WATER SHORTAGE IN THE GORAI RIVER BASIN AND DAMAGE OF MANGROVE WETLAND ECOSYSTEMS IN SUNDARBANS, BANGLADESH

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ABSTRACT

The Gorai River is the major distributary of the Ganges River in the right bank and important provider of fresh water inflows to southwestern region of Bangladesh. The length of the river is 199 km and the area of the Gorai River catchment is 15160 km². The Gorai used to discharge into the Bay of Bengal through the Mathumati and Baleswar Rivers. The Madhumati was connected to the Nabaganga at Bardia point. This is the drainage path of the Gorai water, which now reaches the Bay mainly via the Passur and Sibsa Rivers. The distribution of the Gorai River flow at Bardia between the Nabaganga and Madhumati Rivers and tidal conditions which influence the sediment concentration are not known. From previous study result shows that the annual average bed materials transport in the Ganges River is about $18X10^6$ metric tons and one third of the Ganges sediment is settling down on the Gorai River basin. The mean peak flow in the Gorai River was 6,200 m³/s in 1962 and the present minimum recorded flow in the dry season is only 10 m³/s in 2008. This is the main reason of the Gorai River bed ridged by sedimentation. It has been observed that the major part of the Gorai River basin is dry, and as a result the sea saline water is penetrating in the upstream of the Gorai River catchment. Salinity intrusion along the Nabaganga-Rupsha-Passur system has largely been influenced by the dry season flow of the Gorai River. The high sediment concentration reaches about 20 km upstream of Bardia and a clean concentration gradient can be observed along the down stream direction of the Gorai and the Nabaganga River. The Gorai is a crucial instrument for maintaining both ecosystems and economy of the region. Since 1980s, the flow in the Gorai River has been blocked by the build-up of sediment in the off-take. After construction of Farakka Barrage on the Ganges River in 1975 in India which is 17 km far from the Bangladesh border, as a result the Ganges water flow has reduced significantly in the down stream. This shortage of fresh water in the Gorai basin is the root cause of salinity intrusion in the catchment and damage of mangrove ecosystems and its services of the Sundarbans region. The study is carried out based on primary and secondary data sources. The objective of this study is to investigate the shortage of fresh water in the Ganges-Gorai basins and their negative impacts on socio-economy and mangrove wetland ecosystems in the Sundarbans in Bangladesh.

Keywords: *Gorai River, Water shortage, Sedimentation, Salinity intrusion and Mangrove ecosystem and Sundarbans*

1. INTRODUCTION

The Gorai River is the major distributary of the Ganges River in the right bank and important provider of fresh water inflows to southwestern region of Bangladesh (Addams, 1919). It has a meandering and braiding tendencies. The length of the river is 199 km. The area of the Gorai river catchment area is 15160 km^2. The Gorai used to discharge into the Bay of Bengal through the Mathumati and Baleswar Rivers (Fig. 1). The Madhumati was connected to the Nabaganga at Bardia point. This is the drainage path of the Gorai water, which now reaches the Bay mainly via the Passur and Sibsa rivers. It also brings fresh water in the region through Bhairab and Mathbhanga Rivers. The Gorai is a crucial instrument for maintaining both the environment and economy of the region. The distribution of the Gorai river flow at Bardia between the Nabaganga and Madhumati rivers and tidal conditions, which influence the sediment concentration are not known. From previous study that in 1966-69 the annual average bed material transport in the Ganges River is about 18X106 metric tons. In 1973, 1984 and 1997 the Gorai River discharge were 190 m^3/s, 60 m^3/s and 2 m^3/s. The mean peak flow in the Gorai River is 6,200 m^3/s.The minimum recorded monthly mean flow was 171 m^3/s in April in 1995 (EGIS, 2000).
Dry season salinity along the Nabaganga-Rupsha-Passur system has largely been influenced by the dry season flow of the Gorai River. The effect of this has been an eight-fold increase in maximum salinity at Bardia and a two-fold increase in Khulna in both cases (EGIS, 2000). Due to dry post monsoon hydrological changes in the Post-Farakka period and deterioration of the Gorai off-take by massive sedimentation in the same period, opening of the Gorai mouth without human intervention will not be possible. The high sediment concentration reaches about 20 km upstream of Bardia and a clean concentration gradient can be observed along the down stream direction of the Gorai and Nabaganga River. For the past 100 years, the region depended on fresh water inflows from the Gorai to maintain its last defense against the encroachment of the salinity front during the dry season. Since the end of the 1980s, however, the flow in the Gorai River has been blocked by the build-up of sediment in the off-take. The Gorai river dry season flow may reduce the sediment concentration along the Nabaganga and Rupsa Rivers to some extent.
Gorai River is a major distributary of the Ganges in the right bank (Adams, 1919). The Gorai discharge fells into the Bay of Bengal through the Mathumati and Baleswar River. The Gorai-Mathumati was permanently changed by excavation of the Halifax cut in 1902, where the Mathumati was connected to the Nabaganga at Bardia point (Fig. 1). Therefore the Gorai discharge reaches the Bay of Bengal through Passur and Sibsa rivers. It is caring upstream fresh water to the southwest region and the Sundarbans mangrove wetlands, the Bhairab and Mathabanga also inspiring the water caring process, the Gorai River has become a potential instrument for balancing the ecosystems and economy of the region (EGIS, 2000). After construction of the Farakka Barrage in 1975 it has hastened this process. Due to the reduction of upstream water flow huge amounts of sediment loads are transforming and settling down on the Gorai river bed. Therefore the morphology of the river basin and river banks are always changing which is harmful for river ecosystem services in the Gorai catchment area. The sediment transport tidal waves and salinity intrusion in the down stream of the Sundarbans region are badly affecting of its ecosystem. To protect the Sundarbans mangrove wetlands and ecosystem services of the Gorai river catchment is essential for the greater benefits of the local communities in the southern region of Bangladesh.

