EROSION OF LEFT BANK OF THE PADMA RIVER AT MAWA-DIGHIRPER REACH AND ITS SOCIO-ECONOMIC IMPACT

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BUET

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INSTITUTE OF WATER AND FLOOD MANAGEMENT
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

EROSION OF LEFT BANK OF THE PADMA RIVER AT MAWA-DIGHIRPER REACH AND ITS SOCIO-ECONOMIC IMPACT

A thesis by

Mohammad Arifur Rahman

In partial fulfillment of the requirement for the

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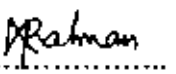

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Dedicated to

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Abbreviations

BBS	Bangladesh Bureau of Statistics
BTM	Bangladesh Transverse Mereator
BWDB	Bangladesh Water Development Board
CEGIS	Center for Envirnmental and Geographic Information Services
FGD	Focus Group Discussion
GMB	The Ganga, the Meghna and the Brahmaputra
GPS	Global Positioning System
IRS	Indian Remote Sensing
JMREMP	Jamuna Meghna River Erosion Mitigation Project
LRP	Land Reclamation Project
MPO	Master Plan Organization
NGOs	Non-Governmental Organization
RS	Remote Sensing
REIS	Rivervbank Erosion Impact Study
USO	Upazila Statistics Office
ULO	Upazila Land Office

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Abstract

The Padma River is highly dynamic and meander in nature. Bank erosion severely affects the socioeconomic condition of the affected reach and not only causes suffering to the people living along its course but also national losses due to loss of cultivated land, settlements, commercial centers and infrastructures. The present research tries to understand the bank erosion of Mawa- Dighirper reach and its present and future socioeconomic impact.

In the present study, a large number of good quality digital data have been prepared from satellite imageries and these data are used to evaluate the channel shifting in the study reach.

The income level of about 70 percent respondents has become less due to change in their working environment. After displacement 28% became day labor, about 16% of the affected are adopted taxipo and bus driving, 16% started to work in the garments and cold storage factories.

A total of 78 percent of the households reported having been displaced by erosion at least once; out of them, 80 percent household reported multiple displacements. Eighty eight percent affected household migrated and resettled at the adjacent villages and unions. The affected people have a tendency and attitude to remain close to their homestead, relatives and surroundings.

Most of the School going children gave up their studies forever due to school shift. About 66 percent of the respondent reported that the educational facilities were deteriorated.

The sinuosity of the recent active bend is 1.02. A Hickin and Nanson type empirical model for the estimation of bank erosion rate was tested in the present study reach. It was observed that the co-efficient of erosion and exponent values for positive trend are 229 and 0.71, respectively and the co-efficient of erosion and exponent values for negative trend are 1280 and 1.77, respectively.

The satellite imageries of 1989 to 2006 indicate that, the left bank of the Padma River at Mawa- Dighirper reach is severely affected by erosion. Lohajang, Teotia, Dighirper and Hasail-Banari union are almost disappearing and Dhaida union become extinct due to bank erosion of the study reach. In the time span of the last 17 years the concerned area of the study reach decreased by about 40 km^2, Seven hundred and fifty crore taka at land value have been lost due to erosion.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The main rivers such as the Jamuna and the Padma grasp thousands of hectares of floodplain every year making thousands of people homeless and destroying valuable infrastructures.

The Padma is one of the three major rivers in Bangladesh and one of the longest rivers in the Sub-Continent. Two hundred and fifty million people of India and Nepal live in its catchment area. More than 20 million people of Bangladesh also live in the catchment area of this river (Kalam and Jabbar, 1991).

Two principle resources of Bangladesh are its land and its people. The rivers have historically played a significant role in the lives and living of people in Bangladesh. Each year, severe bankline erosion deprives thousand of households of their only source of livelihood. Thus, the socio-economic consequences are far reaching and often enormous. It is mostly permanent and most often, long term (Elahi, 1991).

The erosion and shifting of rivers in Bangladesh have long been a dominant environmental problem affecting a sizable population (Elahi, 1991). The loss of land due to erosion of river and consequently dislocation of population has serious problems on the socio-economic spheres (Chowdhury and Kabir, 1991). People displaced by erosion suffer physical, emotional and financial losses, as well as a loss of land and livelihood. This study is intended to estimate the bank erosion of the Padma River at Mawa-Dighirper reach by applying remote sensing and GIS and to assess its socio-economic impact.

The Study area is located in the middle part of the country and north-western part of the Munshiganj district. The left bank floodplain of the Padma River is predominantly agricultural land. The loss of agricultural land and homestead area due to bank erosion is very high in the study area. It has devastating effects on the people of these areas. It

sweeps away houses, trees and other tangible goods. The socio-economic condition of these areas is severely disturbed by the present situation.

Table 1.1: Some key characteristics of Ganges and the Padma rivers.

(Source: Sarker et. al, 2003 and CEGIS, 2007)

Parameters	Ganges	Padma
Catchment area (10^3 km^2)	1000	1573
Average annual rainfall with in the catchment (mm)	1200	1450
Average annual discharge (m^3/s)	11000	30000
Slope (cm/km)	0.5	0.5
Total sediment transport (M tons/y)	550	900
Total material transport (M tons/y)	195	370
Bed material size (D_{50}) (mm)	0.15	0.12
Planform	Wandering	Wandering

Locally the lowermost reach of the Ganga downstream from the off-take of the Hoogly River in India to the confluence with the Meghna at Chandpur, is known as the Padma River. This River can be divided into two distinct reaches, which are hydrologically and morphologically quite differem from each other. The upstream reach stretches from the off-take of the Hoogly to the confluence with the Jamuna at Aricha. The downstream reach extends from Aricha to Chandpur and caries combined flow of the Ganges and Jamuna rivers. The length of this reach of the river is around 100 km. The annual average flow of the river is 30,000 m^3/s and reach averaged width of the river is over 10 km but varies from 2.5 km to 20 km (CEGIS, 2007). However the variability of characteristics of the major rivers in Bangladesh can be seen in Table 1.1.

The Mawa- Dighirper downstream reach is the area of concern at the present study. The study area of Mawa-Dighirper reach is the worst experienced of severe river bank erosion. Severe river erosion created population displacement in the year of 1995, 2000, 2004, and 2005.

1.2 Objectives of the Study

The major objectives of the study are as follows:

1. To assess the magnitude of river erosion of the Padma at Mawa-Dighirper reach.
2. To develop bank erosion map of the study area.
3. To evaluate the socio-economic impact of the bank erosion.

1.3 Justification of the Study

Erosion cannot be completely avoided, but damages from severe erosion can be reduced if effective erosion prevention scheme is implemented. This can be achieved if the sufficient erosion related information is acquired. Prediction tool using GIS & RS is available now. Use of GIS and Remote Sensing will provide supplementary data in erosion for such analysis and will lead to easier interpretation and understanding of the effect of erosion and characteristics.

1.4 Organization of the Thesis

Chapters two and three mainly focus on the literature review and methodology of the study. Chapters four and five explain the results and discussion of the research. Finally, conclusion of the study is summarized in chapter six.

CHAPTER TWO

LITERATURE REVIEW

2.1 River Erosion

River bank erosion is an annual phenomenon in Bangladesh and the country is located in a large floodplain delta complex of three mighty rivers - the Ganges, the Brahmaputra and the Meghna (GBM). River bank erosion is a frequent natural disaster in Bangladesh. Due to river bank erosion, people are displaced and it creates social and economical problem in Bangladesh. The literature review is primarily directed to an overview of the history of erosion and its present status in Bangladesh.

Bangladesh is a country of more than 120 million people with 90 percent dependent on agriculture (BBS, 2001). In a typical year, one fifth of the total 147,570 km^2 of land in the country is severely flooded; and about 2400 km of bankline annually experience major erosion (Islam, 1985).

Currey (1978) identified 66 out of 462 upazilas of the country as affected and likely to bank erosion. Thus, in 1984-85 alone, erosion took place at 285 localities of which 38 were in the Brahmaputra floodplain area; the Ganges caused at 30 places; the Meghna at 6 places; and the Teesta at 8 places and other minor rivers at 201 places (Holiday, 1986). Bangladesh Water Development Board (MPO, 1986) has estimated that about 1200 km of river banks in Bangladesh are under active erosion of which more than 500 km face severe erosion problems which, of course, differ from river to river and reach to reach.

Under the Riverbank Erosion Impact Study (REIS) program Elahi (1991) observed the bank erosion problems of Kajirpur on the right bank of Jamuna River at the upper stream of Sirajganj town for the period 1983-86 and Kajirpur had been totally eroded away in the period between 1980-84. This might be explained as westward shifting of the river Jamuna through erosion that might had been responsible and was evident from the study of Hossain (1984) also. Again, on average of bankline shift at 220 meter per annum continued for few years and this way abruptly changed into an accelerated rate. This was commensurate with estimate of average annual rate of 245

meters by Khan and Rashid (1985). The 1984 flood was responsible for accelerated bankline erosion. During 1984-87, a total loss of 969 meters of bankline in the Meghi village of Kajirpur was encountered. The net result was the destruction of the embankment by Bangladesh Water Development Board (BWDB), nearby settlements and crop lands. With the persistent erosion, the loss of damage of properties, roads and human habitation in general were remarkably high. LRP (1983) remarked that in the south-eastern delta of Bangladesh between 1940 and 1963, about 1077 km^2 of land eroded. The valuable land was lost and replaced by new accretion which was to be reclaimed. These simultaneous processes of erosion and accretion caused untold human suffering and economic loss.

The unique natural setting of Bangladesh in the South Asian Sub-Continent and the characteristics of tropical monsoon are greatly responsible for flood, riverbank erosion, sedimentation and population displacement in Bangladesh. In Bangladesh, river bank erosion is closely related to the magnitude of flood and bank materials of alluvial character. Rivers flowing through these loose alluvial soils carry most of the eroded materials as sediment on their way to the Bay of Bengal (Elahi, 1991 & Islam, 1994).

Elahi (1991) discusses that one of the worst affected coastal islands from erosion had been Sandwip. Its area was 1080 km^2 in 1780 and 575 km^2 in 1916, the area has reached to only 238 km^2 in 1940 and now the area had reached to less than a half of the size. Apart from these, Bhuapur (Tangail), Nagarbari (Pabna), Hijla-Mehendiganj (Barisal), Haragacha and Gangachara (Rangpur) and few other were also badly affected by bank erosion.

Since the early 1990s, erosion has been occurring along a 20 km long stretch of the Padma River very close to Faridpur town. Sarker (2003) estimated that every year the river consumes about 600 hectares of land. Length- average bank erosion rates during the period 1984-1993 are found to be much higher along the Ganges and Upper Meghna rivers. This rate is an indicator of the characteristics of bank materials and river flow play vital role in erosion. For example, the floodplains along the right bank of the Jamuna River are older than those along the left bank. Though a long term westward migration trend is present, the bank erosion was higher along the left (east) bank during widening phase of the river. Similarly, the flood plains along the left

bank of the Padma and Lower Meghna rivers are older than those along the right bank, and the length averaged bank erosion rate was found to be much higher along the left bank.

2.2 Population Displacement

Population displacement due to flood and bank erosion is being considered as one of the major contributes to landlessness and impoverishment of rural population. Ahmed (1991) made a detail study on population displacement in Kazirpur, Sirajganj and found that 461 households out of 675, experienced displacement due to flood and erosion hazards that took place mainly during 1980-86. Due to river bank erosion hazard, movement of households not confined within the same mouza (village) alone. Although 56 percent households were found to have moved within the mouza, 44 percent households moved to different mouzas.

Mesbah (1991) conducted questionnaire survey in Kazirpur on the population displacement due to river bank erosion and found that about 55.7 percent of the total displaces moved within the same mouza, while 44.3 percent went to different mouzas other than their own. Only 25.9 percent of the total displaces moved more than two miles from their original homestead while, about 65.4 percent moved within a mile.

Elahi (1991) noted that 372 m of BWDB embankment in Sariakandi, Bogra were eroded in 1978. The erosion was active and presently, each year about 70 m of the area was being swallowed up by the river. The very presence of the hundreds of uprooted families on the 80 km stretch of the BWDB from Kazirpur to Chouhali via Sirajganj alone testified the magnitude of the problems in the mid-Jamuna floodplain. About 8,000 squatting households had been living on the embankment (Zaman and Babu, 1985). They were uprooted from the villages by erosion over the last few years. In Kazirpur, 23 percent of its total area was eroded during early 1980s. Eight mouzas and the Thana headquarters of Kazirpur were eroded away since 1980. About 46 percent of population experienced displacement during 1980-86 and 42.9 percent of displaces experienced dislocation for more than fours times. It has been estimated about 18,000 people were displaced due to river bank erosion in Kazirpur thana during 1974-1981, of then little over 12,000 had stayed in the same union on the road, embankment and khas lands (Haque, 1985).

2.3 Socio- Economic Impact

The river bank erosion has resulted in many farmers losing their cultivable lands while only few of them could acquire re-emerged lands. Only the landlords "using their economic, social and political leverages, can even profit from the fluvial-geomorphic process by asserting control of newly emerged alluvial and incorporating them into their landed estates" (Romanowski, 1987). Halli (1991) and Haque (1986) has found that the erosion hazard in Kazirpur thana accounted for a loss of land to one third of the displaces. The displaced landlords may find the riverbank erosion as an opportunity to expand their landholding at the expense of the poor and the helpless displaces, who lost whatever little land they had to the erosion.

Haque (1997) mentions the three common effects of erosion induced displacement which influenced the well-being of family members: 1) a severe cut in their standard of living, 2) the occurrence of mental illness in the family, and 3) the loss of valuable assets. The socio-economic impact of riverbank erosion of the Jamuna at Kazirpur has been studied by Chowdhury and Kabir (1991).

2.4 Shifting Characteristics and Erosion Prediction

The ratio of radius of channel curvature to channel width plays an important role in determining the rate of channel migration. Hickin and Nanson (1975) showed that the rate of channel migration in Beatton River (Canada) reaches a maximum value where the radius of channel curvature to width approximately equal to 3. The rate of channel migration rapidly decline for bends with values of channel curvature to width ratio greater or less than 3.

Hossain (1991) conducted a study on the shifting characteristics of the Ganges River and noted that the bankline of the Ganges within Bangladesh was unstable. For a single bank, the maximum erosion was approximately 145 m per year on the left bank and the maximum deposition was approximately 220 m per year on the right bank between some sections. All other sections in the reach experienced either erosion and/or deposition to varying magnitude. Another investigation on the river bank shifting of the Ganges River at Godagari, Rajshahi using remote sensing techniques was made by Kamal and Jabber (1991). The investigators concluded that erosion occurred at Godagari due to the shifting of the river at the up stream at several points.

The shifting was a result of the increasing meandering (sinuosity) of the Ganges River.

At the same time Bhuiyan et al. (2000) also studied and found the change of physical characteristic of the Padma River and their impact on surrounding wetlands using remote sensing and Geographic Information System (GIS).

The Ganges is a wide meandering river having total length of 2600 km of which only last 230 km lies in Bangladesh. Rahman et al. (2007) shows that the sinuosity of the river varies from 1.18 to 1.31 except the most downstream reach before meeting with the Jamuna at Aricha. At the downstream reaches river is mildly sinuous having sinuosity of around 1.06. The meander wavelength varies from 15-30 km; where as average width of the active channel is around 3 km. The length of one wave along the curvilinear meander path of the Panka Narayanpur reach is 20 km and minimum value of radius of curvature is 3 km. The sinuosity of such a meandering channel is 1.29.

Under Jamuna Meghna River Erosion Mitigation Project (JMREMP), Center for Environmental and Geographic Information Services (CEGIS) observed and predicted the erosion along the bank of Padma River. During the last three and half decades (1973 to 2007) the net erosion along the 100 km long Padma River was about 31,000 hectares. The rate of net erosion along the Padma varies over time. For example, the rate at which the Padma River is widening increased from 160 m/year in the 1980s to 230 m/year in the 1990s. Recently the rate of widening reduced to 130 m/year. It is predicted erosion vulnerable lands along the Padma River about 62 hectares land area (with in the range of 50% probability) at Mawa- Dighirper reach for the year 2007 and about 660 hectares of flood plain along the Padma River will be eroded in 2007. The vulnerability of different types of infrastructures like land, settlement, road, educational institutions, commercial places, health center, government and NGO offices etc. has also been assessed along the Padma River (CEGIS, 2007).

