RIVER CHANNEL MIGRATION: A REMOTE SENSING AND GIS ANALYSIS

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ABSTRACT

Remote sensing and geographic information system provide tools for quantitative and qualitative river morphological analysis. Bangladesh is a riverine, flood prone country and, the Padma and the Jamuna are two of major three rivers in the country. The aim of this research is to monitor the channel migration of the Padma and the Jamuna rivers since 1977 to 2004 using remote sensing and GIS. Four scenes for dry season's cloud free Landsat images were used in this study. Images were processed using PCI Geomatica and ArcGIS 9.3 was used for GIS analysis. The Landsat images were visualized and identified nine locations to investigate the channel migration. The images were classified into two broad categories, i.e. water and non-water body. ArcGIS 9.3 was used to transfer these classified images into GIS layers. A standard measurement tool of ArcGIS was applied to measure the movement of river channel based on initial river channel in 1977. General trend of the Padma and the Jamuna river channel migration at locations A, B, C, D, F, G, H and I towards north, northeast and southwest eventually, north, northeast, east, east, west and west, respectively. The confluence point of the Padma and Jamuna (at location E) migrated toward southeast with high rate. During 1977-2004, it migrated about 9000m toward southeast. Trend of migration of the confluence point was faster than any other locations in the channel of the Padma river.

1. INTRODUCTION

The Padma and the Jamuna are rivers that flow within few meters of height in Bangladesh. These are two of important three rivers in the context of water navigation, irrigation, fishing and fresh water for downstream areas. Beside this, those are the rivers of erosion of riverbank and deposition of sandbank. Flood is one of the main causes for riverbank erosion. Bangladesh is a floodplain country and almost every year flood attacks the country. Statistically, during regular flood, about 26,000 sq km (that is 18% of Bangladesh) are flooded. And during severe flood, it exceeds 55% of the total area of the country (Banglapedia, 2008). Bangladesh Water Development Board (BWDB) reported that 140 km of rivers banks fully and another 1345 km partially were eroded by the erosion of rivers floods in 2007 (IRIN, 2008 and Islam, 2009). There were 17 km of flood protection embankments completely and other 48 km partly eroded. Rural roads of about 7524 km and 1323 bridges and culverts were damaged by the rivers erosion and floods in 2007. BWDB estimated that flood and river erosion in 2007 damaged more than US$ 75 million. BWDB says that from the early 1970s, the erosion of Padma was 1400 hectares per year while it increased to 2,200 hectares per year in 1990s. The mean annual erosion of both banks of Jamuna since 1970s to early 1990s was 3300 hectares (IRIN, 2008). However, Khan and Islam (2002) argue that increase of width of the Jamuna River since 1973 to 1992 was 160 m/year. Moreover, the riverbanks erosion of Jamuna was diminished slightly ranging from 1000 to 2500 hectares per year in last decade. Flood and flow of river water erode the banks of the rivers during the monsoon and in the winter, water level of rivers goes down. Sandbanks alongside riverbanks are founded in the winter. These sandbanks seem to be extended desert in the winter. Year after year, erosion, deposition and extension of sandbanks cause channel migration.

Remote Sensing (RS), Geographical Information System (GIS) and Global Positioning System (GPS) facilitate river morphological analysis. Theodolite is also widely used to monitor dynamic river system by measuring three dimensional (3d) coordinates (Chandler *et al.*, 2001). However, regular collection of spatial data using GPS and theodolite for river channel monitoring is very difficult. This process is time consuming and costly. Whereas, RS and GIS technologies are effective widely used tools for dynamic physical environment change detection and monitoring (Andrea *et at.*, 2001; Ahmed, 2002; Stabel and Löffler, 2004; Twumasi and Merem, 2006; Islam, 2009a). The aim of this study is to monitor the river channel migration of the Padma and the Jamuna from 1977 to 2004 using GIS and RS.