2. OBJECTIVE OF THE STUDY

The objective of this study is to understand the river system in the Gorai catchment area and shortage of fresh water discharge in the Ganges and Gorai River and high sedimentation in the basins area. The study seeks the impacts of upstream Ganges fresh water withdrawal and threatened ecosystems in the Sundarbans region as well as in the Gorai catchment area. The study results will make a contribution towards the development and protection of Gorai River morphology and ecosystems in the entire catchment.

3. METHODOLOGY

The present study was carried out based on primary and secondary data sources. The primary data collected from field investigation in 2003 and 2008. PRA practices were arranged with the local people near to the Kushtia town location and Gorai Railway bridge area. The information of Gorai River system in Bangladesh was collected from different government and non governmental organizations. For secondary data collection, EGIS reports on Gorai River restoration project 2000 were used very openly. The specific especial reports of EGIS, FAP 24, FAP 4 reports, BWDB and BCAS reports and publications were also used for this study. Beside these some interviews were arranged with water engineers, environmentalist, geographers, geologists and sociologists and expert peoples on river systems and its ecology. The collected data were reconstructed, analysis and visualized through used MS EXCEL, SPSS, VISIO 32, Expert Fit, MATLAB and ArcGIS tools.

4. GEOGRAPHY AND MORPHOLOGICAL SETTING OF THE GORAI RIVER

The Gorai River catchment area is 15160 km^2 and is located between 21° 30’ N to 24° 0’ N latitude and 89° 0’ E to 90° 0’ E longitude, covering partly or fully of Pabna, Chuadanga, Kushtia, Rajbari, Faridpur, Gopalgonj, Jessore, Jhenaidah, Magura, Norail, Pirogpur, Borguna, Bagerhat, Khulna and Sathkhira districts of south western region of Bangladesh. The average temperature of the catchment area is varies between 22° - 23°C in winter and 23° to 32°C in the summer. The lowest temperature is 6° to 11° C in winter and 40° to 43° C in the summer. The average annual rainfall is between 1516 mm in the northeast and 2478 mm in the southeast (EGIS, 2000). Historically the Brahmaputra River has joined the Ganges just downstream of the Gorai River off-take. Recent development of paleo-geographic maps (Umitsu, 1993; Goodbred and Kuehl, 2000) suggested that the main course of the Ganges shifted from the Bhagirathi to the present course after abandoning several other courses like the Jalingi, Mathabhanga, Gorai, Kumar etc (Williams, 1919). During the shifting of courses from the west to the east, the old courses often became distributaries of the main river. A similar phenomenon was observed in the case of Gorai River. The Ganges was flowing close to the present course of the Gorai river nearly 5000 years ago (Sarkar, 1993). Later it shifted its course further east and since then the Gorai has become one of its distributaries. As a result the backwater effect has strengthened the Gorai a major distributary of the Ganges (Adams, 1919). The Gorai River upstream water falls into the Bay of Bengal through the Mathumati and Baleswar River. The Gorai-Madhumati was permanently changed by excavation of the Halifax cut in 1902, when the Madhumati was connected to the Nabaganga at Bardia point. After this evolved the drainage path of the Gorai water, which now reach to Bay of Bengal mainly via the Passur and Sibsa Rivers. The Ganges upstream freshwater is carrying to the southwest region and to the Sundarbans, such as the Bhairab and Mathabanga River. The Gorai River is playing a potential role to maintaining, environmental, social and economy of the region. The Gorai River was free from anthropogenic influence and pollution. But after construction of Farakka Barrage and withdrawal of upstream fresh water at the Farakka point, the water discharge has decreased drastically. As a result two types of environmental impacts have been created in the Gorai catchment area. The sediment particles are settling down on the Gorai River bed rapidly, which is one of the major problems of Gorai River morphology protection. On the other hand the saline sea water penetrated in the upstream area due to capillary upward movement. The Gorai River is presently called a distributary of the Ganges River. Its length is 199 km which can be divided in 5 distinct reaches according to morphologically consideration (EGIS, 2000).

Gorai 1 - Off-take to Railway Bridge –11 km, Gorai 2 - Railway Bridge to Kamarkhali – 87 km, Gorai 3 - Kamarkhali point to 4th Reach - 110 km, Gorai 4 -4th Reach to 5th Reach point-125 km, Gorai 5 - 125 km to Bardia point - 199 km