2.5 Summary

The literature review discussed only history of erosion and its socio-economic impact in the main rivers of Bangladesh. The literature review emphasis mainly on the displacement and socio-economic impact of bank erosion with a limited emphasis on prediction of river bank erosion. From the literature review, it is concluded that scarce

researeh work had been done along the present study reach in Padma River. Recently, CEGIS observed and predicted that during the last three and half decades (1973 to 2007) the net erosion along the 100 km long Padma River (Aricha to Chandpur) was about 31,000 hectares. CEGIS also identified the most vulnerable location of the reach is Hasail - Banari area. So a complete study is required for the understanding of overall situation of the study reach. The present study assesses the bank erosion of the Mawa- Dighirper reach and its present and future socio-economic impact as well as predicts the erosion along the Hasail-Banari reach (most active bend). The present study will be helpful for conducting future development action and policy formulation related to bank erosion.

CHAPTER THREE

METHODOLOGY

3.1 The Setting

The study area, Mawa-Dighirper reach along the Padma River under Munshiganj district is one of the erosion affected region of Bangladesh. From the reconnaissance survey and literature review, it is also found that the characteristics of erosion of Mawa-Dighirper reach are almost same with the bank erosion of other parts of Bangladesh. So a bank erosion study on Mawa-Dighirper reach using GIS and Remote Sensing will be a representative one.

In selection of the study area, availability of Satellite images of the area for the required time period is also essential. In this aspect, Mawa-Dighirper reach is suitable.

More over in the case of other study related information, existing communication system and assistance for GO and NGO Mawa-Dighirper reach is suitable for conducting the research work.

3.2 Reconnaissance Survey

Reconnaissance survey is essential for conducting a research, for understanding the magnitude of river bank erosion and its impacts on socio economic condition of the concern area. It is also essential for setting an outline for the overall study.

For this study, a reconnaissance survey is conducted with the individual respondents and at the same time a number of respondents also interviewed for the variation of the study. The objective of the survey was to quickly obtain the basic information and developing the overall understanding about the area. The formal questionnaire was designed in an understandable manner that is relevant to the impact on socio-economic due to erosion, farmers' circumstances and sensitive local issues related to erosion.

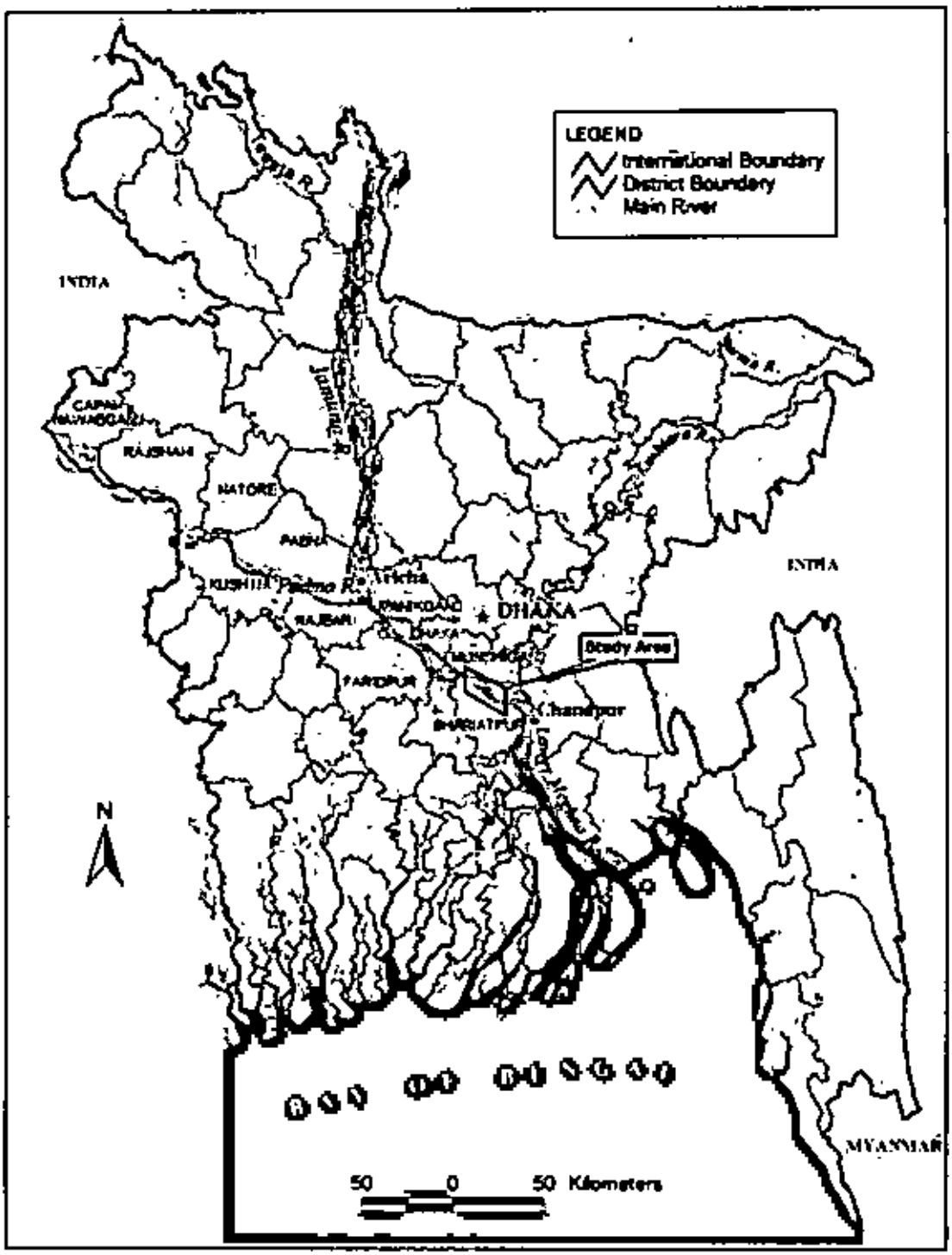


Figure 3.1: River System of Bangladesh showing the Study area.

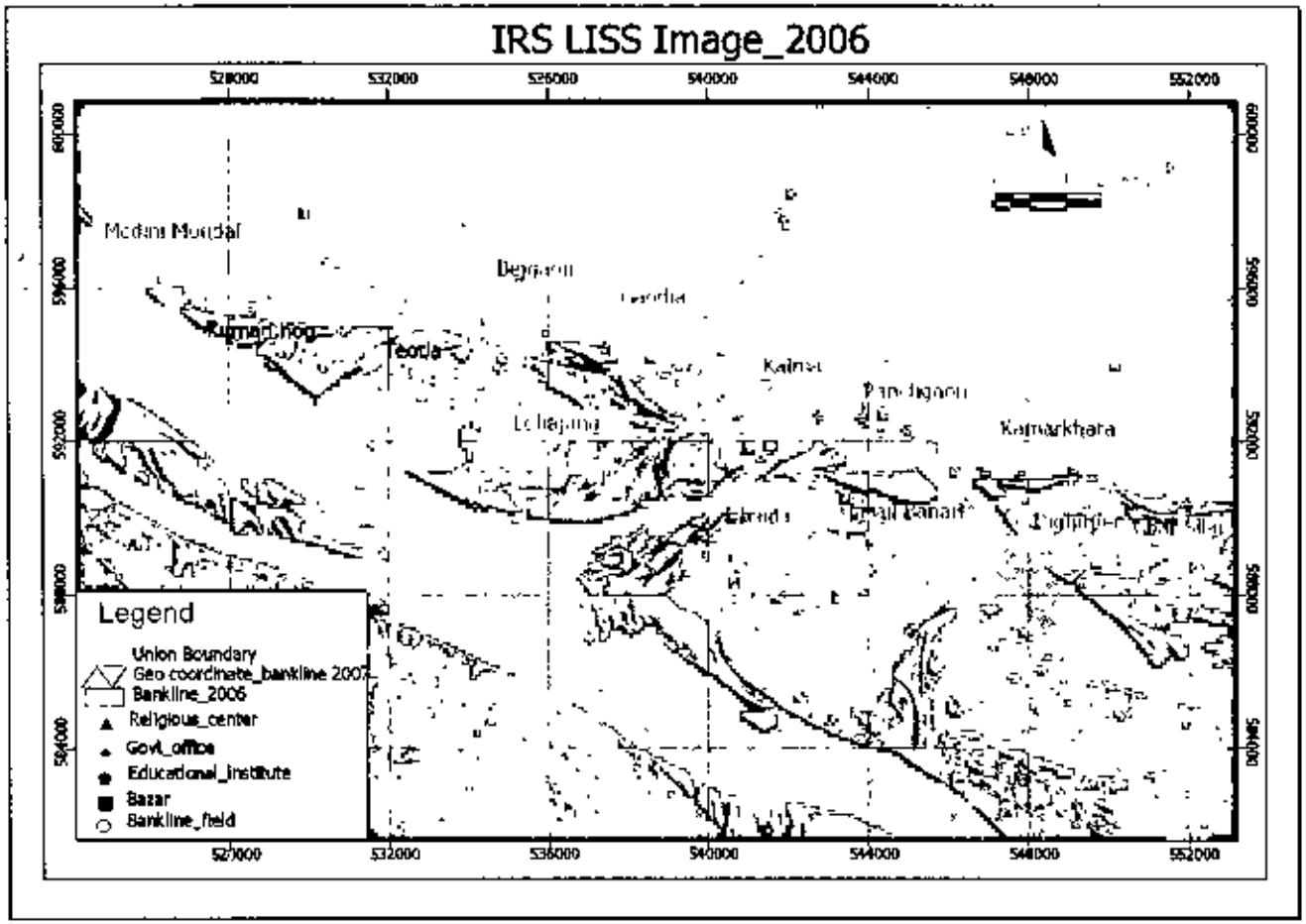


Figure 3.2: The study area along the left bank of the Padma River at Mawa- Dighirper reach.

Economic losses are calculated in terms of losses of land values under different uses and losses of property values (infrastructure, crops and livestock) while social losses are quantified in terms of the number of people displaced by riverbank erosion. Finally, the socio-economic impacts are assessed based on the survey data and reports.

In additional to this, informal discussions were conducted with officers/engineers of Bangladesh Water Development Board (BWDB), Center for Environmental and Geographic Information Services, the agricultural officers of the concern area, and some aged experienced people about the existing situation of the area.

3.3 Sampling Techniques and Design

Random sampling technique has been applied as sampling procedure. Households are considered as the sampling unit and each interviewed person of the household is the respondent. The households who are more or less affected also considered as the respondent. Almost 50 No. of sample was distributed randomly out of 4,800 affected households for all the villages of Mawa-Dighirper reach.

This study is based on both primary and secondary data. Primary data were used for socio-economic impact evaluation and secondary data were used for erosion analysis.

3.3.1 Primary Data Collection

A semi-structured questionnaire was prepared to collect the primary data. The questionnaire was prepared considering the objectives of the study, mainly to evaluate the socio-economic impacts of bank erosion. In this regard, selection of the interviews, affected people are given more emphasis. And the age of the interviewers were not less than 50 years, because the questionnaire was used to obtain information on the situation of the study area in the past.

Focus Group Discussion (FGD) is conducted to collect qualitative data and information regarding socio-economic impact of bank erosion. FGDs can be a powerful research tool which provides valuable spontaneous information in a short period of time and at relatively low cost (Khan et al., 1991).

A good size for a discussion group is between 8 to 10 participants per session for the study (Debus and Novelli; 1986). During this study, some focus group discussion consisted of only 6 participants who still provided valuable information. The chosen number of session is fifteen; so, around one session is conducted in each union because the study reach have thirteen affected unions.

Grain size is one of the prominent factor for river erosion, so it is necessary to know the grain size distribution for understanding the river erosion. In the present research sieve and hydrometer analysis are used for grain size distribution.

3.3.2 Secondary Data Collection

Secondary data and information that helps the socio-economic analysis were collected from the relevant organizations like BBS, USO, ULO.

Time series satellites images are used in studying the planform and bank erosion processes of the left bank of Padma River at Mawa- Dighirper reach (Table 3.1). Dry season satellite images are used for the analysis as cloud free optical images are available during this period.

Processed satellite images are used in this study as a good source of information. Satellite images are collected from Center for Environmental and Geographic Information Services (CEGIS). In this regard, Arc View 3.3 software is used. The number of the images is selected on the basis of availability of images.

Images available in CEGIS had been subset using ERDAS IMAGINE 8.5 software. Then all analysis and figure are prepared using Arc View 3.3 software. Geo-referenced images are used to delineate the bankline. Collected data such as location of educational institutions, health centers, hat-bazars (Commercial places), launch/ferry ghats, religious centers, Government offices etc. are identified by Global Positioning System (GPS) from field Surveys is processed by using Path Finder Software, and then projected in Bangladesh Transverse Mercator (BTM) projection. Table 3.1: shows images acquisition date, type, and resolution. All images acquisition dates are in dry seasons.

Table 3.1: List of images that are used in the analysis.

Year	Image acquisition date	Image type	Resolution
1973-1989	28 Jan, 1989	Landsat	80m×80m
1992-2002	08 Mar, 1992; 18 Nov, 1994; 18 Feb, 1996; 19 Jan, 2000; 1 Feb 2002.	Landsat	30m×30m
2003 and onward	19 Jan 2003; 11 Dec 2003; 8 Jan 2005; 10 Feb, 2006.	IRS LISS	24m×24m

3.4 Schematic Diagram of the Methodology

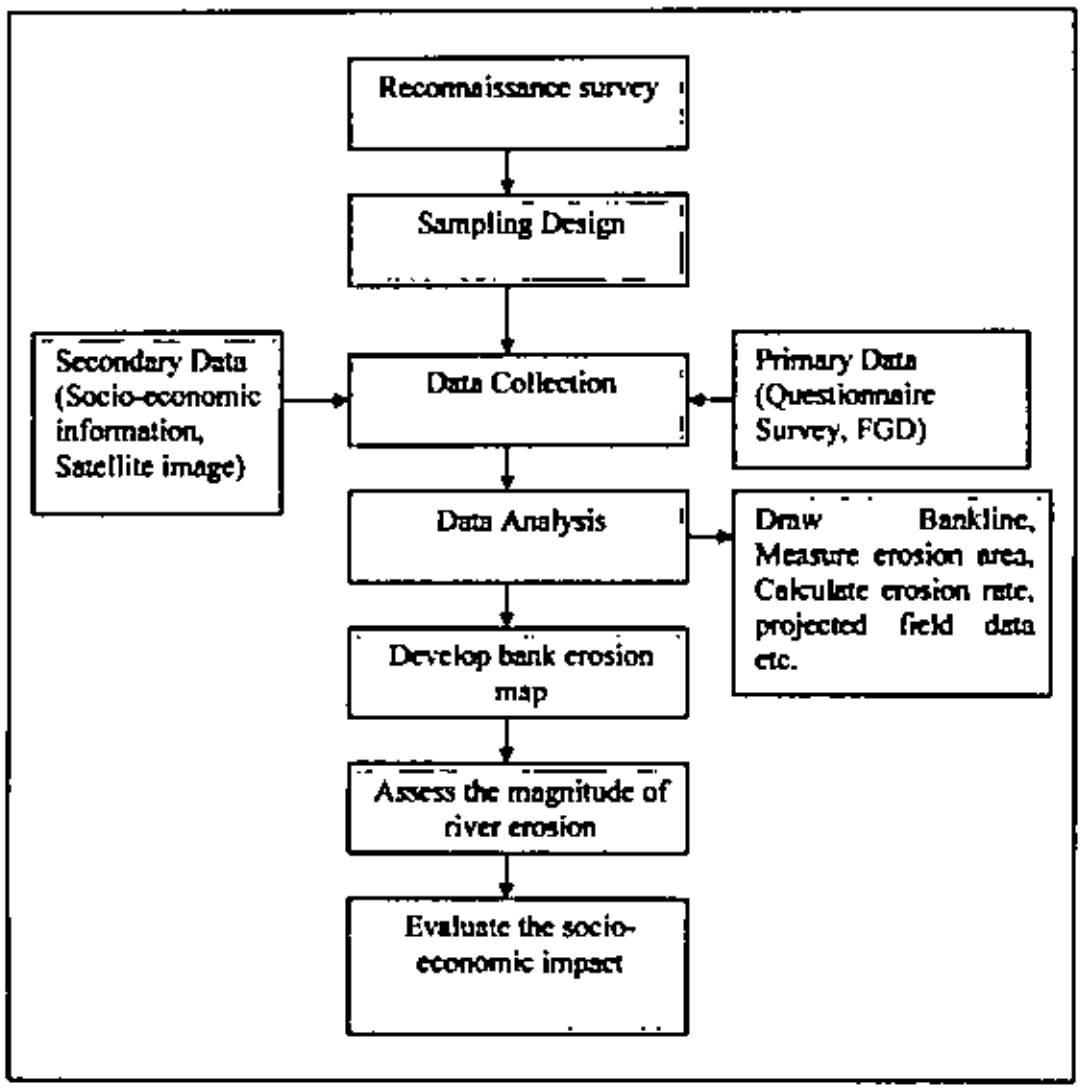


Figure 3.3: Schematic View of the Methodology.