2. STUDY AREA AND DATA DESCRIPTION

There are about 700 rivers in Bangladesh. Padma and Jamuna are two of three major rivers in Bangladesh. The mother river of the Padma is the Ganges that is originated at the Gangotri. The part of the Ganges that crosses to Bangladesh is called Padma. The Padma is about 120 km long and 4-8 km width. The mother river of the Jamuna is the Brahmaputra that is originated from the Chemayung-Dung glacier. The part of the Brahmaputra that crosses to Bangladesh is called Jamuna. The Jamuna is about 205 km long and 3-18 km

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width. The average width is about 10 km. The Padma and the Jamuna join together at Goalanda thana of Rajbari district and then flow as Padma River until it joins the Meghna River at Chadpur in Bangladesh. The rest of the way, it flows as Meghna River into the Bay of Bengal. The Padma and the Jamuna riverbanks until their confluence is the study areas for this research (see Fig. 1).

Bangladesh is situated at tropical region. Tropical climate is founded in this country with November-February considered as dry season. Average rainfall is about 15 cm to 20 cm per year. The average temperature in the dry season is 17^0C to 18.5^0C. The geology of this area is flooded and delta plain land with peat, silted, acidic brown and grey soil (Haque et at., 2008; Islam 2009).

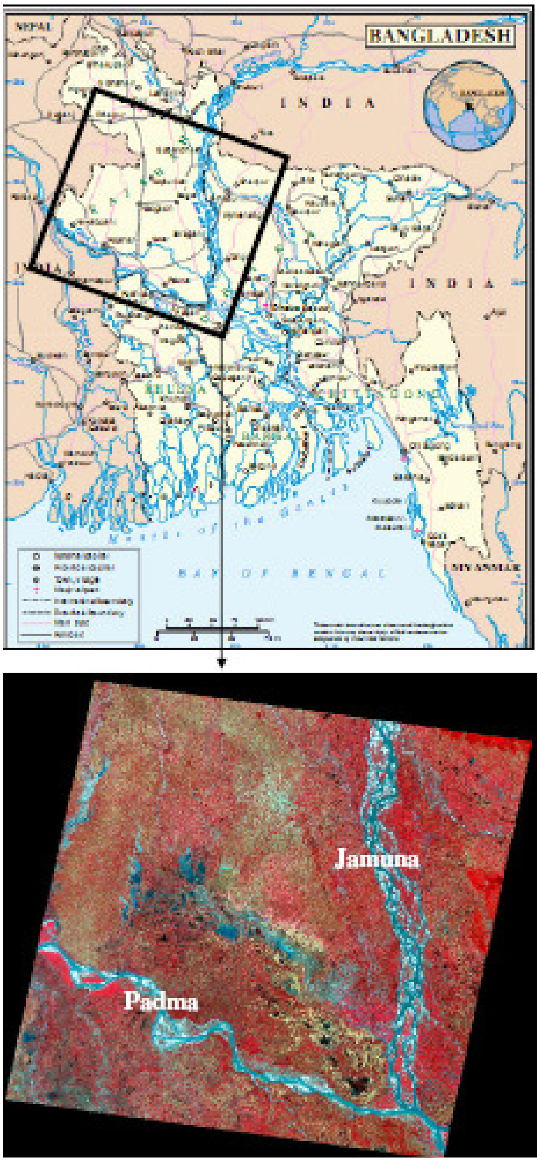

Figure 1. Location of the study area

Landsat imagery is used in this study as main data source. The spatial resolution of Landsat imagery is sufficient for river morphological analysis particularly identify and monitor the dynamics of river systems, migration of the confluence, movement of river channels, and eroded and deposited riverbanks (Priestnall and Aplin, 2006). Four scenes of Landsat images i.e. Multi-Spectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery were acquired in February 1977, November 1989 and November 2004, and November 2000, respectively was obtained from the Global Land Cover Facility (GLCF) (GLCF, 2004). These images were captured in the dry season with cloud free. These images were modified and projected using Universal Transverse Mercator (UTM) 45 R D000 earth model by GLCF. The left long water channel of Fig. 1 (bottom) represents the Padma River and the right one represents the Jamuna River. River channels of the Padma and the Jamuna are studied under this research.