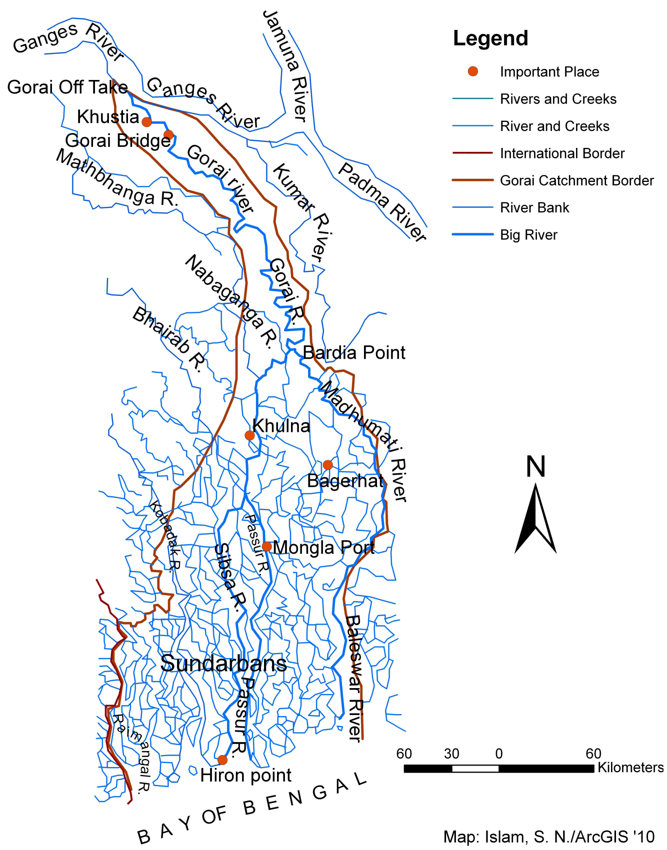

Figure 1: Gorai River catchment area in south western region in Bangladesh

The Gorai River reach from Gorai 1 to Gorai 4 is the non tidal condition and the tidal nature of Gorai River is the 5th reach which is called tidal lower course is extremely active and flowing (EGIS, 2000). The Madhumati River is a distributary of the upper Ganges flowing through southwestern Bangladesh. It leaves the Ganges just north of Kushtia and flows 306 km before turning south across the Sundarbans and into the Bay of Bengal. In its upper course it is called the Gorai River, in its lower course it is known the Baleswar River and its estuary mouth which is 14 km wide is called the Haringhata River. The Baleswar River length is 57 km, and the Nabganga River from Bardia point to Gazirhat is 29 km. The length of Gorai-Madhumati-Baleswar rivers is 371 km (37 km in Kushtia, 71 km in Faridpur, 92 km in Jessore and 104 km in Khulna and 67 km in Barisal in the Eastern border of Sundarbans).The Bhairab river length is 250 km and it runs Jessore and Khulna region, the length of Chitra river is 170 km (BBS, 1999), The length of Nabaganga is 230 km (26 km in Kushtia and 204 km in Jessore). The Mathabhanga river length is

156 km (16 km in Rajshahi and 140 km in Kushtia). The Gorai River has been largest perennial distributary of the Ganges River in Bangladesh.

The Mathabhanga and Bhairab also provided fresh water inflow during dry season in earlier times, there were disconnected from the Ganges. This natural process involving the decay of distributaries has taken place as the Ganges itself had moved its route. The dry season flow in the Gorai is also strongly influenced by the dry season hydrology and platform evolution of the Ganges River. The dry season flow of the Ganges has decreased since the commissioning of the Farakka Barrage. The slow natural decline of the Gorai has however been hastened by the diversion of water by the Farakka Barrage since 1975. There has been no natural dry season flow in the Gorai since 1988 (Islam, 2008; 2009; EGIS, 2000).

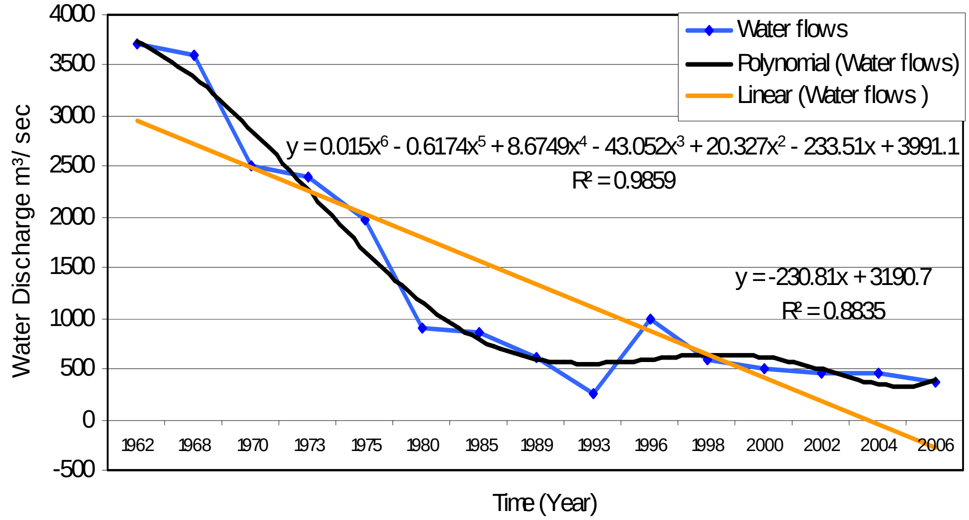

Figure 2: The Historical Ganges Water flows in the Harding Bridge point

The river landscapes have been started to change when a part of Sundarbans began to lose the saline fresh water balance during the early 19th century, the intake mouth of the Mathbhanga, kobadak and other rivers that used to bring fresh water from the Ganges to the south region was silted up and they lost their connection with the Ganges. As a result, the regeneration of Sundari, the dominant timber species in the forest began to be reduced in south western part of Sundarbans. The fragile situation became further imbalanced when India constructed the Farakka Barrage in early 1974 on the Ganges river, 17 km upstream from Bangladesh border, and began diverting more then half of water to the Hoogly river in India. Blocks the perennial flow of the Ganges and diverts its water through a feeder canal into the Bhagirathi-Hoogly River for the improvement of navigation for the Calcutta port of India. The whole estuary depends entirely on fresh water of the Gorai at Bardia also it is playing a role to prevent saline intrusion. Historically the upstream flows was normal for example the Ganges River flows at the Harding Bridge in 1962 the discharge was 3,700 m³/s and 1968 when the average monthly flow of the Ganges in the dry season exceeded 3,600 m³/s, after 1976 the flows of the Ganges and the Gorai is dropped in 1976 (Fig. 2 and 3) (Ben, 1995). With the commissioning of Farakka Barrage, the discharge in the downstream was drastically reduced. The Ganges recorded lowest flow of 9,437 cusec on April, 1993 against a flow of 65,000 cusec as the pre diversion period. In 1995 and recent years the flows have been recorded less than 500 m³/s. The reduction of Ganges flow in the south western region of Bangladesh wholly dependent on the Ganges has produced disastrous effects on Agriculture, fisheries, navigation, hydro-morphology, salinity intrusion, industrial products, drinking water and forest ecosystems (Hoque, 1995).

5. WATER SHORTAGE AND SEDIMENTATION IN THE GORAI BASIN

Water is a vital for the existence of human being and other species. Due to increasing water consumption, the loss of potential sources of freshwater resulting from unsustainable water resources management practices (Wei, 2009). The Gorai is a crucial instrument for maintaining both the environment and economy of the region. The distribution of the Gorai River flow at Bardia point between the Nabaganga and Madhumati rivers and tidal conditions, which influence the sediment concentration are not known. From previous study that in 1966-69 the annual average bed material transport in the Ganges River is about $18X10^6$ metric tons. In 1973, 1984, 1990, 1996, 2001, 2003 and 2008 the Gorai River discharges were 190 m^3/s, 60 m^3/s, 70 m^3/s, 171 m^3/s, 5 m^3/s, 2 m^3/s, and 10 m^3/s (Fig.3). The mean peak flow in the Gorai River is 6,200 m^3/s. The minimum recorded monthly mean flow was 171 m^3/s in April in 1996 (EGIS, 2000).