CHAPTER FOUR

EROSION AND PLANFORM CHANGES

4.1 Planform Changes

The length of the study reach is about 30 km. The study reach is sub-divided into three parts named upstream, middle and downstream of the study reach. The length of the each part is around 10 km.

4.1.1 Changes during 1989 to 1991

The Satellite Imageries of 1989-92 indicate that the erosion is high in the downstream of the study reach including Dighirper, Kamarkhara, Hasail Banari and Char Shilai unions; low at the upstream of the study reach including Teotia, and Kumarbhog unions but Dhaida union is considerably affected (Figure 4.1). During this period, the total river bank (left) erosion of the study reach is 814 hectares (1 Hectare = 2.47 Acres = 100 Gunthas). The bank shifted in Dighirper is 1200 m, Kamarkhara is 650 m, Hasail Banari is 850 m, Char Shilai is 950 m, Teotia is 880 m, Dhaida is 50 m, and Kumarbhog is 500 m in 1989 to 1991 as shown in Figure 4.2 and Table 4.1. Figure 4.1 also shows a sand bar is developing opposite of the downstream reach.

Landset Image_1992

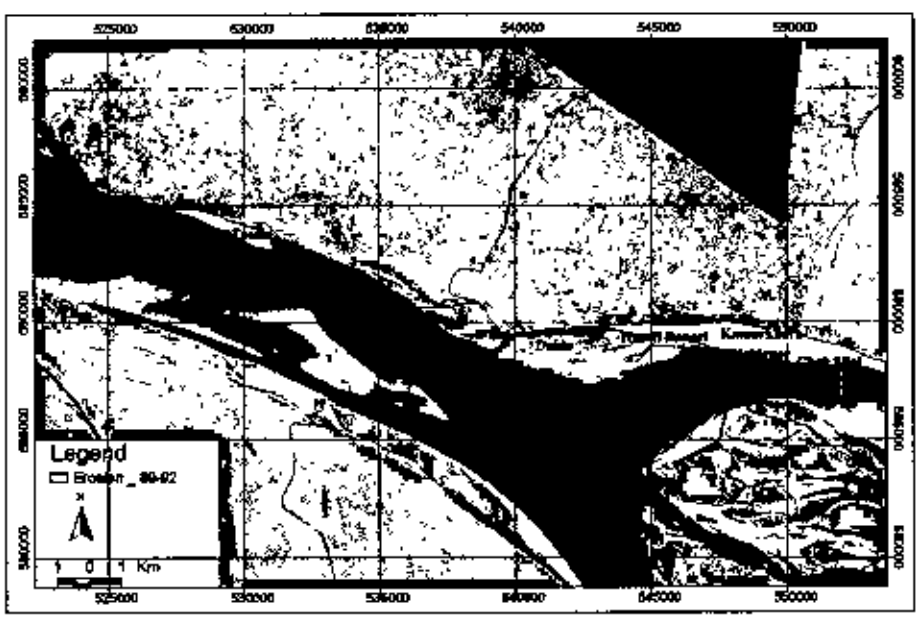


Figure 4.1: Erosion affected areas along the left bank of the Padma River at Mawa- Dighirper reach from 1989 to 1991.

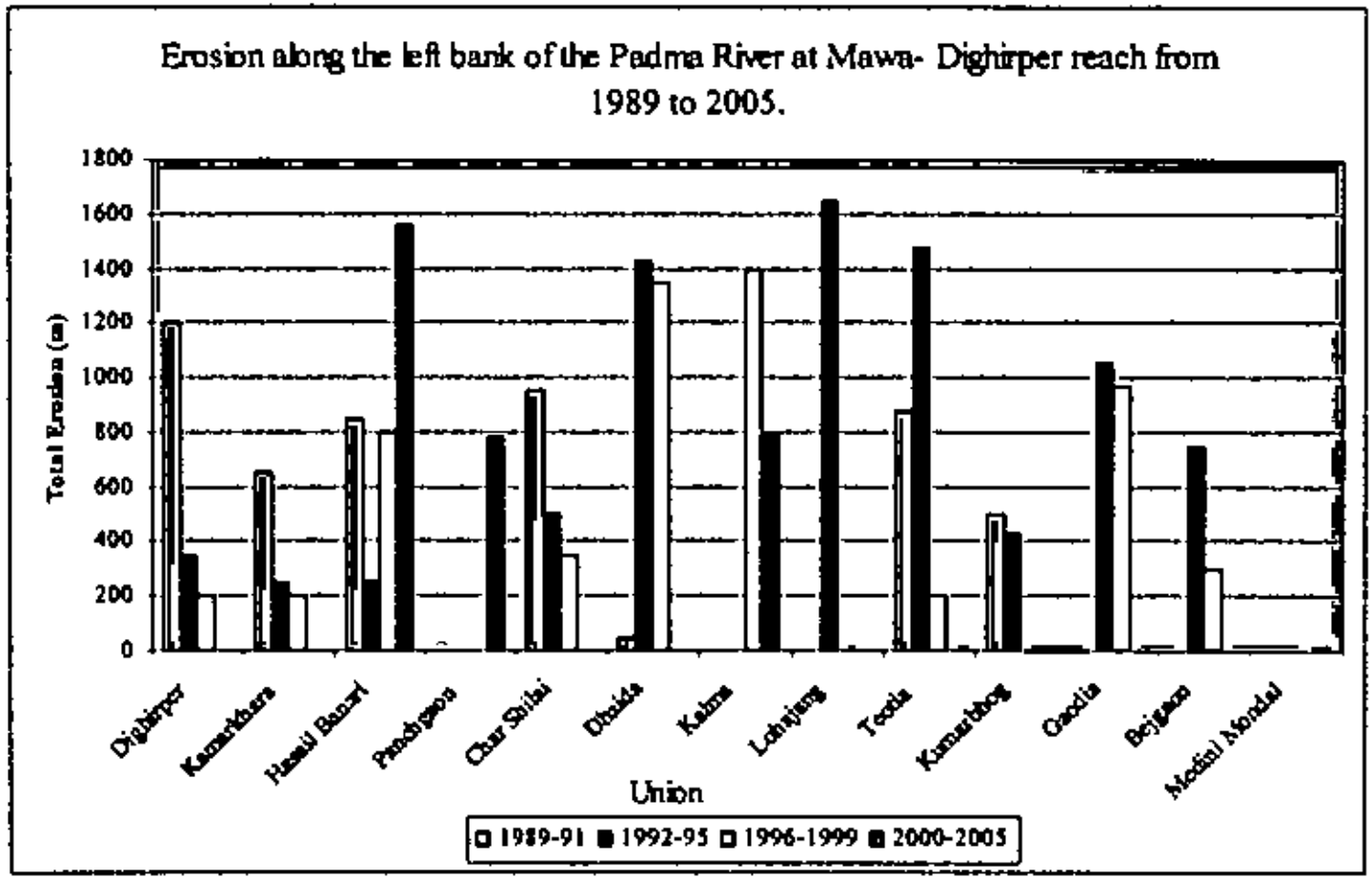


Figure 4.2: Erosion of left bank of the Padma River at Mawa- Dighirper reach from 1989 to 2005.

Table 4.1: Erosion along the left bank of the Padma River at Mawa- Dighirper reach from 1989 to 2005.

Year	Total Erosion (m)												
	Dighirper	Kamarkhara	Hasail Banari	Panchgaon	Char Shilal	Dhaida	Kalma	Lohajang	Teotia	Kumarbhog	Gaodia	Bejgaon	Medini Mondal
1989-91	1200	650	850	0	950	50	0	0	880	500	0	0	0
1992-95	350	250	250	0	500	1430	0	1650	1480	430	1060	750	0
1996-99	200	200	800	0	350	1350	1400	0	200	0	970	300	0
2000-05	0	0	1560	780	0	0	800	0	0	0	0	0	20

4.1.2 Changes during 1992 to 1995

In the total time frame of the present analysis (1989-2005); the bank erosion is massive and the entire study reach is significantly affected during 1992 to 1995. The Satellite Imageries of 1992-96 indicate that the major bank erosion occurred in the upstream and middle region of the study reach including Dhaida, Lohajang, Teotia, Kumarbhog, Gaodia, Bejgaon unions, while downstream of the study reach including Dighirper, Kamarkhara, Hasail Banari and Char Shilai unions are affected slightly (Figure 4.3). During this period, the total river bank (left) erosion of the study reach is 1900 hectares (1 hectare = 10,000 m^2).

The bank shifted in Dighirper is 350 m, Kamarkhara is 250 m, Hasail Banari is 250m, Char Shilai is 500 m, Dhaida is 1430 m, Lohajang is 1650 m, Teotia is 1480 m, Kumarbhog is 430 m, Gaodia is 1060 m, and Bejgaon is 750 m in 1992 to 1995 as shown in Figure 4.2 and Table 4.1. Figure 4.3 also shows a sand bar is developing opposite of the middle reach and another sand bar is developed opposite of the downstream reach.

Landset Image_1996

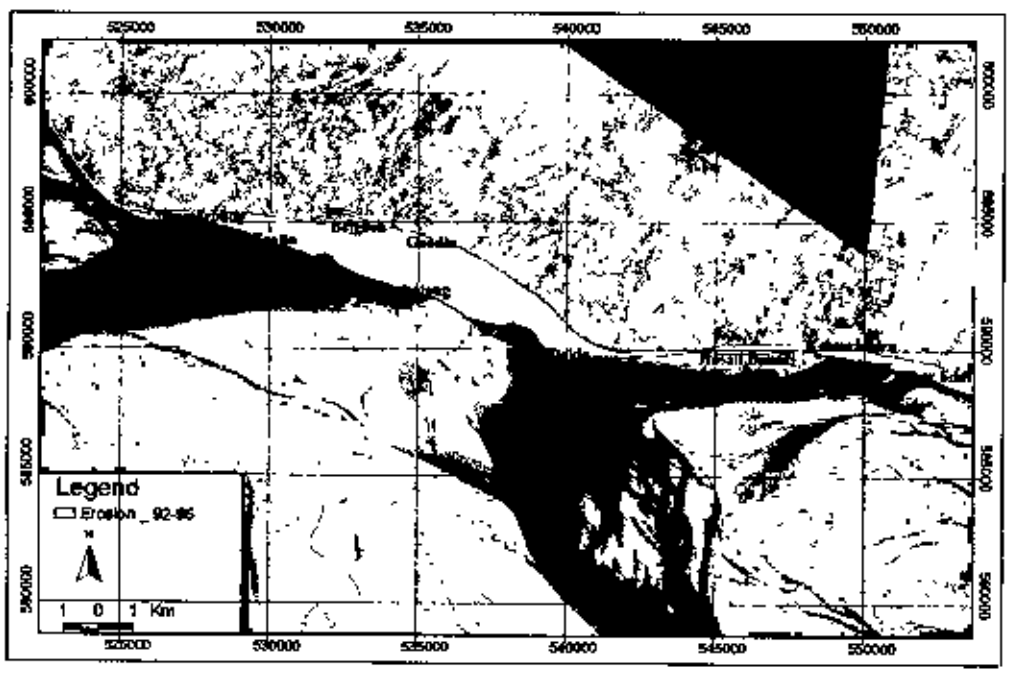


Figure 4.3: Erosion affected areas along the left bank of the Padma River at Mawa- Dighirper reach from 1992 to 1995.

4.1.3 Changes during 1996 to 1999

In this phase, considerable erosion took place at the middle of the study reach including Hasail Banari, Kalma, Dhaida and Gaodia unions. Downstream of the study reach including Dighirper, Kamarkhara and Char Shilai unions and upstream of the study reach including Teotia, Bejgaon are affected (Figure 4.4). During this period, the total riverbank (left) erosion of the study reach is 830 hectares. The bank is shifted in Dighirper is 200 m, Kamarkhara is 200 m, Hasail Banari is 800 m, Char Shilai is 350 m, Dhaida is 1350 m, Kalma is 1400 m, Teotia is 200 m, Gaodia is 970 m, and Bejgaon is 300 m in 1996 to 1999 as shown in Figure 4.2 and Table 4.1. Figure 4.4 also shows a sand bar is developed opposite of the middle reach and another sand bar is developing adjacent of the downstream reach.

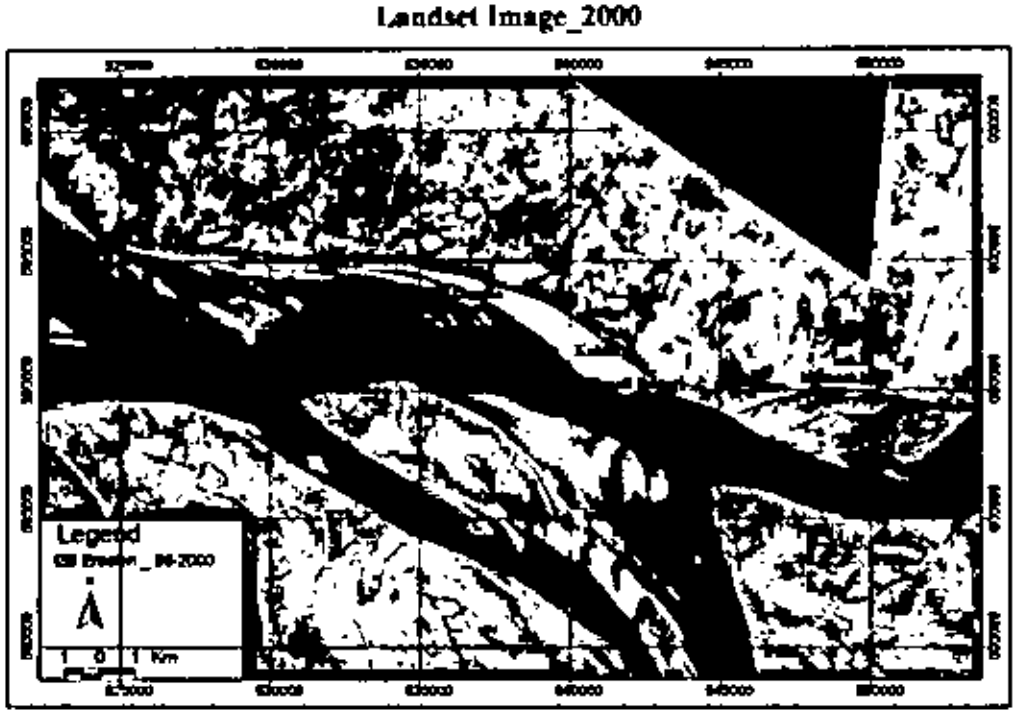


Figure 4.4: Erosion affected areas along the left bank of the Padma River at Mawa- Dighirper reach from 1996 to 1999.

4.1.4 Changes during 2000 to 2005

In this phase, erosion concentrates in Hasail Banari, Panchgaon and Kalma unions. The other parts of the bank of study reach are remaining same in previous period

(Figure 4.5). The Satellite Imagery of 2006 shows a curve in this reach that radius of curvature is around 4.1 km and stream centerline is 9.4 km.

During this period the total river bank (left) erosion of the study area is 467 hectares. The bank is shifted in Hasail Banari is 1560 m, Panchgaon is 780 m, Kalma is 800 m and relatively very small amount in Medini Mondal union is 20 m in 2000 to 2005 as shown in Figure 4.2 and Table 4.1. Figure 4.5 also shows many sand bars are developed opposite of the study reach and downstream of the study reach combined with the adjacent bar.