3. METHODOLOGY

First, PCI Geometica is used to visualize Landsat images. To avoid the large data handling and computer storage, approximately 8 to 12 km from the both side of riverbanks are taken as subset for this study area. Then nine locations are identified to investigate the migration of river channel (see Fig. 2). These nine locations are selected based on where erosions are occurred in the highest rate. The images are classified into two broad categories, i.e. water body and non-water body. ArcGIS 9.3 is used to transfer these classified images into GIS layers. River channel is separated and standard measurement tool of ArcGIS is applied to measure the movement of river channel based on initial river channel in 1977.

4. RESULTS

The Jamuna and the Padma are the rivers with peculiar characteristics i.e. heavy water flows in the monsoon but less in the dry season (winter). The Jamuna has a lot of islands which are inundated in the monsoon in normal water level. Due to the heavy water flow in the monsoon and flood, the locations of the Jamuna River channel are always changing. The same phenomenon is also observed for the Padma. Tab. 2 describes the migration of the Jamuna River’s channel in meters (m) from the initial observation river channel in 1977.

From analysis of Tab. 2, the channel at the location F migrated 7300 m toward east during 1977-89. Then direction of migration changed to west and migrated about 3685 m during 1989-2000 from its existing situation in 1989. After that, it again migrated 385 m toward east during 2000-04. At the location G, the channel migrated 2650 and 975 m toward east and west, respectively during 1977-89. During 1989-2000, the west part of the river channel was disappeared. The east part continued to migrate about 1670 m toward east. During 2000-04 the channel flowed with stable situation. In this period it was remain unchanged.

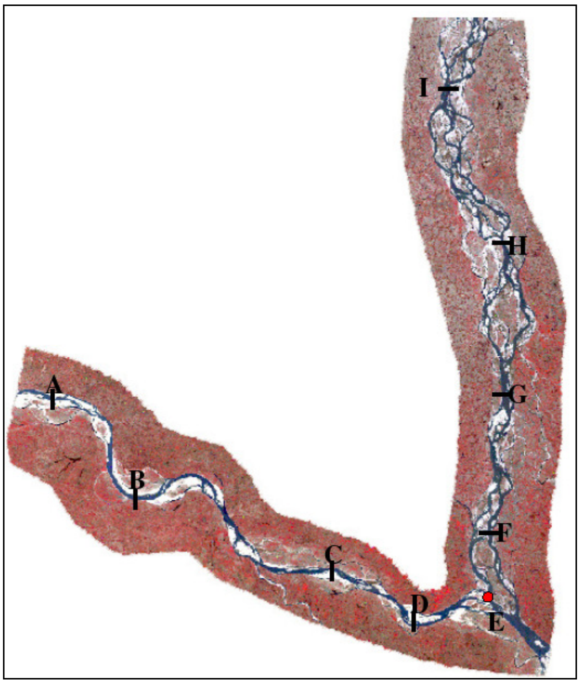

Figure 2. Location of the observation point in initial year 1977

Table 2. The Jamuna River channel migration (in meter) from initial year 1977

Location	In 1989		In 2000		In 2004	
	Migration	Direction	Migration	Direction	Migration	Direction
F	7300	East	3615	East	4000	East
G	2650	East	4320	East	4320	East
	975	West				
H	11412	West	11182	West	11777	West
			1750	East		
I	6272	East	9220	East	9450	East
	2115	West	680	West	2500	West

At the location H, the channel migrated 11412 m toward west during 1977-89. Then it divided into two parts and migrated 230 and 13162 m toward east during 1989-2000. During 2000-04, the east part was disappeared but west part continued to migrate about 595 m in west direction. The channel at the location I migrated into 6272 and 2115 m toward east and west, respectively during 1977-89. During 1989-2000, both east and west parts migrated 2948 and 1435 m, respectively toward east. Then east part continued to move about 230 m toward east during 2000-04 but the west part changed migration direction toward west and migrated about 1820 m.

