regarding riverbank erosion or any other disasters?

State of execution	Status	Number
Yes, almost always	1	
Frequently executed	2	
Sometimes executed	3	
Rarely executed	4	
Never executed	5	

31. Occupation of the household head

Categories	Status	Number
Govt. /non govt. service	1	
Business	2	
Immigrant (Remittance)	3	
Farming/fishing/rearing livestock	4	
Day labor	5	

32. Monthly income of your family members:

Amount	Status	Number
>25000	1	
19000-24000	2	
13000-18000	3	
7000-12000	4	
<6000	5	

33. Monthly expenditure of your family

Amount	Status	Number
<6000	1	
7000-12000	2	
13000-18000	3	
19000-24000	4	
>25000	5	

34. Saving status of your family

State of saving	Status	Number
Yes, I can save money for the family	1	
A little saving capacity	2	
Save when income is sufficient	3	
Less ability for saving	4	
Do not have any savings	5	

35. Loan status of your family

State	Status	Number
Don't have to take loan	1	
Hardly taken loan	2	
Occasionally taken loan	3	
Take loan in time of crisis	4	
Always have to take loan	5	

36. Do you get any financial support from Government or non-government organizations due to riverbank erosion?

State of support	status	Number
Get sufficient support	1	
Get support during flood only	2	
Get little amount of money for once	3	
Hardly got any support	4	
Do not get any support	5	

37. What is the situation of your village road network due to bank erosion?

Volume of damage	Status	Number
No damage happened	1	
Hardly damaged	2	
Little damaged	3	
Half of total road network damaged	4	
Maximum part is damaged	5	

38. Aid given by government organizations:

State of aid	Status	Number
Get sufficient aid	1	
Get aid during flood only	2	
Get little aid	3	
Hardly get aid	4	
Do not get aid	5	

39. Aid given by NGOs

State of aid	Status	Number
Get sufficient aid	1	
Get aid during flood only	2	
Get little aid	3	
Hardly get aid	4	
Do not get aid	5	

40. Help from relatives:

State of aid	Status	Number
Get sufficient aid	1	
Get aid during flood only	2	
Get little aid	3	
Hardly get aid	4	
Do not get aid	5	

41. Help from neighbor;

State of aid	Status	Number
Get sufficient aid	1	
Get aid during flood only	2	
Get little aid	3	
Hardly get aid	4	
Do not get aid	5	

42. Community support scenario

State of aid	Status	Number
satisfactory role & support	1	
support during flood only	2	
play little role & support	3	
Hardly play any role	4	
Do not play any role	5	

43. Do you take loan from money lenders due to bank erosion?

State of taking loan	Status	Number
Don't have to take loan	1	
Hardly taken loan	2	
Occasionally taken loan	3	
Take loan in time of crisis	4	
Always have to take loan	5	

44. Do you take any adaptive technique to cope with river bank erosion?

State of adaptive technique	Status	Number
Take adequate actions	1	
Hardly take any actions	2	
No knowledge about any adaptive technique	3	
Fewer capacity to take any actions	4	
Do not take any actions	5	

Thank you for your co-operation.

Appendix 2: Study area photograph