IRS LISS Image_2006

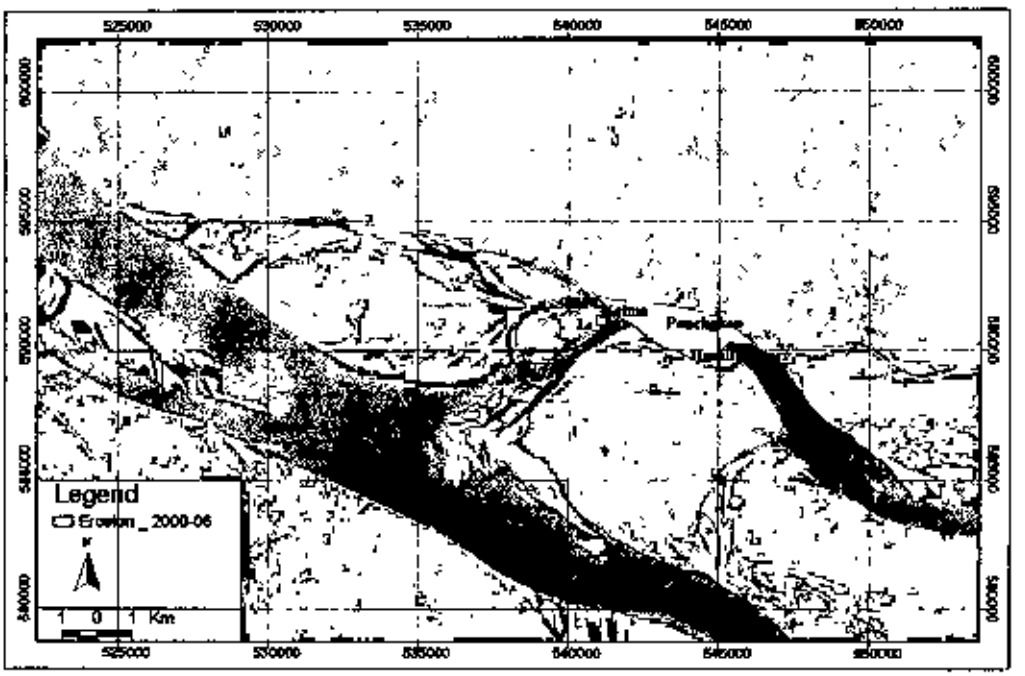


Figure 4.5: Erosion affected areas along the left bank of the Padma River at Mawa- Dighirper reach from 1999 to 2005.

4.1.5 Changes during 1989 to 2005

Tongibari, Lohajang and Munshiganj Sadar Thana are consists of 33 unions. Out of twelve unions in Tongihari Thana four unions are severely affected. Within the time spans of last 17 years, the areas of the study reach decreased by about 37.5 km^2 as shown in Figure 4.6.

Table 4.2 shows that the eroded land areas by riverbank erosion from 1989 to 2005 at Mawa – Dighirper reach. It is observed that total 814 hectares land is eroded from the year 1989 to 1991; 1900 hectares land is eroded from the year 1992 to 1995; 830 hectares land is eroded from the year 1995 to 1999 and 467 hectares land is eroded from the year 2000 to 2005.

Table 4.2: Erosion from 1989 to 2005 at Mawa – Dighirper reach.

Year	Eroded Land Area (ha)
1989-91	814
1992-95	1900
1996-1999	830
2000-05	467

IRS LISS Image_2006

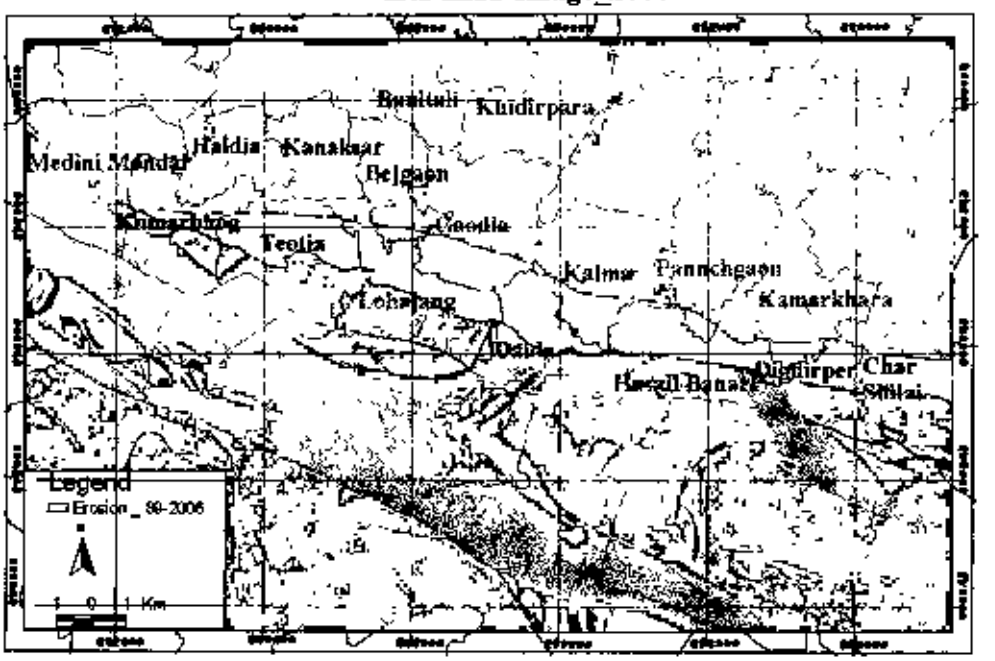


Figure 4.6: Erosion affected areas along the left bank of the Padma River at Mawa- Dighirper reach from 1989 to 2005.

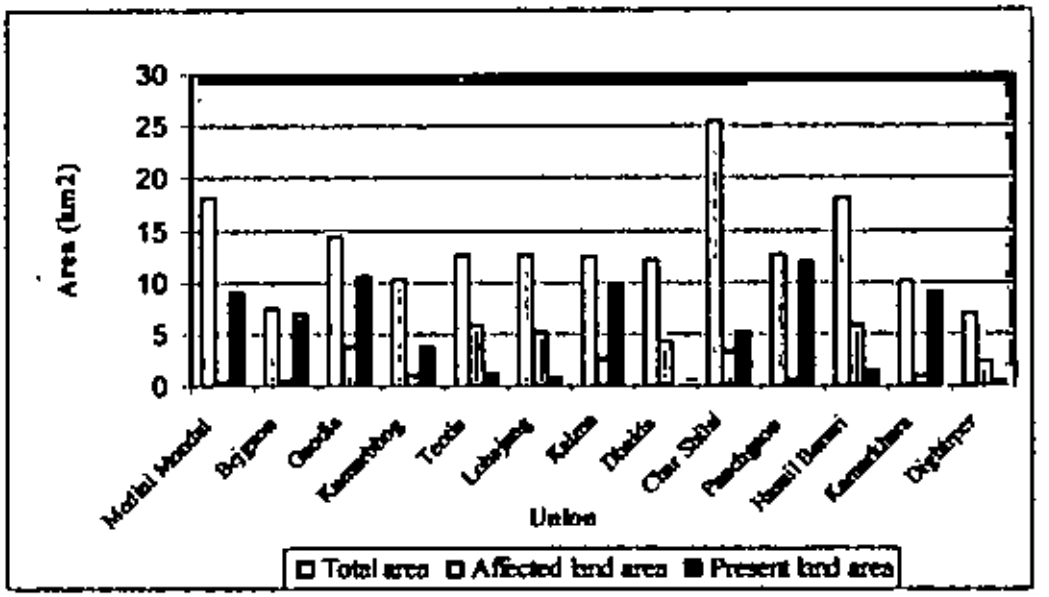


Figure 4.7: Comparison of the affected land area with the total area and present land area from 1989 to 2005 at Mawa - Dighirper Reach.

Figure 4.7 shows that Dighirper and Hasail Banari union in Tongibari Thana are almost disappearing due to last seventeen years bank erosion. Most of the part of Lohajang Thana is affected by river erosion. Figure 4.7 also shows Lohajang and Teotia unions are almost disappearing and Dhaida union is become extinct. Only Haldia, Kanaksar, Baultali, Khidirpara unions are not affected by river erosion as shown in Figure 4.6. Munshiganj Sadar Thana consists of nine unions and within the study reach only Char Shilai union is affected.

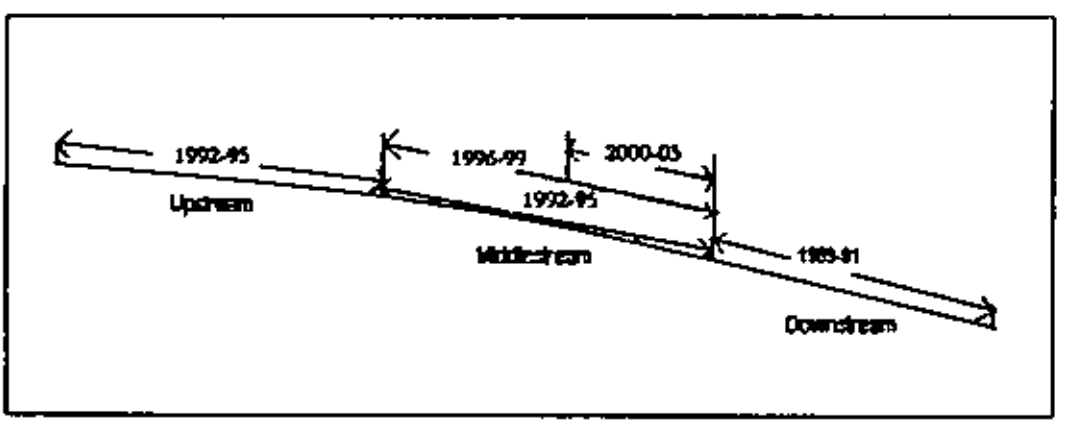


Figure 4.8: The overall changes from 1989 to 2005 at Mawa - Dighirper Reach.

The overall changes of the study reach during 1989 to 2005 are summarized in Figure 4.8. It can be seen that during 1989-91, the erosion is high in the downstream of the study reach; during 1992-1995, the major bank erosion occurred in the upstream and middle region of the study reach; during 1996-99, considerable erosion took place at the middle of the study reach and during 2000-05, erosion concentrates in Hasail Banari, Panchgaon and Kalma unions of the middle reach.

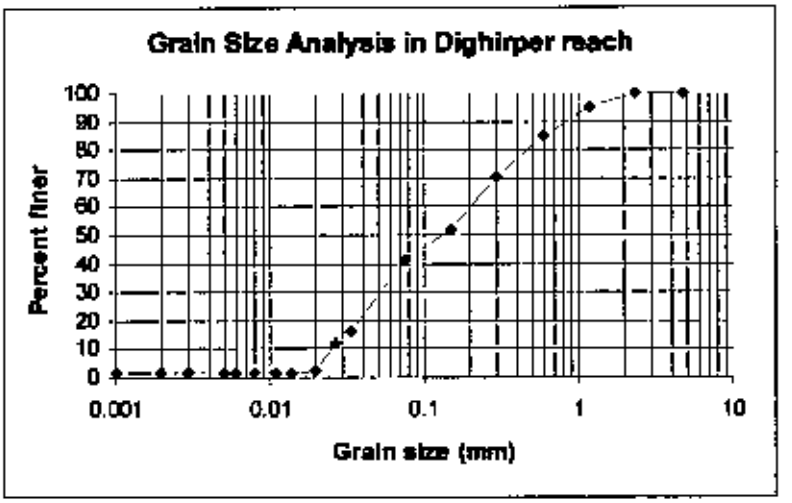
4.2 Grain Size Analysis

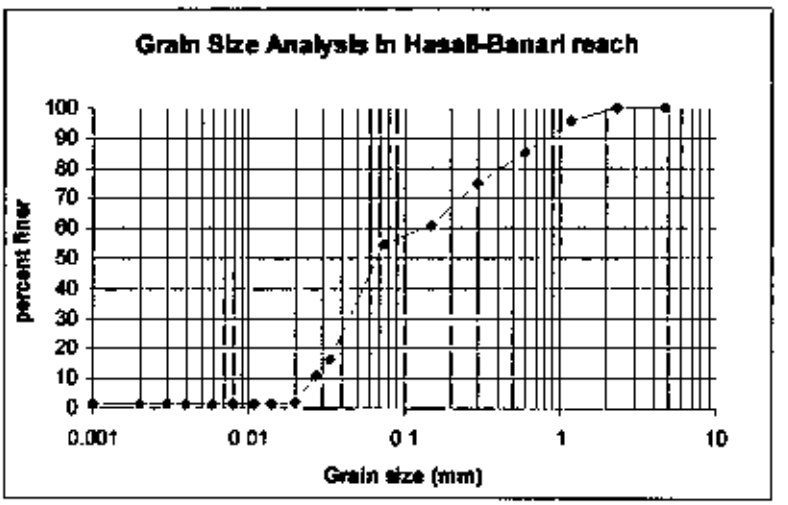
The distribution of different grain sizes affects the properties of soil. Soil properties also affect the river erosion. The grain size analysis is performed to determine the percentage of different grain sizes contain within a soil. The sieve analysis is performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

Table 4.3: Location and date of sample collection and value of d_{50}.

Date	Location	Value of d_{50}
13.03.08	Dighirper	0.14
	Hasail-Banari	0.074
	Lohajang	0.19

Figure 4.9 shows the grain size distributions of the study reach. The grain size distribution d_{50} of Dighirper reach is 0.14 mm, Hasail-Banari reach is 0.074 mm and Lohajang reach is 0.19 mm as shown in Table 4.3. So the d_{50} of the study reach is around 0.13 mm which represent the soil of the reach is non-cohesive silty sand and that type of soil is vulnerable to erosion. In the previous studies the value of d_{50} of the bed materials of Padma River varies between 0.09 mm (FAP 24, 1996) to 0.12 mm (Sarker, 2003), which very close to the d_{50} found in the study reach though the present study shows only the distribution of the bank materials.





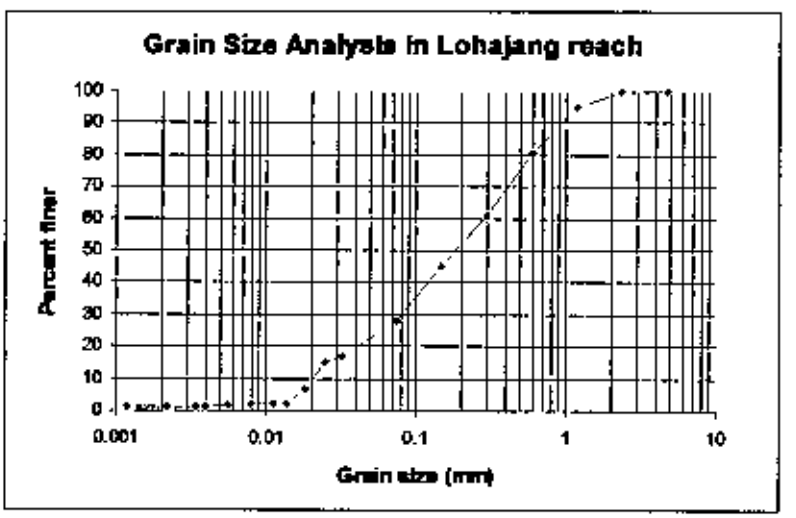


Figure 4.9: Grain size distributions in the study reach.

4.3 Characteristics of the Study Reach (Hasail Banari-Panchgaon-Kalma bend)

4.3.1 Lateral migration rates and Channel curvature

Radius of channel Curvature to channel width plays an important role in determining the rate of channel migration (Hickin and Nanson, 1975). The relation of Er to R/B is shown in Figure 4.10. During the initial development of the active channel bend, the rate of lateral migration is at first slow. However, as R/B approaches a value of about 2.0, the migration rate increases to a maximum and then rapidly decline for values of R/B greater or less then 2.