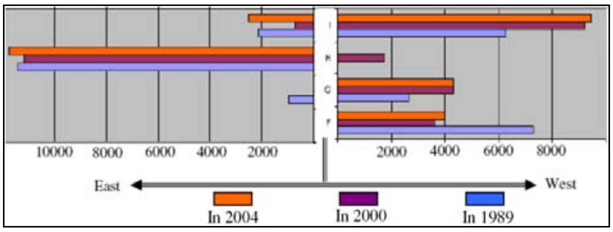

Figure 3. The Jamuna River channel migration (in meter) from initial year 1977. F, G, H and I indicate location of river channel. The bar represents river channel migration in meter towards east and west.

Fig. 3 shows the Jamuna River channel migration from initial year 1977. This figure shows clearly that river channel at some places moved in the same direction and/or in the opposite direction eventually. Fig. 4 shows the location of the Jamuna river channel in different year. As seen in the Fig. 3 and Fig. 4, and from the results of the Tab. 2, general trend of channel migration of the Jamuna River at locations F, G, H and I were toward east, east, west and west, respectively.

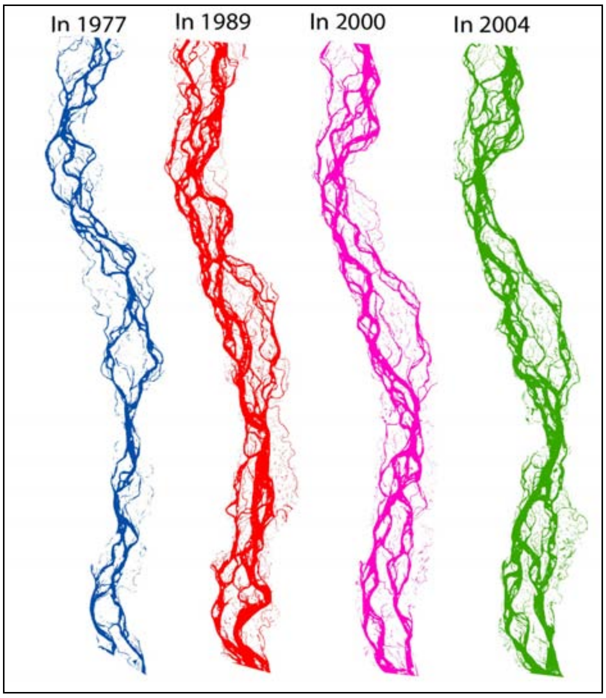

Figure 4. Jamuna River channel in different year

Tab. 3 describes the Padma River channel migration since 1977 to 2004. From analysis of Tab. 3, river channel at location A migrated about 850 m toward north during 1977-89. It continued to migrate about 850 m toward north during 1989-2000. During 2000-04, the channel was divided into two parts and both two parts moved about 200 and 640 m toward south. At location B river channel was more susceptible. It was divided into two parts and migrated both in northeast and southwest directions with high rate. During 1977-89, 1989-2000 and 2000-04, the northeast part migrated about 1800, 1470 and 600 m toward northeast and southwest part migrated about 3000, 4500 and 250 m toward southwest, respectively.

Table 3. The Padma River channel migration (in meter) from initial year 1977. N, S, NE and SE indicate north, south, northeast and southeast, respectively.

Location	In 1989		In 2000		In 2004	
	Migration	Direction	Migration	Direction	Migration	Direction
A	850	N	1700	N	1500	N
					640	S
B	1800	NE	3270	NE	3870	NE
	3000	SW	7500	SW	7750	SW
C	380	N	235	N	500	N
	3650	S	1700	S	1540	S
D	3200	NE	3300	NE	3300	NE
E	4400	SE	8000	SE	9000	SE

At location C, the channel also migrated towards both north and south. During 1977-89, it migrated 380 and 3650 m in north and south direction, respectively. Two parts of the channel at this location were getting closer during 1989-2000. In this period, migrations of north and south parts of the channel were about 145 and 1950 m towards south and north, respectively. Migration of south part continued toward north but north part changed direction to north during 2000-04. In this period, migration of north and south parts were about 265 and 160 m in north direction. The channel at location D migrated 3200 m toward northeast during 1977-89. Then it continued to migrate toward northeast that was about 100 m during 1989-2000. During 2000-04 there was remain unchanged.