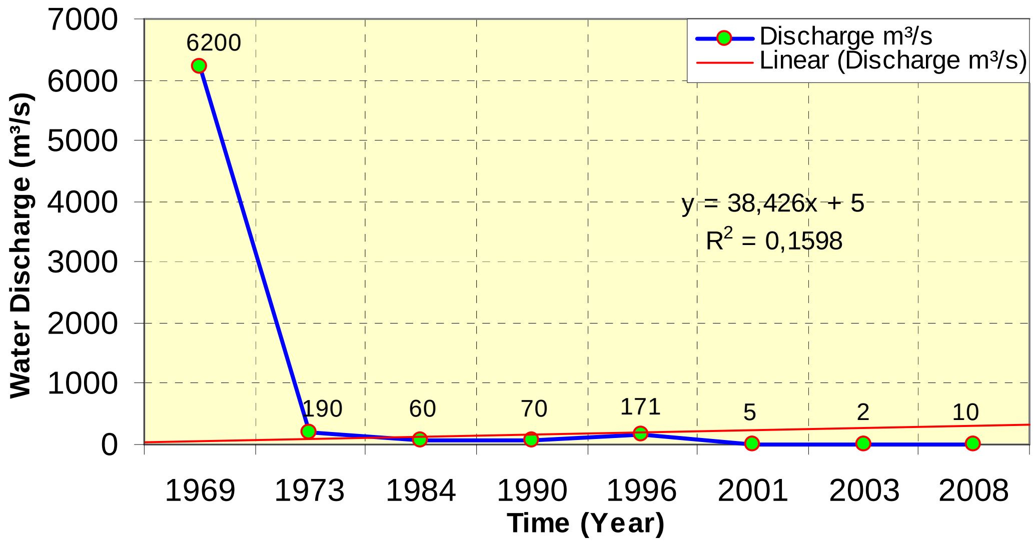

Figure 3: Water Discharge of Gorai River (1969 -2008)

Dry season salinity along the Nabaganga-Rupsha-Passur system has largely been influenced by the dry season flow of the Gorai River. Figure 3 shows the Gorai water flow tendency from 1969 to 2008, the polynomial behaviour of Gorai River water flow gradually decreasing trends where the regression value $R^2 = 0.1598$ it is not acceptable value but this value is showing the average grade from 1973 when the water flow already in the lowest discharge passing in the Gorai Railway Bridge (Fig 3).

The effect of this has been an eight-fold increase in maximum salinity at Bardia and a two-fold increase in Khulna in both cases. Due to dry post monsoon hydrological changes in the Post-Farakka period and deterioration of the Gorai off-take by massive sedimentation in the same period, opening of the Gorai mouth without human intervention will not be possible. The high sediment concentration reaches about 20 km upstream of Bardia and a clean concentration gradient can be observed along the down stream direction of the Gorai and Nabaganga River. For the past 100 years, the region depended on fresh water inflows from the Gorai to maintain its last defense against the encroachment of the salinity front during the dry season. Since the end of the 1980s, however, the flow in the Gorai River has been blocked by the build-up of sediment in the off-take. The Gorai river dry season flow may reduce the sediment concentration along the Nabaganga and Rupsa Rivers to some extent.

6. RESULTS AND DISCUSSION

The Gorai River catchment is a potential region for the south western part of Bangladesh. The Gorai is playing an important role to balance the mangrove wetland ecosystem services and the protection of morphological landscapes in the basin area. The Sundarbans mangrove is located in the Ganges-Brahmaputra delta and such as in Gorai catchment area. For making a management plan for the protection of ecosystem services in the region the river water salinity modeling is essential (Islam, 2007). Therefore 13 influential rivers of Sundarbans mangrove area were considered for water salinity modeling (Fig. 4). A model is therefore is necessary for any kind of problem solving and an adequate management planning. Water salinity modeling of Sundarbans rivers shows the gradually increasing tendency in the region which could be helpful for the decision makers. The Gorai River and other 13 rivers of Sundarbans have been considered for salinity modeling. The 16 rivers namely are Gorai, Madhumati, Nabaganga, Baleswar-Bogi, Selagang-Harintana, Sibsa-Nalianala, Bal-Jhalia, Passur-Pasakhali, Betmargang-Kathka, Chunnar-Munchiganj, Kholpetua-Kabadak, Notabaki-Notabakikhal, Arpongasia-Deboki, Nilkomal-Hironpoint and Malancha-Mandarbaria River.