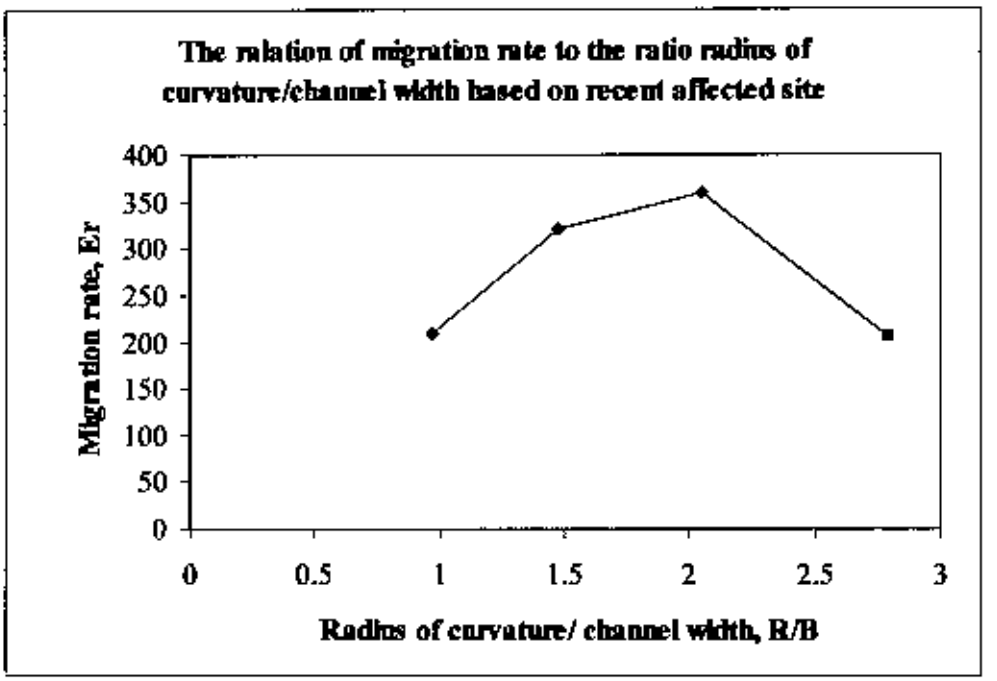


Figure 4.10: The relation between migration rate with the ratio of radius of curvature to channel width.

Hickin and Nanson (1975) showed that the rate of channel migration in Beatton River (Canada) reaches a maximum value where the radius of channel curvature to stream width approximately equal to 3. The rate of channel migration rapidly decline for bends with values of channel curvature to stream width greater or less than 3. Such an empirical finding more than 30 years ago remark still valid. This indicates the truths of natural features are more or less same over the longer time scale.

4.3.2 Planform: sine-generated curve

It appears to be generally accepted nowadays that the centerline of a natural regular meandering stream is best idealized by the sine-generated curve (Leopold and Langbein, 1966). As is well known, this periodic (along the general flow direction) curve is determined by the following equation.

$$\phi = \phi_0 \sin\left(\frac{2\pi s}{m}\right) \quad or, \frac{1}{R} = \frac{1}{R_0}\cos\left(\frac{2\pi s}{m}\right) \quad where, R_0 = \frac{m}{2\pi\phi_0} \qquad (4.1)$$

Where,

ϕ = deflection angle at any point along the meander wavelength,
ϕ_0 = maximum deflection angle with the valley direction,
s = curvilinear distance along the wave length,
m = length of one wave along the curvilinear meanderpath,
R_0 = minimum values of radius of curvature
R = radius of curvature

A fundamental property of sine generated curve exhibit a continuous variation of centerline curvature, |1/R| along the streamwise, s direction. At, apexes where s = 0, m/2, m ... etc., then |1/R| = 0; at crossover, where s = 3m/4, m/4 ... etc., then 1/R is maximum.

The sinuosity (k) of a meandering channel can be expressed as (Leopold and Langbein, 1966):

$$k = \frac{4.84}{4.84 - \phi_0^2} \qquad (4.2)$$

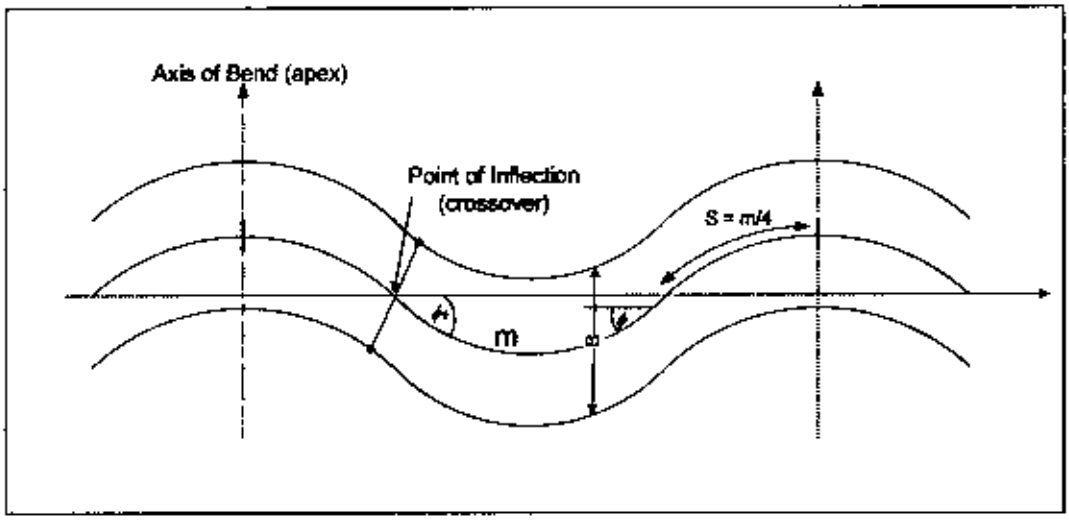


Figure 4.11: Sketch of a meander bend representing sine-generated curve.

Table 4.4 shows the active mender bend at the maximum deflection angle with the valley direction (ϕ_0) is increased from the year 2002 to 2005; while the length of one wave along the curvilinear meander path (m) is increased.

Table 4.4: Characteristics of active bend.

Year	m (km)	ϕ_0 (°)	Ro (km)
2002	3.502	11°	2.9
2003	5.992	15°	3.7
2004	8.968	20°	4.1
2005	9.672	21°	4.2

a) IRS LISS Image_2003

b) IRS LISS Image_2004

c) IRS LISS Image_2005

d) IRS LISS Image_2006

Figure 4.12: Imageries of active reach from 2003 to 2006.

Using the value of ϕ_0 in Table 4.4 the sinuosity of the bend can be estimate using the equation 4.2 as below,

In the year of 2002:

$$k = \frac{4.84}{4.84 - (11°)^2}$$

$$k = \frac{4.84}{4.84 - (0.19)^2}$$

Or, $k = \frac{4.84}{4.84 - 0.036}$

$\therefore k = 1.01$

Similarly,

In 2003, $k = 1.01$

In 2004, $k = 1.03$

In 2005, $k = 1.03$

Therefore, the sinuosity of the bend with time is increasing.

4.4 Estimating Rates of Channel Migration

The relations established for the recent affected site provide a basis for predicting migration rates for the whole study reach. The rate of maximum bank erosion can be expressed by the regression equation (Hickin and Nanson, 1975):

$$Er = E_0(R_0/B)^n \quad \text{.....(4.3)}$$

Here Ro is the radius of curvature (km), B is channel width (km), E_0= Co-efficient of bank erosion

Er= Migration rate (m/yr) and n is regression exponent.

Table 4.5 shows when the Channel width is decreased from the year 2002 to 2005 because sand bar is developed opposite of the recent active reach; while the radius of curvature is increased. The migration rate is increased from the year 2002 to 2004; but in 2005 the rate is decreased.

Table 4.5: Parameters of the Padma River at Mawa - Dighirper Reach of recent affected site in 2002 to 2005.

Year	Channel width, B (km)	Radius of curvature, R_0 (km)	R_0/B	Migration rate, Er (m/year)
2002	3	2.9	0.97	210
2003	2.5	3.7	1.48	320
2004	2	4.1	2.05	360
2005	1.5	4.2	2.8	205

The relation of Er to R_0/B in Figure 4.10 can be described by the above equation (4.3):

In 2002, from equation (4.3),

$$Er_{2002} = E_0(R_0/B)^n$$

$$\text{or, } 210 = E_0(0.97)^n$$

$$\text{or, } E_0 = 210/(0.97)^n \quad \text{.....(4.4)}$$

In 2003, from equation (4.3),

$$Er_{2003} = E_0(R_0/B)^n$$

$$\text{or, } 320 = E_0(1.48)^n$$

$$\text{or, } E_0 = 320/(1.48)^n \quad \text{.....(4.5)}$$

In 2004, from equation (4.3),

$$Er_{2004} = E_0(R_0/B)^n$$

$$\text{or, } 360 = E_0(2.05)^n$$

$$\text{or, } E_0 = 360/(2.05)^n \quad \text{.....(4.6)}$$

In 2005, from equation (4.3),

$$Er_{2005} = E_0(R_0/B)^n$$

$$\text{or, } 205 = E_0(2.8)^n$$

$$\text{or, } E_0 = 205/(2.8)^n \quad \text{.....(4.7)}$$

From equation 4.4 and 4.5,

$$E_o - E_0 = 320/(1.48)^n - 210/(0.97)^n$$

$$\text{or, } 210/(0.97)^n = 320/(1.48)^n$$

$$\text{or, } (1.48/0.97)^n = (320/210)$$

$$\text{or, } (1.52)^n = 1.52$$

$$\text{or, } n = 1$$

Putting the value of n in equation (4.4),

$$E_0 = 210/(0.97)^1$$

$$\text{or, } E_0 = 210/0.97$$

$$\text{or, } E_0 = 216$$

From equation 4.5 and 4.6,

$$E_0 - E_0 = 360/(2.05)^n - 320/(1.48)^n$$

$$\text{or, } 320/(1.48)^n = 360/(2.05)^n$$

$$\text{or, } (2.05/1.48)^n = (360/320)$$

$$\text{or, } (1.39)^n = 1.125$$

$$\text{or, } n = 0.36$$

Putting the value of n in equation (4.5),

$$E_0 = 320/(1.48)^{0.36}$$

$$\text{or, } E_0 = 320/1.15$$

$$\text{or, } E_0 = 278$$

From equation 4.6 and 4.7,

$$E_o - E_0 = 205/(2.8)^n - 360/(2.05)^n$$

$$\text{or, } 205/(2.8)^n = 360/(2.05)^n$$

$$\text{or, } (2.05/2.8)^n = (360/205)$$

$$\text{or, } (0.73)^n = 1.76$$

$$\text{or, } n = -1.8$$

Putting the value of n in equation (4.7),

$$E_0 = 205/(2.8)^{-1.8}$$
$$or, E_0 = 205/0.167$$
$$or, E_0 = 1316$$

A predictive model in Figure 4.10 for migration rates on the recent active bend can be built on the forms:

$$Er = 229\,(R_0/B)^{0.71} \quad \text{.....}(0.97 < R_0/B < 2.05) \text{.....} (4.8)$$
$$Er = 1353/(R_0/B)^{1.77} \quad \text{.....}(2.05 < R_0/B < 2.8) \text{.....} (4.9)$$

$$\text{So, } Er_{2003} = 229(0.97)^{0.71} = 229 \times 0.98 = 224$$
$$Er_{2004} = 229(1.48)^{0.71} = 229 \times 1.32 = 301$$
$$Er_{2005} = 229(2.05)^{0.71} = 229 \times 1.66 = 381$$

Where, Co-efficient of bank erosion, E_0 = 229, and Co-efficient of bank erosion, n = 0.71.

$$\text{And } Er_{2006} = 1280/(2.8)^{1.77} = 1280/6.19 = 207$$

Where, Co-efficient of bank erosion, E_0 = 1280, and Co-efficient of bank erosion, n = 1.77.

Table 4.6 shows the observed and predicted migration rate of the active bend from 2003 to 2005. The percent error of the observed and predicted migration rate in 2003 is -43; 2004 is -20; 2005 is 46. So the model involves an average error of -5 percent for predicts of lateral migration.

Table 4.6: The observed and predicted migration rate from 2003 to 2005.

Year	Observed migration rate (m/yr)	Predicted migration rate (m/yr)	Error	Percentage error, (error/observed value)×100
2003	320	224	-196	-43
2004	360	301	-59	-20
2005	205	381	176	46

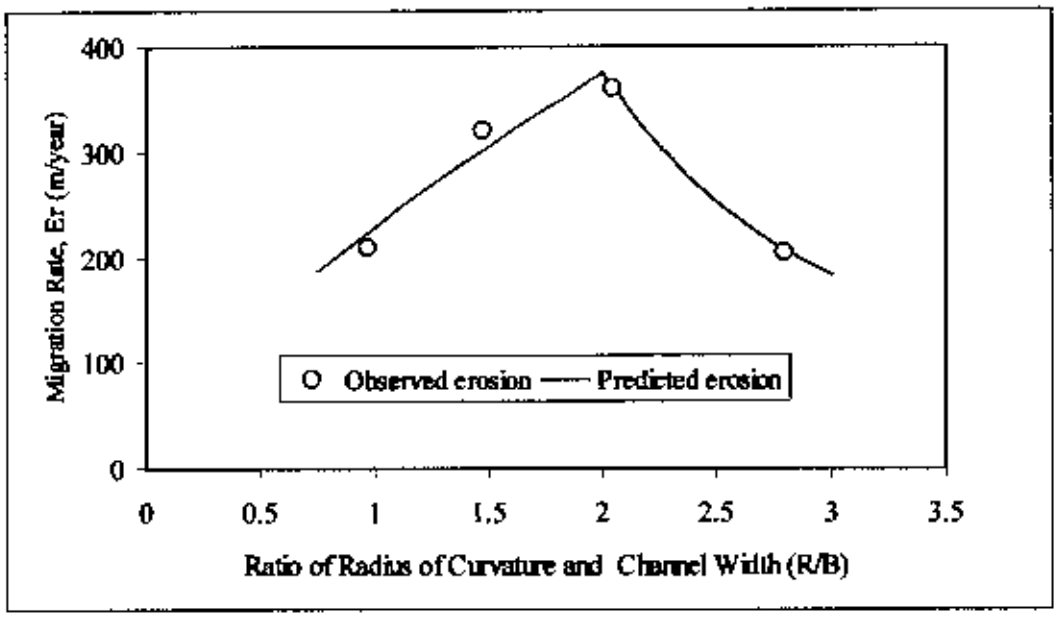


Figure 4.13: The relation between predicted and observed migration with the ratio of radius of curvature to channel width.

Figure 4.13 shows the relation between predicted and observed migration with the ratio of radius of curvature to channel width.

The average rate of lateral migration of the recent active bend is 274 m from 2003 to 2005. If the current rate will continued, in 2015 the active bend will be migrated more than two km from the recent position. So Hasail Banari union will disappear; Kanlma and Panchgaon unions will severely affect.

Table 4.7 shows, CEGIS predict the erosion of the recent active bend as 50 percent probability is 240 m in 2007. But at the same time the actual erosion of the recent active bend is 500 m. However the present study average prediction in 2006 is 207 m which is very close to the actual erosion in 2006.

Table 4.7: Comparison of CEGIS prediction, study average prediction and actual erosion at recent active bend.

CEGIS prediction, 2007			Study Average prediction, 2006	Actual erosion, 2006
70% probability	50% probability	30% probability		
160 m	240 m	330 m	207 m	275 m

CHAPTER FIVE

SOCIO-ECONOMIC IMPACT

5.1 Population Displacement and Resettlement

In the study, the fact of population displacement is examined within the context of the occurrence of riverbank erosion. Erosion of land is a serious concern for affected people because land is the main source of income and the principle indicator of socioeconomic well being. The loss of their principle resource base (i.e., land) restricts the permanent sources of income of displaces; consequently the level of poverty of the affected people is speeded up and they eventually become economically inarginal.

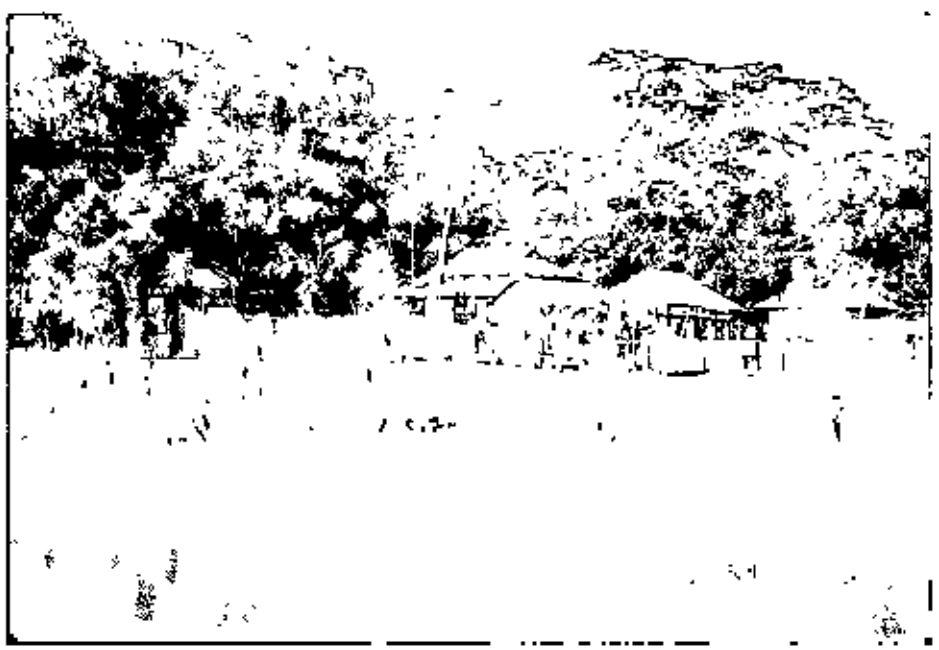


Figure 5.1: Homestead at the bank of the study reach.