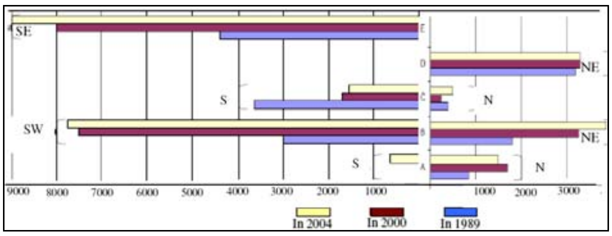

Figure 5. The Padma River channel migration (in meter) from initial year 1977. A, B, C, D and E indicate location of river channel. The bar represents river channel migration in meter towards specific direction. SE, S, SW, NE and N indicate movement direction of river channel toward southeast, south, southwest, northeast and north, respectively.

The confluence point of the Padma and Jamuna (at location E) migrated with high rate. During 1977-2004 it migrated about 9000 m toward southeast. Average migration of this point in the entire periods was 333.33 m per year. The rate of migration of this confluence point occurred faster during 1977-89, that was 366.66 m per year. Trend of migration of the confluence point was faster than any other locations in the channel of the Padma River.

The bar chart in the Fig. 5 shows the channel migration of the Padma River from initial year 1977. The river channel at location B was migrating towards northeast and southwest eventually with high rate. The confluence point of the Padma and the Jamuna was migrating only toward southeast. Fig. 6 shows the location of the Padma river channel in different period. As seen in Fig. 5 and Fig. 6, and from the results of Tab. 3, general trend of channel migration of the Padma River at locations A, B, C and D towards north, northeast and southwest eventually, north and northeast, respectively.

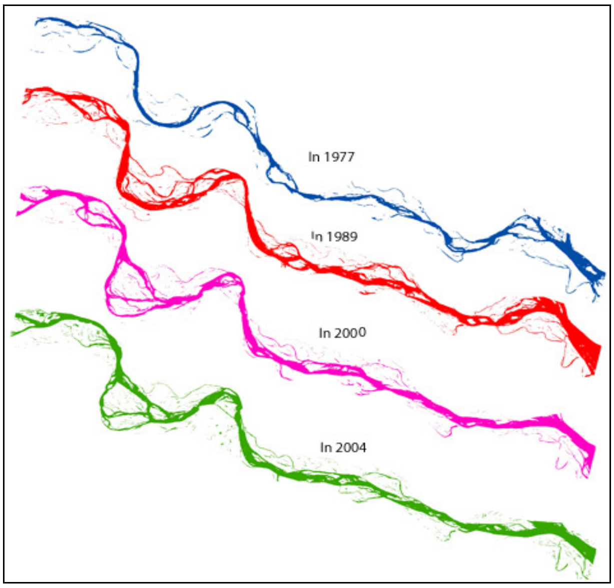

Figure 6. The Padma River channel in different year

5. DISCUSSION

Migration of river channels of the Padma and the Jamuna doesn't indicate only erosion of riverbank. It means either erosion or deposition. However, most of the cases, in this study, erosion of riverbank are observed. Moreover, location and direction of erosion and deposition of riverbank neither is nor identified in this study. General trends of river channel migration at different locations of the Padma and the Jamuna have been being changed since 1977 to 2004 is studied. Tab. 4 shows net migration of river channel of the Padma and the Jamuna since 1977 to 2004. Movement of channel was occurred more between 1977 and 1989 than between 1989 and 2000. However, period 2004-04 is not compared with periods 1977-89 and 1989-2000. Period 2000-04 is too shorter than other and sever flood was not occurred in this period.