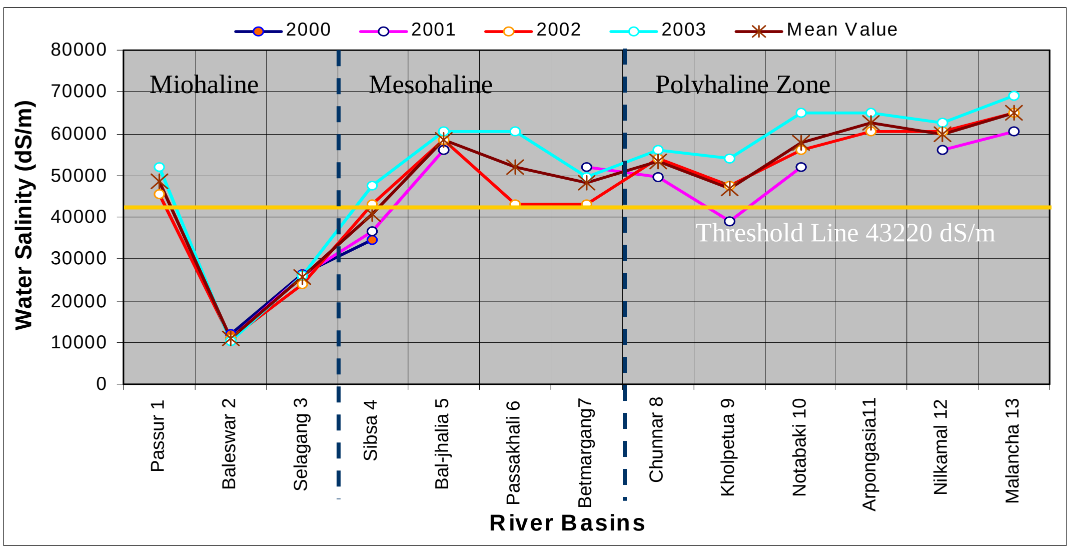

Figure 4 Water Salinity Modelling Results of 13 Rivers in Sundarbans Region

All the rivers are carrying the salinity increasing behaviour (Fig. 4). The water salinity model results show that the salinity trend is much higher in southern and south western rivers, whereas rivers of the middle area are of medium rate salinity and the north south corner is very low salinity (Fig 4). For the Sundarbans mangrove wetlands ecosystems protection the water salinity threshold value has been considered 43220 dS/m. considering the salinity models only one river exceeded the threshold level (43220 dS/m) in 2000, whereas 11 rivers such as Passur-Mongla, Sibsa-Nalianala, Bal-Jhalia, Passur-Passakhali, Betmargang-Kathka,Chunnar-Munchiganj, Kholpetua-

Kobadak, Notabakikhal-Notabaki, Arpongasia-Deboki, Nilkamol-Hironpoint, and Malancha-Mandarbaria Rivers (Fig. 4) exceeded the water salinity threshold in 2003. Considering the water salinity model results it can be stated that two third of the Sundarbans area has covered the high salinity trends and only third of the mangrove wetland area is representing as less saline zone that mean this are is still suitable condition of mangrove ecosystems. The upper portion of Gorai catchment and its salinity trends have been discussed in the following sub chapter.

6.1. Saline Water Intrusion in the Gorai River Catchment

The Gorai is a meandering river until the upper part (116 km) which is non tidal tendency and the downstream of the river is tidal tendency. At Bardia, the river bifurcates into Nabaganga and Madhumati. The Nabaganga River carries the major part of the flow of the Gorai River. The upper Nabaganga River is an inland non-tidal river joins with the inland tidal river at downstream of Bardia, such as Chitra and Bhairab and Passur River into the Bay of Bengal (Figure 5). The Passur and Sibsa rivers are connected through lower Salta, Jhapjhapia and Chunkuri Rivers upper stream of Mongla port (Fig.5) (EGIS, 2000). The Kabadak is a large river in the south western region it is also declining. The lower part of this river is tidal and joins with tidal river Arpongasia and it is joins with the Malancha River falls into the Bay of Bengal. Kabadak also joins with Sibsa River near Paikgacha. The present water salinity values range are 54025 dS/m to 69152 dS/m and the area has been extended from south to north and east to west direction which is extremely high and it is threats for the mangrove ecosystem services in the Sundarbans region as well as in the whole Gorai catchment area in Bangladesh (Islam, 2009; EGIS, 2000).

The figure 5 shows the water salinity tendency in the whole Gorai River catchment. There are 6 salinity zones are recognized through this investigation. Shortage of Ganges water flows in the upstream as a result the Gorai River is receiving less water in the basin (Fig. 3). Due to shortage of upstream fresh water the downstream of Gorai river catchment has penetrated by high saline water in the catchment. The south west corner are of the catchment is affected by high salinity intrusion. The salinity range is over 54225 dS/m in 7^{th} zone, salinity range is 43220 to 54225 dS/m in 6^{th} Zone, salinity range is 32415 to 43220 dS/m in 5^{th} zone, salinity range is 21510 to 32415 dS/m in 4^{th} zone, salinity range of is 10805 to 21510 dS/m in 3^{rd} zone, salinity range is 32415 dS/m in 2^{nd} zone and the range of salinity of 1st zone of the catchment is less than 2110 dS/m which is very low and it is almost free of salinity impact (Fig. 5). In figure 5 also shows that the zone 7^{th}, 6^{th}, and 5^{th} are affected by high salinity intrusion and the range has crossed the water salinity threshold value (43220 dS/m). The major cities such as Mongla, Khulna, Bagerhat and Satkhira are located within this high salinity range. As per an earlier soil investigation conducted by SRDI in 1970, the soil salinity was mainly found in the Ganges tidal floodplain of the study area. The Ganges river floodplain and the peat basins in the study area were classified as a non saline. Soil salinity occurred south of Khulna and Bagerhat districts. Salinity range was between 8644 dS/m and 17288 dS/m. a rise of soil salinity has been noticed however, since 1975 when Farakka Barrage constructed on the Ganges River. At present soil salinity level has recognized at south of Khulna and Bagerhat town ranges between 17288 dS/m to 32415 dS/m during the dry season (November-May).

Figure 5 shows the salinity intrusion trends in the Gorai river catchment, where 6 different ranges of water salinity are shown; range is almost saline free and salinity range is less than 2161 dS/m, and the southern region which is located in the Sundarbans mangrove wetland where salinity range is over 54025 dS/m, it is the highest salinity range in the catchment which has crossed the water salinity threshold line of mangrove wetland ecosystems.

Soil and water salinity is rapidly increasing in the Gorai catchment area, currently, river water salinity moves up as far as Kamarkhali River port in Jessore (Fig. 5) (SRDI, 1997; EGIS, 2000;

Islam, 2008). Since the Ganges water withdrawal and there is extensive withdrawal of ground water for agricultural use, saline ground water and saline sea water from the south intrudes into the fresh water aquifer in the north. This salinization process is steadily engulfing more upstream areas of the Gorai catchment (Fig. 5) (Helcrow, 1993; SRDI, 2000).