Erosion activity is a repetitive phenomenon in the study area. From the field survey of the study area, a total 78 percent of the households reported having been displaced by erosion at least once; out of them, 80 percent reported multiple displacements (Table 5.1). Mesbah (1991) noted that in Kazirpur, Sirajganj district 59 percent and in Chilmari, Kurigram district 52 percent of the households reported having been displaced by erosion at least once.

Kassem Bapari respondent of Hasail-Banari union had moved five times in last 17 years (1989 - 2005). He said ***"Padma snatched away whole of my life; my wealth, esteem, family and also my youth"***.

Table 5.1: Distribution of displaced households in the study area, 1989-2005.

Displacement frequency	Percentage (%) of household
Never Displaced	22
Once	16
Twice	30
Three Times	26
Four Times	4
Over Four Times	2

Affected people are forced to move to other places; Table 5.2 shows that the most of the affected household (88 percent) migrated and resettled at the adjacent villages and adjacent union. This indicated the tendency and attitude of displaces to remain close to their homestead, relatives and surroundings. The people who lost land are resettled at the newly accreted chars. Some of the affected households (rich) migrated to the capital city Dhaka and Narayanganj district.

Table 5.2: Place of resettle of households in the study area, 1989-2005.

Place of resettle	Percentage of household
Own village	8
Own Union	58
Nearby union	22
Reemerged Char land	8
Nearby Thana or district	2
Capital City	2

5.2 Loss of Land

The people (i.e., small, middle and big farmers) of the study area become landless due to riverbank erosion. The total amount of land lost due to erosion is 3754 hectares. The respondents were intent to mention the amount of land they lost prior to the year of 1990, 1995 and 1999. CEGIS (2007) estimated that bank erosion along the Padma River during the period 1973-2007 was 5560 hectares.

Jamal Shekh villagers of Dighirper union say ***"I lost every thing within a day by river bank erosion; now I am empty"***.

The value of lost land in the study area is extremely difficult to estimate. Based on the information provided by the respondents the value of land varies from ten thousand to thirty thousand per Guntha (1 Guntha = 100 m^2). So the estimated land value of total lost land is about 750 crore taka.

The present land value in the riverbank area is very low due to threat of river erosion. On the other hand, the land values increase rapidly from one kilometer of the riverbank due to scarcity of land.

5.3 Income and Occupation

There is no doubt that the river bank erosion does have a devastating economic impact on the affected people. The river bank erosion increases the percentage of landless people and also contributes to the surplus of agricultural labor force. It has resulted in many farmers losing their cultivable land. The affected people do not have any alternative option other than to change their occupation. It has also resulted loss of business of people in river side bazar. In dry season, sand bars (chars) are formed and creates barriers on water way. Historically, the people of Kachikata, Naopara unions of Shariatpur district are dependent for their business activities on Dighirper and Hasail bazar. On the other hand, these bazars are set up on the need of fulfillment of the customer of Kachikata, Naopara union. Due to char formed all the businessmen of Dighirper and Hasail bazar are affected and lost their business.

Rashid Halder, the former Businessman of Dighirper Bazar said ***"River bank erosion destroys my business that survives my life"***.

The affected bazars in the study area are shown in Table 5.3. Most of the bazars are displaced more than two times. These increase installation charge and finally create negative impact on the income of the affected people. CEGIS (2007) predicted in the year 2007, Hasail bazaar and Garurgaon bazar are vulnerable to erosion.

Table 5.3: Names of affected Bazars and nos. of displacement in the study area, 1989-2005.

Name of affected Bazar	Nos. of displacement
Dighirper Bazar	Four Times
Hasail Bazar	Four Times
Garurgaon Bazar	Vulnerable
Kalma Bazar	Vulnerable
Dahuri Bazar	Three Times
Gwor dhor Bazar	Two Times
Kanakshar Bazar	Two Times
Haldia Bazar	Two Times
Lohajang	Vulnerable

Figure 5.2: Dighirper Bazar affected several times and also vulnerable in recent time.

The current study shows that about 70 percent of the respondents' income level has become less due to change in their working environment. The higher income group has slightly affected due to their occupational pattern and the most of them are migrate to others countries for earning. Table 5.4 shows the income distribution per month of respondent in the study area.

Table 5.4: Income distribution per month of the households in the study area.

Income Groups (Taka)	Previous distribution (Percentage of households)	Current distribution (Percentage of households)
Less than 1,000	46	70
1,001-2,000	38	18
2,001-3,000	12	8
3,001 - over	4	4

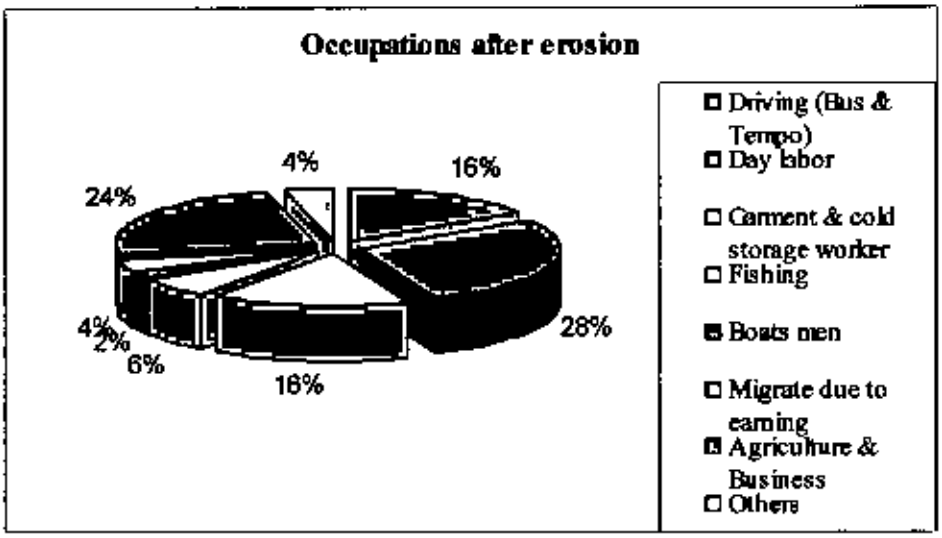


Figure 5.3: Occupation changed among the affected people.

Figure 5.3 shows that about 16% of the affected are adopted tampo and bus driving as their main source of livelihood; 28% became day labor; 16% started to work in the garments and cold storage factories with very low wages; 6 % engaged in fishing and 2% started to work in the engine boats in the river specially in the rainy season; about 4 % of the affected are migrate to foreign countries for earning; 24 % remained in their paternal (previous) occupation (agriculture & business); 4% were engaged in the others occupations.

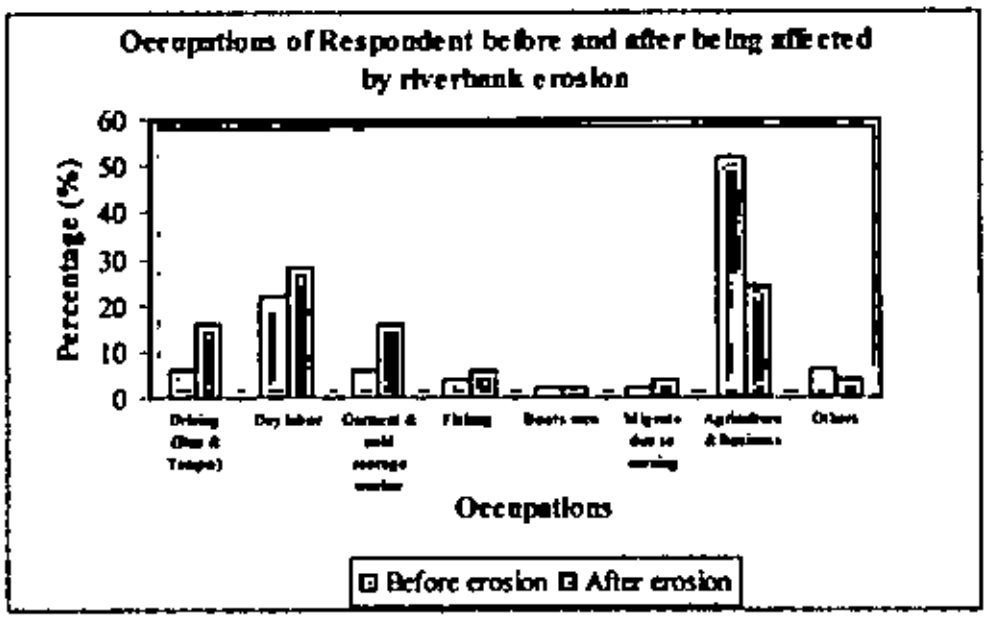


Figure 5.4: Occupation of respondents before and after being affected by riverbank erosion.

Figure 5.4 shows that after erosion the highest proportion (28%) of the respondents are engaged in daily laboring while it was only 22 percent before they were displaced by riverbank erosion. The dramatic change has occurred in the agricultural and business sectors. The majority (52%) were employed in agricultural and business activity before they were displaced by riverbank erosion whereas currently only 24% of the respondents have some kind of agricultural and business income.

5.4 Education

The education system of the study area is severely affected by the erosion. Many primary school and high school are affected by erosion. Most of the School going children gave up their studies forever due to school shift. About 66 percent of the respondent reported that the educational facilities were deteriorated as shown in Table 5.5.

Table 5.5: Changes in Educational facilities of the study area.

Improve	No change	Deteriorate	No response
24%	6%	66%	4%

"*I have dropout my study due to school shift by river bank erosion*" says Babul ex-student of Milara Primary School of the study area.

Table 5.6 shows that most of the high schools in the study area are affected and the Dighirper A.C Institution and Haldia High School is displaced more than one time. CEGIS (2007) predicted in the year 2007, two educational institutions are vulnerable to erosion.

Table 5.6: Names of affected Schools and nos. of displacement in the study area, 1989-2005.

Name of affected Bazar	Nos. of displacement
Dighirper A.C Institution	Two Times
R. N High School	Vulnerable
Hasail Banari High School	One time
Kalma L. K. high School	Vulnerable
Hairadhia High School	One Time
Brammon Gao High School	One Time
Haldia High School	Two Times

The bank erosion of the river Padma severely affected religious centers like Mosques, Mondir etc. Many historical Mosques and Mondir are eroded during last 17 years by the bank erosion.

5.5 Health and Sanitation

The present study shows that the percentage of tube-well and sanitary latrine has increased due to hygienic awareness of governmental and NGOs intervention. However, due to repeated erosion more than 36 percent of the households still have no access to a tube-well and are forced to draw water from the river or ponds and the sanitation situation is the worst in the area. About 18 percent of the households have no access to a sanitary latrine as shown in Figure 5.5.

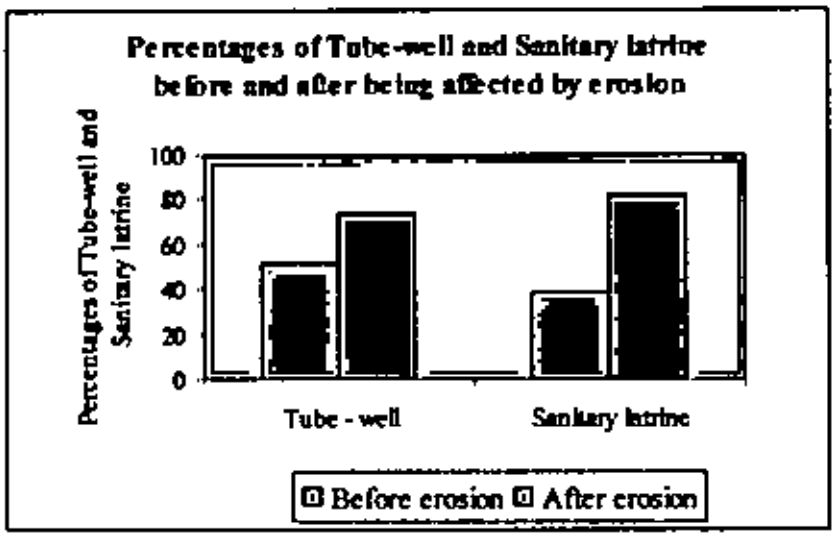


Figure 5.5: Percentages of Tube-well and Sanitary latrine before and after being affected by riverbank erosion.

The present study shows the enlarged percentages of tube-well and sanitary latrine improves the health condition of household of the study area. But about 42 percent of the respondents mention a severe deterioration of their health condition as shown in Table 5.7.

Table 5.7: Changes in Health condition of household of the study area.

Improve	No change	Deteriorate	No response
34%	22%	42%	2%

5.6 Increased Unusual Incident

River bank erosion begins at the start on of the rainy season; land-losing family has to migrate one place to another. But at this time road transportation is very much difficult for the inundation of roads. So people use Trawler/boat for transporation of their domestic resources. In this time, many people lose their belongings by sinking of trawler/boat in the huge current by river flow. The limitation of road transportation makes their life vulnerable.

Figure 5.6: People shifting their houses by boat.

The river side people have a tendency to make soil-hearth for cooking in the winter season. For this purpose, they want to collect suitable soil at the bank side of the river which is eroded and has a further tendency to erosion in any time and especially women/girl are injured or died by the type of land slide. At the time of erosion, life has been risk due to massive erosion but post erosion period life is also danger due to lack of awareness.

CHAPTER SIX

CONCLUSION

The river bank erosion of the study reach severely affected the population and households; agriculture, income and occupation, education and religious activities, health and sanitation activities. River bank erosion is one of the main causes of shifting rich to middle class, middle class to poor and poor to landless.

- About 70 percent of the respondents' income level has become less due to change in their working environment. After displacement 28% became day labor, about 16% of the affected are adopted tampo and bus driving, 16% started to work in the garments and cold storage factories with very low wages.

- A total of 78 percent of the households reported having been displaced by erosion at least once; out of them, 80 pereent household reported multiple displacements. Eighty eight percent affected household migrated and resettled at the adjacent villages and union. The affected people have a tendency and attitude to remain close to their homestead, relatives and surroundings.

- Seven hundred and fifly crore taka at land value have been lost due to erosion. Hasail Banari, Kalma and Panchgaon unions will be fully affected due to erosion if the recent rate continues. So agriculture, communication, income, occupation of the households of mentioned unions severely affected.

- Most of the School going children gave up their studies forever due to school shift. Most of the high schools in the study area are affected and the Dighirper A.C Institution and Haldia High School is displaced more than one time. About 66 percent of the respondent reported that the educational facilities were deteriorated.

- Due to repeated erosion more than 36 percent of the households still have no access to a tube-well and are forced to draw water from the river or ponds and

the sanitation situation is the worst in the area. About 18 percent of the households have no access to a sanitary latrine

- The satellite imageries of 1989 to 2006 indicate that, the left bank of the Padma River at Mawa- Dighirper reach is severely affected by erosion. During the time period of 1989-91, the erosion is high in the downstream of the study reach. From 1992 to 1995, major bank erosion is occurred in the upstream and middle of the study reach, but downstream of the study reach are also affected. In 1996-99 phase, considerable erosion took place at the middle of the study reach. But during the period of 2000 to 2006 erosion concentrates in small portion of the middle reach of the study area.

- In the active mender bend the sinuosity is 1.02. From the predictive model for migration rate based on the recent affected site, the Co-efficient of bank erosion can be estimated as 229 and the exponent as 0.71 for positive trend and the Co-efficient of bank erosion can be estimated as 1280 and the exponent as 1.77 for positive trend. The model involves an average error of -5 percent for predicts of lateral migration.

- Lohajang, Teotia, Dighirper and Hasail Banari union are almost disappearing and Dhaida union become extinct due to bank erosion of the study reach. The time spans of last 17 years the concerned area of the study reach decreased by about 40 km^2.