*Table 4. Net migration (in meter) of the Padma and the Jamuna River's channel at different location in different period. N, NE, S and SW represent north, northeast, south and southwest, direction respectively. * denotes deposition. "–" and "0" indicates the channel was disappeared and not migrated in specified period.*

Location	Net Migration		
	1977-89	1989-2000	2000-04
A	850 N	850 N	200 S*
			640 S
B	1800 NE	1470 NE	600 NE
	3000 SW	4500 SW	250 SW
C	380 N	145 S*	265 N
	3650 S	1950 N*	160 N*
D	3200 NE	100 NE	0
E	4400 SE	3600 SE	1000 SE
F	7300 E	3685 W*	385 E
G	2650 E	1670 E	0
	975 W	-	
H	11412 W	230 E*	595 W
		13162 E	-
I	6272 E	2948 E	230 E
	2115 W	1435 E*	1820 W

Three sever floods were occurred since 1977 to 2004 i.e. in 1987, 1988 and 1998. There were two sever floods occurred during 1977-89 (see Tab. 5). Around 37%, 63% and 72% of the land area of the country were flooded in 1998, 1988 and 1987 flood, respectively. Although, Meghna River took part in these flood but the major portion of area inundation was caused by floods of the Padma and the Jamuna (Mirza *et al.,* 2001). The mean bank level at the stations of Bahadurabad in the Jamuna and at Hardinge Bridge in the Padma are 18.93 and 14.01 meters, respectively. The flood levels in 1987, 1988 and 1998 exceeded far from mean bank level (see Tab. 5).

Table 5. Flood level of the Padma and the Jamuna (Islam & Chowdhury, 2002; Islam, 2009, p. 49*).*

Rive-Station's name	Mean bank level (in meter)	Maximum flood level (in meter)		
		In 1987	In 1988	In 1998
Bahadurabad (Jamuna)	18.93	19.68	20.61	20.41
Hardinge Bridge (Padma)	14.01	14.79	14.87	15.19

Water discharge capacity of the Padma at Hardinge Bridge and the Jamuna at Bahadurabad is 43000 and 48000 m^3/s, respectively (see Tab. 6). Maximum discharge of the rivers in 1987, 1988 and 1998 were almost twice their capacity level (Islam, 2009). Flood and high flow of water is the main cause of erosion and deposition and consequences of that, river channel migrate. Frequent and high rate of the Padma and the Jamuna river channel migration during 1977-89 compared to 1989-2000 and 2000-04 were caused of two sever floods in 1987 and 1988. And river channel migration in the Jamuna were more than in the Padma since 1977 to 2004 (see Tab. 4).

Table 6. Maximum and bank full discharge in the Padma and the Jamuna (Islam & Chowdhury, 2002; Ferdows & Hossain, 2005; Islam, 2009, p. 49).

Rive-Station's name	Year	Maximum discharge (cum/s)	Bank full discharge (cum/s)
Padma-Hardinge Brige	1987	76000	43000
	1988	72300	
	1998	80300	
Jamuna-Bahadurabad	1987	73000	48000
	1988	98300	
	1998	93658	

6. CONCLUSION

Bangladesh is situated at the downstream of the Padma and the Jamuna with flood plain flat land. So migration of river channel of the Padma and the Jamuna is quite normal phenomenon. But river channel migration of the Padma and the Jamuna is occurred too fast. The movement of river channel of the Jamuna is faster than the Padma that is shown in this study since 1977 to 2004 using RS and GIS. This causes lot of cost, destroy land property, damage agricultural products, disrupt water navigation etc. River channel migration, erosion and deposition of riverbank are one of the foremost natural disasters responsible for poverty of Bangladesh. It has the great impact on rural unemployment in Bangladesh. Regular monitoring of riverbank line, understanding the trend of river channel migration and strategies setting for adaptation on probable effect could minimize potential risk and loss.

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