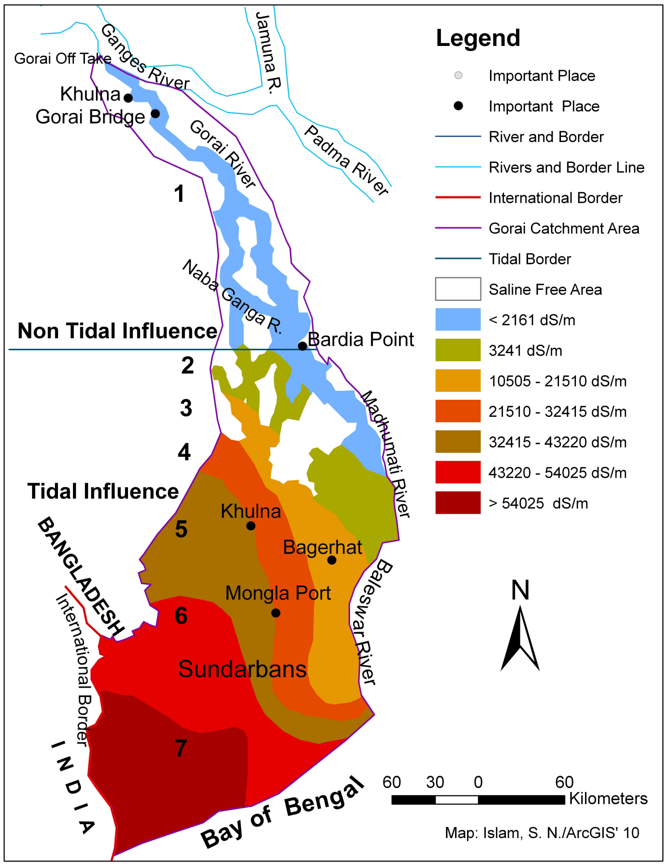

Figure 5 Salinity Intrusions in the Gorai River Catchment in Ganges Delta

Table 1 The Changing pattern of the Gorai River with from 1973 – 1997

Name of the river	Section	1973 m	1980 m	1990 m	1997 m
Gorai River	Gorai 1	577	602	997	1085
	Gorai 2	924	862	814	820
	Gorai 3	493	621	476	466
	Gorai 4	813	854	735	774
	Gorai 5	739	830	772	794
	Average	709	754	757	788

Table 1 shows the Gorai River's sectional width changing pattern from 1973 to 1997. The average width was 709 m in 1973 whereas it was 788 m in 1997. The reason is huge sedimentation and less water flow in the basin. The present study result shows that, about half of Jessore and Magura districts and whole area of Narail district have been affected by soil and water salinity (SRDI, 1997; EGIS, 2000; Islam, 2008a). The figure 5 shows the salinity trends in the Gorai River catchment, based on the present study findings on salinity on Gorai catchment area is stated that the agro ecological region 12 which are located in the low Ganges river floodplain and Ganges tidal floodplain areas are most affected by soil and water salinity in the Ganges delta region. Therefore the ecosystems and ecosystem services are severely affected due to salinity intrusion in the Gorai catchment area.

6.2. Changes of Landscape Morphology of Gorai River Basin

The deforestation intensity in the upstream Himalaya increase deposits of sediments in the down stream and consequently changes of river morphology frequently. The actual allocation of Ganges water at Farakka Barrage point in India has been causing serious concern to Bangladesh due to the reduced availability of flows during past 35 years (Islam, 2007a). The abnormal reduction of Ganges flows caused excessive siltation, elevation of the bed levels and consequent reduction in the flood discharging capacity of the channels, silting of the Ganges thereby blockage of the Gorai River off-take (Anwar, 1988; Islam, 2009a). The Gorai River flows through the part of delta which has been formed about 500 years ago, at present geomorphologically changeable and unstable (EGIS, 2000). The morphological trends are depending on the off-take of the river. The mean annual peak discharge of the Gorai River in the late 1990s is about 4,500 m^3/s; its bed material varies from fine sand to fine sand and silts. The annual average sediment transport is about 50 million tons (for last 3 decades) in which about 40% and bed materials and the rest is wash load consisting of silt and clay. The mean size of bed materials at the mouth of the Gorai River is 0.17 mm (Helcrow, 1993; Delft Hydraulics and DHI, 1996a).

a. Gorai River passing b. Gorai east bank c. Gorai Railway Bridge
Figure 6. Changing pattern of Gorai River morphology in 2003 (a, b, c)

d. Gorai River 7th May 2009, daily Star e. Saline water penetrating at Gorai basin
Figure 7 The Gorai river dry basin and sea saline water penetrating in the upstream (d, e)

The water shortage and sedimentation process in the Gorai basin the bed has been ridged and the width has been shrink and spacious and depth has deduced in different section of the river (Fig. 6

a, b, c). Due to shortage of Gorai River flows and sedimentation, the hydro-morphology of the catchment of the river is rapidly changes. The land use pattern also changing because of soil and water salinity and siltation which is reduced the fertility of soil and agricultural production. The figure 7 shows the shortage of Gorai basin water (Fig. 7 d) and as a result sea saline water are penetrating in the upstream (Fig. 7 e) and increasing in the upstream direction through capillary upward movement (IECO, 1980). Through this process the whole catchment area are affected by high saline water.

In the catchment most of the river water is turbid indicating suspended sediments except in small stretches of the Gorai-Madhumati and Sibsa River. The closed water bodies which are essentially identified in low Ganges floodplain. The area along with floodplains comprises of the major inland capture fisheries area, shrimp farm, beel area, crop land, freshwater bodies, settlements, current fellow land, mangrove forest, dry river and beach sand in the most south of the catchment. The area is covered under different land use categories are as follows; The Gorai River is the distributary of the Ganges and flows through relatively erosion resistant materials along a 90 km reach in the upstream. The maximum rate of bank erosion in this reach is a few materials per year, while it is a few tens to hundreds of materials per year at the most downstream reach (EGIS, 2006; Sarkar, et. al., 1999). The qualitative impact assessment suggests that the wash load must have increased which caused little influence on the river morphology (except the tidal reaches). The changes in the bed materials depends on the intensity and characteristics of the types of interventions, which is the main triggering agent to the changing river landscape morphology of Gorai River basin in the south western region in Bangladesh. The landscape morphology changing patterns are shown in figure 6 and 7.