- Any loss of land by a household is devastating. However, each year due to severe bank erosion people not only lose their agricultural lands and houses but also become displaced. Thus the socioeconomic consequences of the study area are far reaching and often enormous. The local people think construction of bank protection is the best solution to prevent river erosion.

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Appendix: A

Institute of Water and Flood Management (IWFM)
Bangladesh University of Engineering and Technology (BUET)

BUET

The Title of the Thesis: "Erosion of left bank of the Padma river at Mawa- Dighirper reach and its socio-economic impact"
(Questionnaire for thesis purpose only)

SURVEY FOR SOCIO-ECONOMIC IMPACT

Sample no.....
Date.....

Name: **Age:** **Occupation:**

Address: **Educational Qualification:**

A. Homestead Related Information:

1. What kinds of your homestead?
   a) Small village homestead
   b) Scattered homestead
   c) Linear homestead

2. Mention the year you replace from last 30 year.

3. Where you replace your homestead?
   a) On the embankment
   b) Char area
   c) Nearest town
   d) Capital of the country

4.Mention the location before and after erosion.

Before	After	Length

5. Mention the name of villages which are fully eroded in your Union.

Name of Union	Name of Villages	Year

6.Which villages are now at risk by erosion in your Union?

Name of Union	Name of Villages	Present Year

7. What reason you decide to settle at present location due to last displacement?

8. Where your relatives are resettled due to erosion?
   a) Same village
   b) Different villages at same Union
   c) Other Union
   d) Other Thana/ Upazila

9.Mention the different types of home in you village.

B. Agricultural Land Related Information:

1.Mention the types & quantity of land of your village before erosion.

Land type	Quantity (%)
Agricultural land Non Agricultural Homestead	

2.Mention the types & quantity of land of your village after erosion.

Land type	Quantity (%)
Agricultural land Non Agricultural Homestead	

3. Mention the length of erosion from river bank in your village and mention the year.

Name of Village	Year	Length (meter)

C. Migration Related Information:

1. Mention the no. of family in your villages before erosion.
2. Mention the no. of replaced family in your villages due to erosion.
3. Mention the population change pattern (increase/decrease) in percentage in your villages due to erosion?

D. Destruction Related Information:

1.Name of Village:

Description	Before erosion Nos.	After erosion Nos.
Homestead		
Big tree		
Pond & Beel		
Primary school		
High School		
Madrasha		
Mosque		
Bazar		
Shop		

E. Occupation Related Information:

1.What your occupation before erosion?

2. What your present occupation?

3. If you are agricultural labor, what are you doing now?

4. What kinds of crops are cultivated before erosion in your agricultural land?

5. What kinds of crops are cultivated at present in your agricultural land?

6. If you change your occupation, mention your income source.

7. Mention your yearly income before erosion.

8. Mention your present yearly income.

9.Mention the types of occupation in percentage in your village.

Types of Occupation	Percentage
Farmer	
Agricultural –labor	
Day labor	
Service	
Business	
Others	

10. Mention the monthly income status in percentage in you village.

	Percentage
Less than 1,000	
1,001-2,000	
2,001-3,000	
3,001 - over	

F. Education Related Information:

1. Percentage of literacy rate before erosion.
2. Percentage of present literacy rate.
3. Mention the problems due to replacement of school.
4. Mention the no. of children/ student to stop their study due to erosion.

G. Health Related Information:

1.Mention the no. of health centers before erosion.

2.Mention the no. of health centers after erosion.

3. Mention the no. of tube wells are destroyed due to erosion.

4. Mention the drinking water problems you facing at present.

5. Are you received any kinds of help?

6. What kinds of help you received different organization due to erosion?

Types of help	Name of Organization

Appendix: B

Figure B1: Some Newspaper clips which describes the vulnerability of bank erosion in the study reaches.

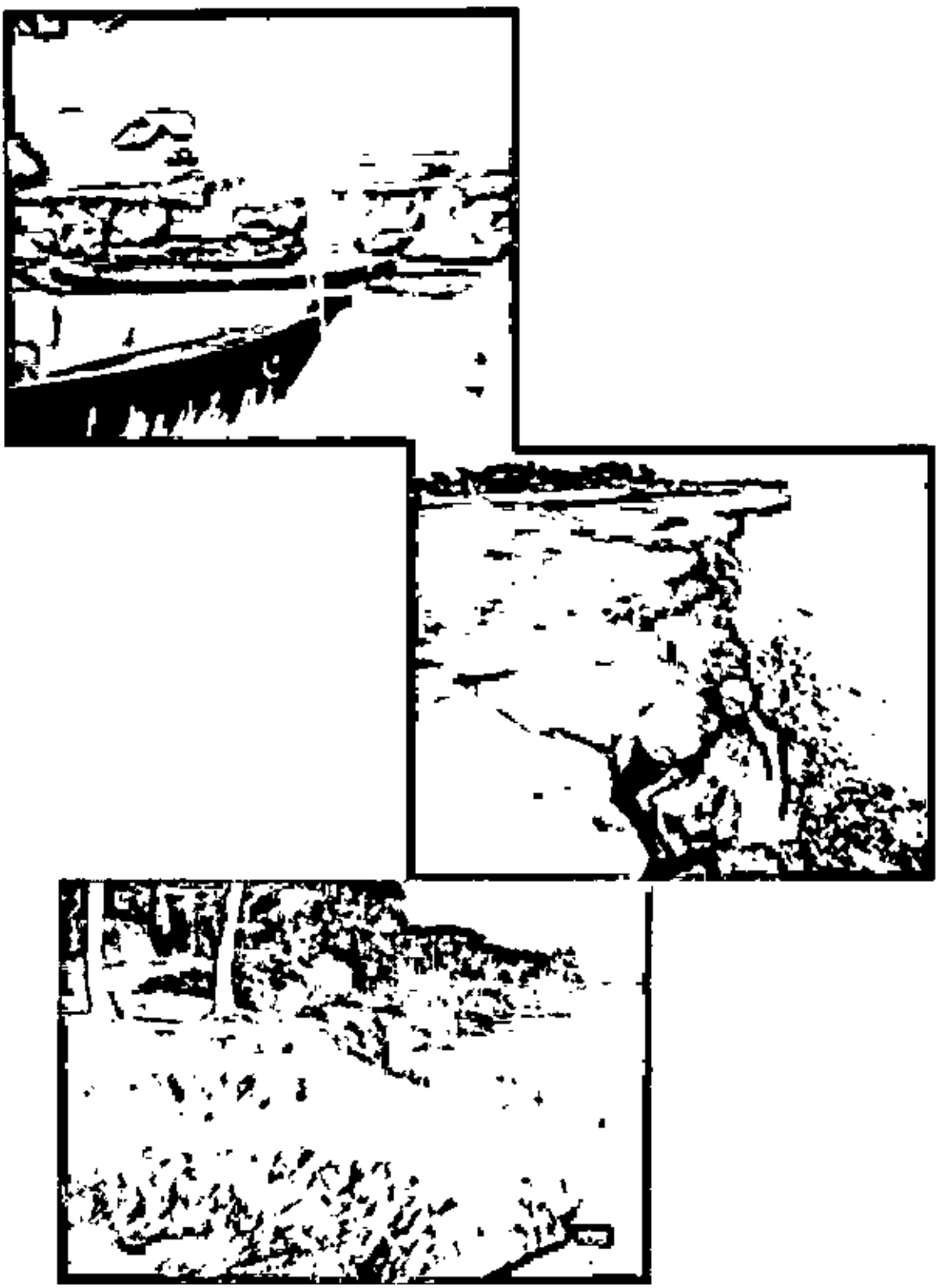

Figure B2: Loss of land in the Study reach.

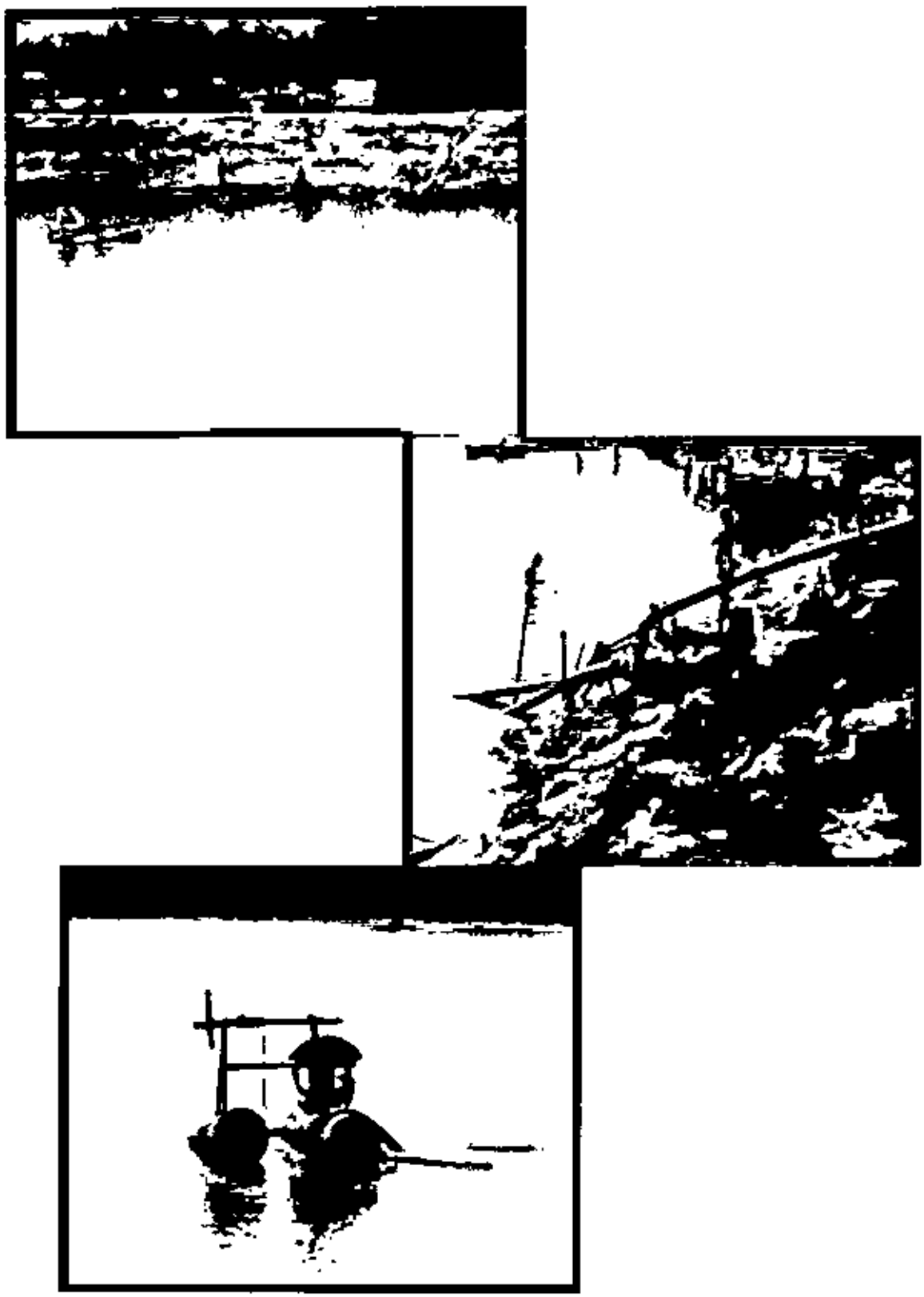

Figure B3: Soil is collected from river for land filling by dredging in dry season.

Figure B4: New Char formed reverse of the bank of Hasail-Banari and Dighirper reach.

Figure B5: Livelihood in Char land at the adjacent study reach.

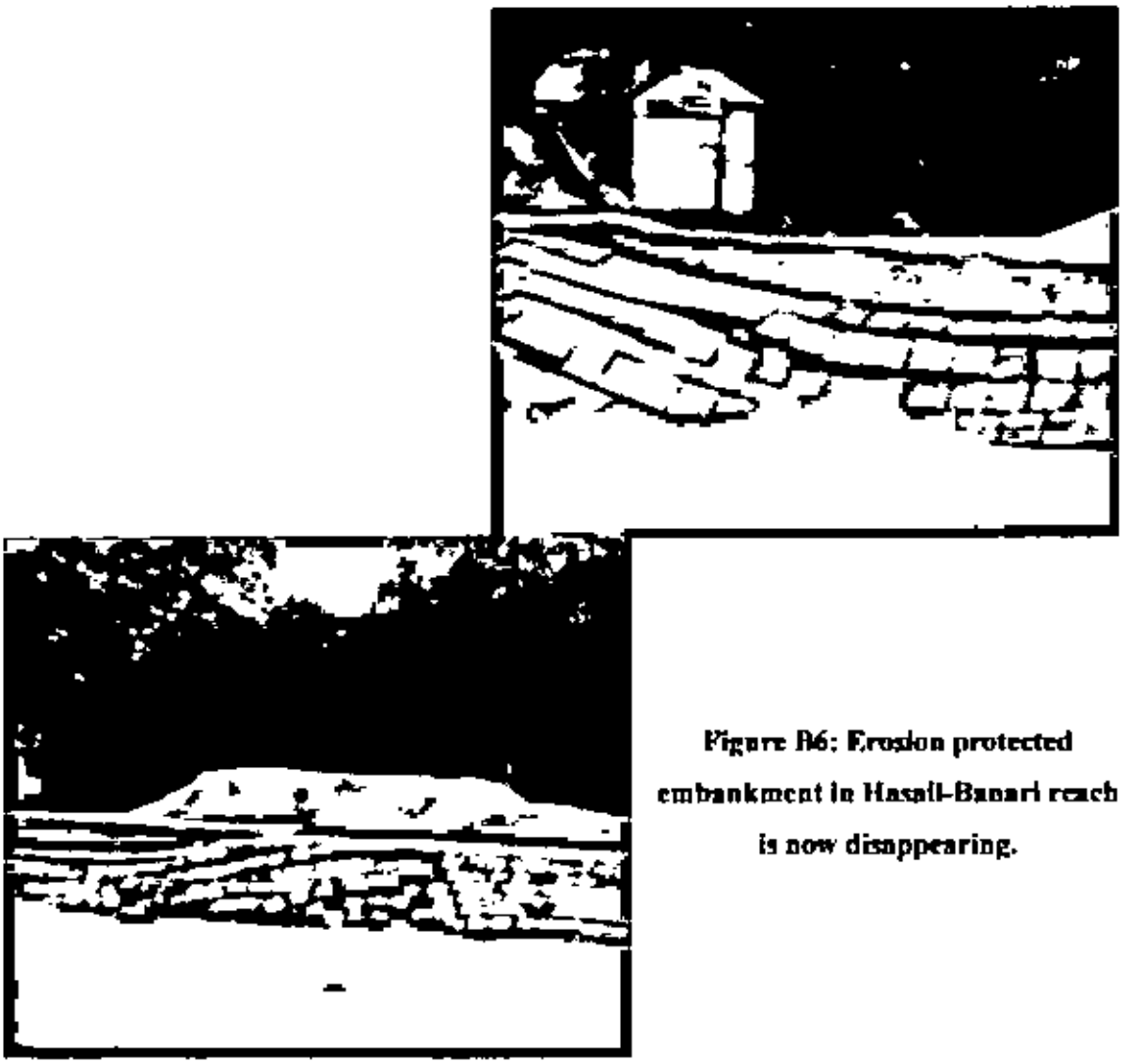

Figure B6: Erosion protected embankment in Hasail-Banari reach is now disappearing.

Figure B7: Vegetation cover reduce the rate of Erosion.

Figure B8: Technology of agriculture in Char land at the adjacent study reach.

Figure B9: Architectural viewed building (Barrister Nazmul Huda's building adjacent Padma river at upstream of Lohajang reach) is possible if bank protection measures is active.

Figure B10: People shifting their houses by boat.

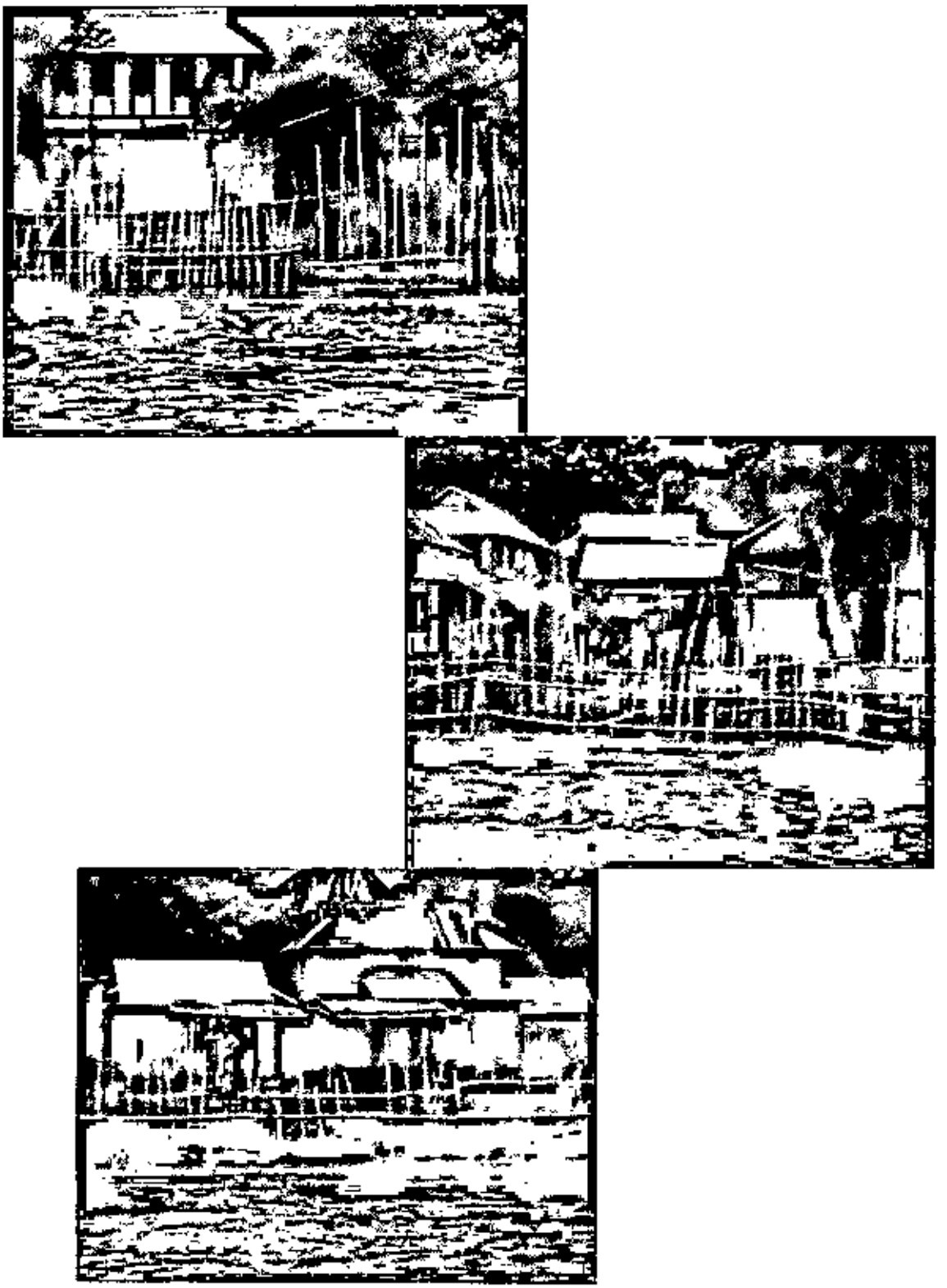

Figure B11: Rich people protect their house from bank erosion by bamboo fence.

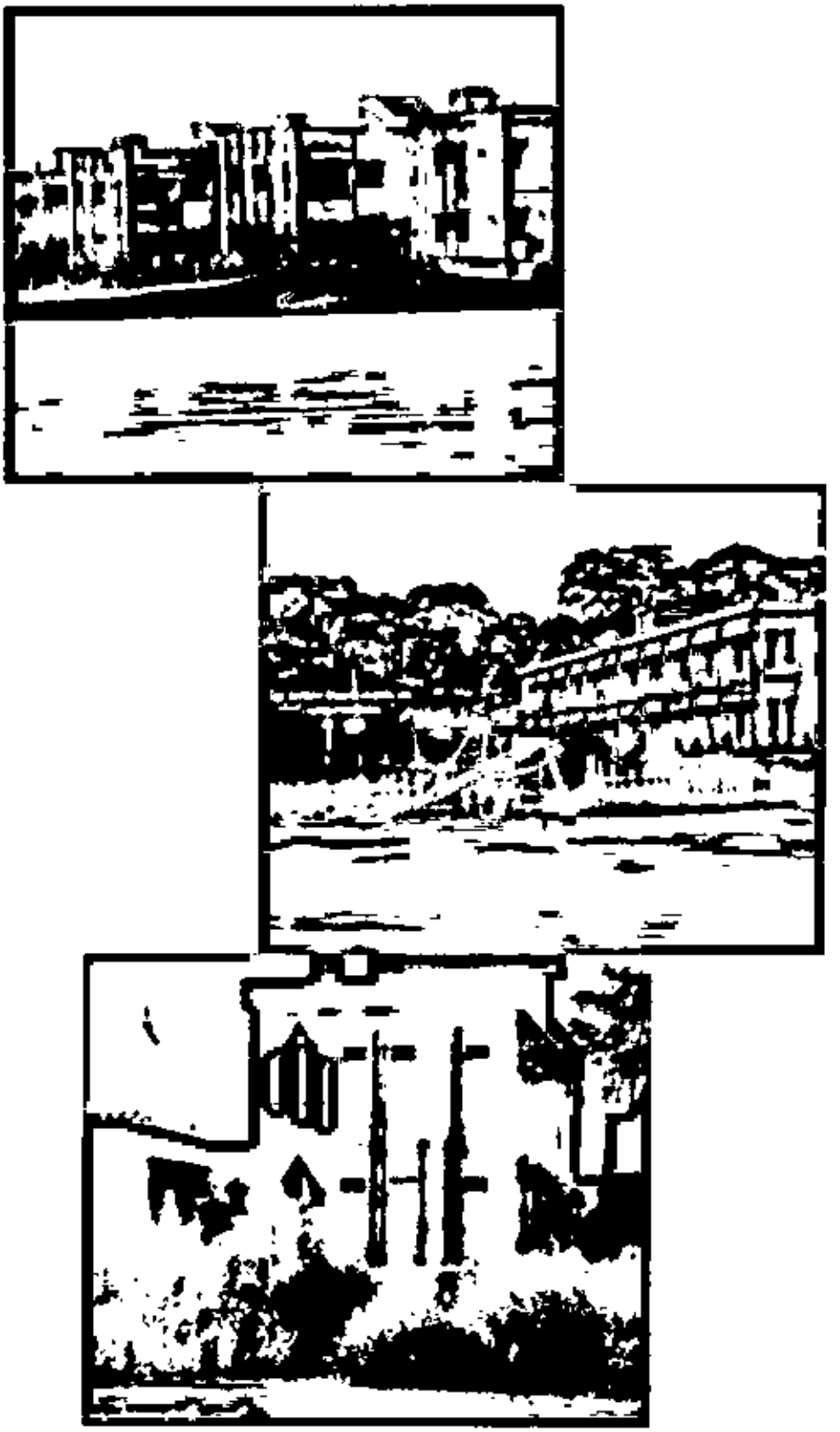

Figure B12: Government office and structures are vulnerable.

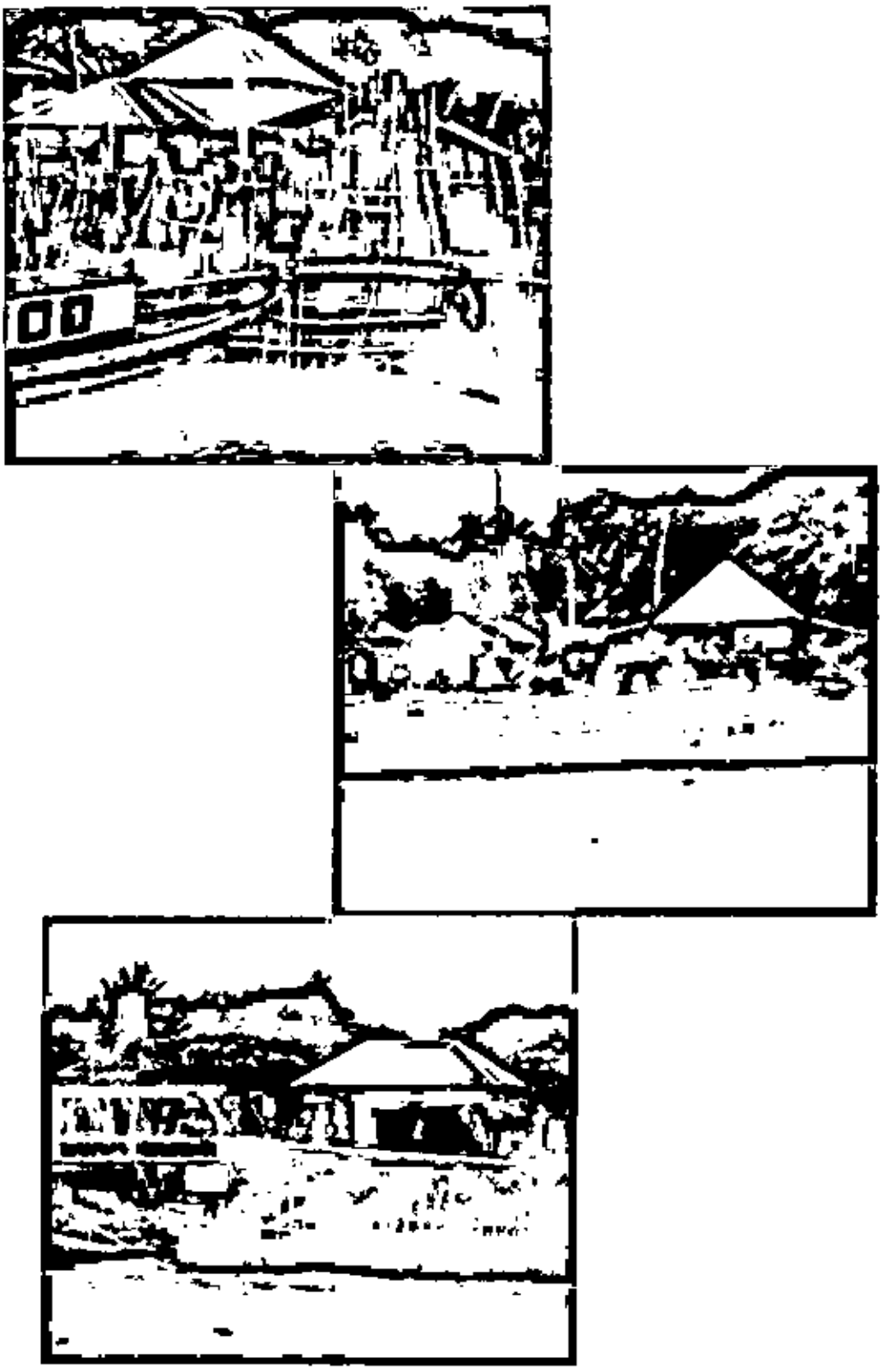

Figure B13: Commercial places are vulnerable.

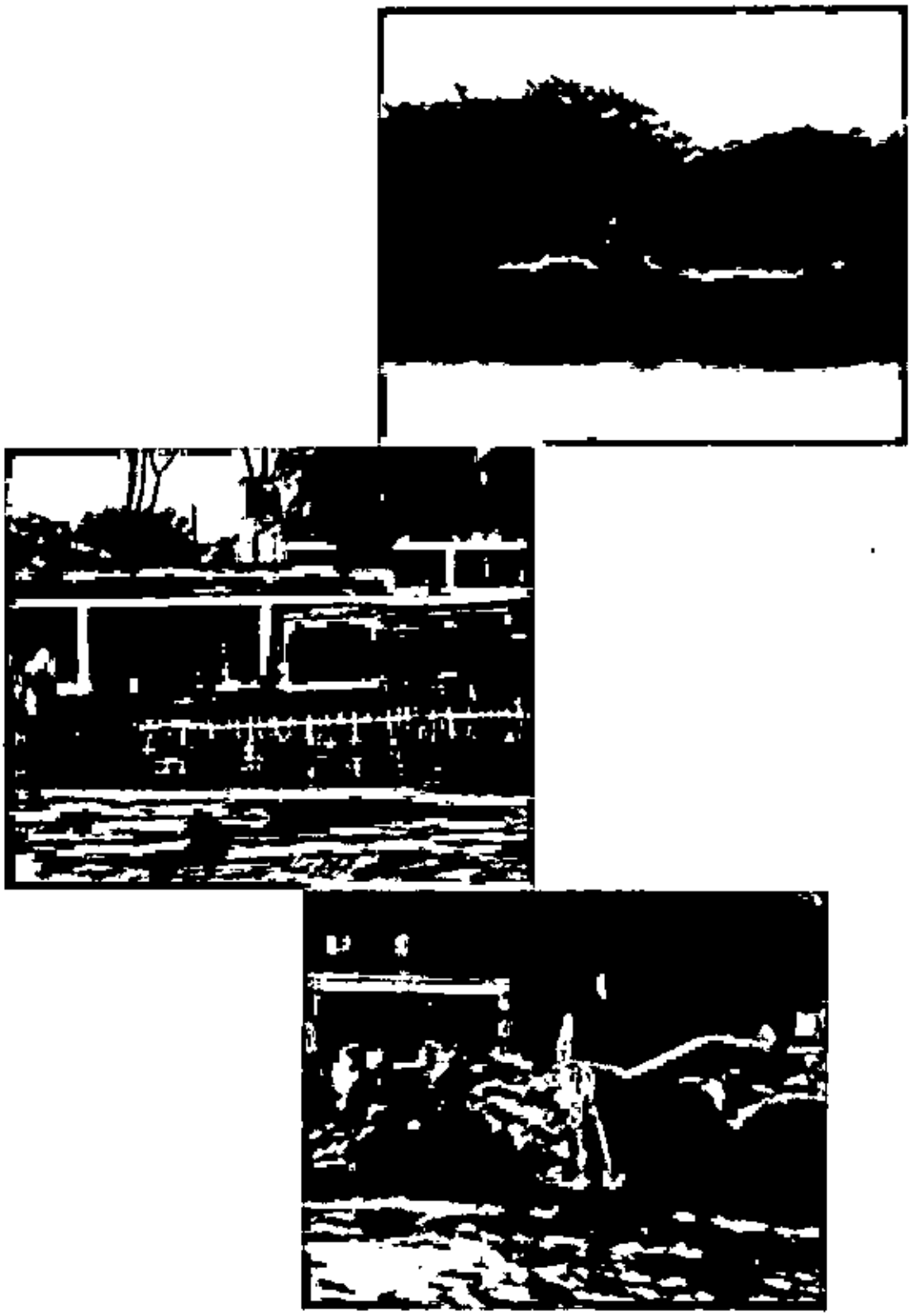

Figure B14: Cultural and educational structures are vulnerable.

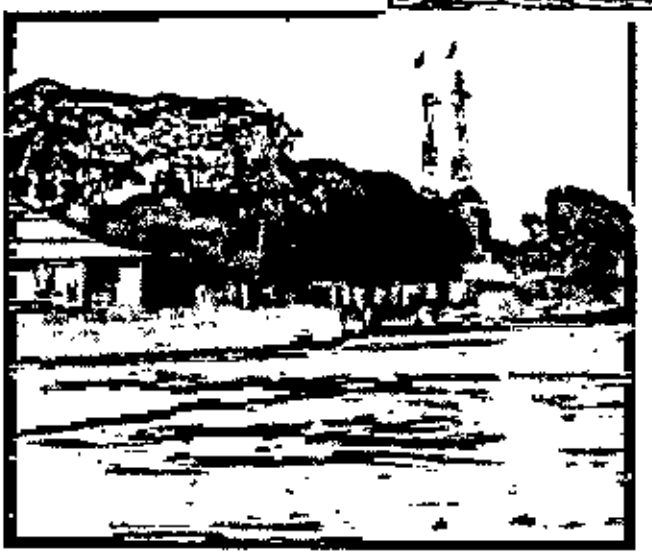

Figure B15: Bridge/ Tele-communication tower are vulnerable.

Figure B16: The researcher collects Information's by individual interview.

Figure B17: The researcher collects Information's by FGD.

Figure B18: Mawa Ferry Ghat.

Figure B19: Narrow channel is form near Dighirper union.

Figure B20: Present (31.05.08) river erosion in the Hasail- Banari reach.