6.3. Damage of Mangrove Wetland Ecosystems in the Sundarbans

The mangrove ecosystem system is getting more attention to the environmental community for conservation of nature and natural recourses. It has recognized as potential agenda: the ecosystems are socially valuable and in ways that may not be immediately intuited (Daily, 1997). Ecosystems and their services are the benefits that society receives from soil, water, air, organisms and the processes that govern the interactions. Nourishing food and clean water in sufficient quantities are two examples of human needs that would not be met without cycling, and regulating the earth's climate. Other services include meeting the recreational, aesthetic and cultural amenities that are essential for human well being (SWCS, 2009).

According to Dokuchave's theory of ecosystem; it can be defined as a relationship in a mathematical format; where the sophisticated definition of ecosystems can be structured on the following formulas. The meanings of ecosystems mean the functions of biotic and abiotic like as:

Ecosystem = f (biotic and abiotic characteristics); and

Ecosystem = f (s, cl, pm, o, mo, r, w, e, t ,……………)

Where , s – soil, cl – climate, pm – parent material, o – organism, mo – micro organism, r – relief of topography, w – water, e – energy and t – time etc

Ecosystem components include resources such as surface water, oceans, vegetation types and species. Ecosystem process and functions are the biological, chemical and physical interactions between ecosystem components (Vogt et al., 1996).

The Sundarbans mangrove wetlands ecosystems are functioning according to the above mentioned definition and the mathematical formula are given by Vogt et al., in 1996. Mangrove wetlands are a unique environment of floral-faunal assemblages, providing a complex detritus-based food-web

for a number of marine and brackish water organisms. Also the size treats runoff, accumulate sediment, capture runoff and release it slowly to its surroundings and route floods. However, seasonal water shortage is the lack of proper conservation and protection schemes in Bangladesh (Islam and Gnauck, 2007).Ecosystems management takes into account the totality of the relationships between wetlands organisms and their environment where biological considerations take over economic and social factors (Curry and Mcguire, 2002).
The mangrove ecosystem that is simultaneously produces food, fodder, and bio-energy. The coastal mangrove ecosystem of Sundarbans region of Bangladesh is supporting local economy of the country which is under threat due to various degrees of environmental and anthropogenic impacts. The Sundarbans mangrove ecosystem services are public goods, it is damaging due to climate change impacts and anthropogenic influences on upstream fresh surface water supply. They protect coastal communities from cyclone and storm damage, and this function may become even more important as climate change intensifies. Globally, mangroves are being cleaned or degraded at the alarming rate of 1-2% annually, their area declining by a third since the 1980s. In Bangladesh almost 45% of mangrove wetlands are destructed because of multiple pressures including pollution, fuel wood collection, land clearance for aquaculture and coastal development, and natural disasters.

The four types of ecosystems services are functioning in the Sundarbans coastal region and in the Gorai River catchment area. Ecosystems are providing four types of potential services such as supporting services, regulating services, provisioning services and cultural services; those are now under threat due to anthropogenic influences and climatic change impacts on natural resources in the Sundarbans coastal region as well as in the Gorai catchment area. It is also been studied that the changes of Gorai morphological landscapes and present land use has both negative and positive impacts on ecosystems and its services in the catchment area.

7. CONCLUSIONS

The rivers of Bangladesh from one of the largest networks of the world and most of these rivers emanate from outside the country, of which 56 comes from India and 3 from Myanmar. The continuous reduction and deterioration of quantity and quality of the Gorai River's fresh water in the catchment is the root cause of salinity intrusion and damaged of the Sundarbans ecosystems. Considering the present salinity intrusion trends in different ecological zones in the Sundarbans and management condition, an applied research and awareness education programme should be included as a potential environmental development agenda and should introduce for the stakeholders in different stages. Water resources assessment and planning tools that integrate groundwater and surface water are capable of assessing both quantitative and qualitative responses. Water resource models are essential to assess water resource availability and vulnerability at both regional and local scales and to assess impacts of ecosystems and its services. To protect the mangrove wetland ecosystems in the Sundarbans region the alternative approach of proposed upstream water reservoir in Nepal and fresh water supply in the downstream should be ensured. To solve this environmental problem more applied research is necessary and emergency. Water salinity approximation on the Sundarbans Rivers will support planning by decision makers to protect the special natural heritage site and world largest mangrove wetland ecosystems and its services in the Gorai river catchment area in the south western region of Bangladesh. The following suggestions are strongly recommended for implementation for the better development and protection of Gorai River morphology in the basin area and mangrove ecosystems in the catchment;

- Ganges dam could be constructed at the Gorai off-take area or in Rajbari point on the Ganges River. Where huge fresh water could be stored.

- It is essential to make the Gorai River as a breathing river which could supply fresh water year round to protect the ecosystems and its services in the Gorai catchment area specially to protect the Sundarbans mangrove ecosystems.
- Northern region river‘s water could be transferred to the south western region through the Gorai channel; in such case Ganges dam could play a potential role to protect the Sundarbans mangrove wetland ecosystems.
- Gorai water supply could solve the high sedimentation problems and its negative impacts on ecosystems and its services in the catchment area.

REFERENCES

Adams, W.C. (1919). History of the Rivers in the Genetic delta, 1750-1918. East Pakistan: Bengal Secretariat Press.

Adel, M.M. (2001). Effect of water resources from upstream water diversion in the Ganges Basin. In: Journal of Environmental Quarterly. Vol. 30, March-April. 2001. (Environmental Issue), USA. pp 356-368

Anwar, J. (1988). Geology of Coastal area of Bangladesh and Recommendation for Resource Development and Management. In: National workshop on coastal area resource development and management, Part II. CARDMA, Dhaka, Bangladesh. pp 36-56.

Ben, C., Lindquist, A., and Wilson, D. (1995). Sharing the Ganges-the politics and technology of river development. University Press Limited, Dhaka. 272 pp

Curry, J. M. and Mcguire, S. (2002). Community on land/Community, ecology, and the public interest, Rowman and Littlefield publishers, Maryland. USA.

Daily, G. (2006). Conservation planning for ecosystem services. PloS Biology 4: 2138-2152.

DHI (Delft Hydraulic Institute), (1996a). River survey project (FAP 24) - Morphology of Gorai off-take: special report no.10. Dhaka, WARPO.

EGIS – (Environmental and Geographical Information System), (2000). Environmental baseline of Gorai river restoration project, EGIS-II. Bangladesh Water Development Board, Ministry of Water Resources, Government of Bangladesh. Delft, the Netherlands 150 pp.

ESCAP–(Economic and Social Commission of Asia and the Pacific), (1988). Coastal environment management plan for Bangladesh. Vol. 2. Final: Report. ESCAP, Bangkok, Thailand. pp 1-25

FAP 24 (Flood Action Plan), (1996). River Servey Project- Morphology of Gorai off-take: Special Report no.10, Dhaka. WARPO.

FAP 4 (Flood Action Plan) (FPCO), (1993). Draft final report, Vol 3: morphological studies. Ministry of Irrigation, Bangladesh (unpublished).

Fongwa, E. and Gnauck, A. (2009). Value Creation from ecosystems services for business development. In: Modellierung und Simulation von Ökosystemen workshop Kölpinsee 2008, Shaker Verlag, Aachen, Germany. pp 43-56

Goodbred, S.L. and Kuehl S. A. (2000). Late quaternary evolution of the Ganges –Brahmaputra River delta: Significance of high sediment discharge and tectonic process on margin sequence development. Sedimentary Geology, 133:227-248

Halcrow, (1993). Southwest Area Water Resources Management Project (FAP 4) morphological studies, Dhaka: FPCO.

Hoque, M. M. and Alam, S. M. K. (1995). Post Farakka dry season surface and ground water conditions in the Ganges and vicinity. In: Hasna, J. M. (ed). Women for Water sharing. Academic Publishers. Dhaka.

IECO, (1980). Southwest Regional Plan: Supplement e: saline intrusion and tidal hydraulics; supplement f: environment and ecology (part I & II), supplement g: fishery (part I & II), Supplement h: forestry (part I&II), Supplement i: navigation; supplement j: augmentation of the dry-season flows of the Ganges. Dhaka: Bangladesh Water Development Board.

Islam, S. N., and Gnauck, A. (2007). Increased salinity in the Ganges delta and Impacts on Coastal Environment in Bangladesh. In: Skvorsova, L.A (ed.) Proceedings of the International Scientific-Practical Conference Logistics and Economics of Resource and Energy- Saving in Industries (ISPC "LEREI -2-2007") 12th September to 15th September 2007 at Saratov State Technical University, Saratov, Russia. pp 244 - 248

Islam, S. N., and Gnauck, A. (2007a). Effects of salinity intrusion in mangrove wetlands ecosystems in the Sundarbans: An alternative approach for sustainable management. In: Okruszko, T., Jerecka, M., and Kosinski, K. (eds.) Wetlands: Monitoring Modelling and Management. Taylor & Francis, Balkema, Leiden, The Netherlands**.** pp 315-322

Islam, S. N., and Gnauck, A. (2008). Mangrove wetland ecosystems in Ganges Brahmaputra delta in Bangladesh. Frontiers of Earth Science in China. Higer Education Press and Springer Verlag. pp 439-448

Islam, S. N., and Gnauck, A. (2009)**.** Threats to the Sundarbans mangrove wetland ecosystems from transboundary water allocation in the Ganges basin: A preliminary problem analysis. In: Saeid. E. (ed.,) International Journal of Ecological Economics & Statistics (IJEES). Winter 2009, Vol. 13, No. W09; J. Ecol. Econ. Stat; CESER, India. pp 64-78

Islam, S. N., and Gnauck, A. (2009a). The Coastal mangrove wetland ecosystems in the Ganges Delta: A case study on the Sundarbans in Bangladesh. In: Proceeding of American Association of Petroleum Geologist-AAPG Hedberg Conference on Variations in Fluvial-Deltaic and Coastal Reservoirs Deposited in Tropical Environments, 29th April – 2nd May, 2009, Jakarta, Indonesia. pp 26-29

Jabbar, M. A. (1979). Land accretion in the coastal area of Bangladesh- Report of Bangladesh landsat programme, Dhaka. 43 pp

Joseph, P. S. (2006). The environmental management do better supply of fresh water in transboundary basin river. In: Proceedings of III International Symposium on Transboundary Water Management Boundaries, Ciudad Real: Universidad de Castilla-La Mancha, Spain. pp 1-101

Sarkar, D. Chattopadhyay, G.N. and Naskar, K.R. (1999). Nature and properties of coastal saline soil of Sundarbans with relation to mangrove vegetation. In: Bakshi, D.N.G., Saynal, P. and Naskar, K.R. (eds.)., Sundarbans Mangal. Naya Prokash, Calcutta, pp 199-204

SRDI (Soil Resource Development Institute), (2000). Soil salinity in Bangladesh. Government of the People's Republic of Bangladesh. Soil Resource Development Institute, Dhaka, Bangladesh. pp 1-107

SRDI-(Soil Resource Development Institute), (1997). Land and soil utilization guide-Mollarhat, Mohammedpur, Kumarkhali Thana. ISRI, Dhaka.

SWCS, (2009). WWW. SWCS.Org/ 10 AC on 14th December 2009

Umitsu, M. (1993). Late quaternary sedimentary environments and landforms in the Ganges delta. Sedimentary Geology, 83: 177-186

Vogt, K. A. Gordon, J. C. Wargo, J. P. Vogt, D. J. Heidi, A. Peter, A. P. Clark, H. J. Hara, J. L. O. Keaton, W. S. Weygand, T.P. and Witten, E. (eds.,) 1996. Ecosystems – balancing science with management, Springer –Verlag, New Haven, USA. pp 367 - 387

Vitousek, P. (1997). Human domination of earth's ecosystems. Science 277, pp 494-499

Wei, S.K., Lei, A.L. and Islam, S.N. 2009. Modelling and simulation of industrial water demand of Beijing municipality in China. Front. Environ. Sci. Engin. China 2010, 4 (1): 91-101

Williams, C. A. (1919). History of the Rivers in the Gangetic delta 1750-1918. Bengal Secretariat Press, Calcutta. (Reprinted 1966, East Pakistan Inland Water Transport Authority, Dhaka), 96 pp