Reviving Decaying Rivers: Case Studies from Indian Sundarbans

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Abstract: Natural and anthropogenic interferences do hinder channel equilibrium, often resulting into channel adjustments. Among the natural factors, tectonic settings, climate, composition of riverbank, fluctuations in base level are responsible for controlling river morphology. Anthropogenic activities like channelization, river engineering, change in land use result in drainage disruption, channel realignment with meander obliteration. Anthropic changes in the upstream do change bedload causing floods too. Channel shifting is commonly observed in the alluvial rivers. Also, channel oscillation, avulsion and abandonment are present in all the physiographic zones of West Bengal. Up country diversion of water, clogging of offtakes have resulted in reduction in discharge degenerating the distributaries of Ganga in the last 225 years. Reduction of channel capacity arises due to their natural decay or tidal silting which is aggravated by human interference [1]. The three river systems of Indian Sundarban – Adi Ganga, Bidyadhari, Ichhamati systems are in jeopardy with decayed stretches leading to sediment starvation in an already retrograding situation. These river systems are at present severed from their upcountry sources. The deltaic distributaries of Ganga – Bhagirathi, Bhairab, Jalangi, Mathabhanga donot receive water from river Ganga during the lean seasons. The offtake points have already decayed over a century and the main flow of Ganga is diverted towards Padma. This phenomenon leaves the three river systems of Indian Sundarban severed from freshwater sources, only to be maintained by tides. This study aims to chart out a programme for revival of these three river systems of Indian Sundarban through excavation of the former drainage lines and identification of probable alternative routes through an analysis of SOI toposheets (base years 1918,1922-23, 1968, 1993) and Google Earth imageries of 2025-26.

Keywords: Rejuvenation, Decaying rivers, Indian Sundarban, Retrogradation.

I Introduction

The Indian Sundarban forms a unique ecosystem in a tidally influenced halophytic environment. Having an area of 9630 km^2, Indian Sundarban is characterized by an intricate network of rivers and creeks. The crux of this environment is the separation of these creeks from their upstream sources thus causing a starvation of sediments and freshwater inflow. The deltaic part of Sundarban forms the active part of the Ganga delta [2]. The Sundarban has evolved over the millennia through natural deposition of upstream sediments accompanied by intertidal segregation. The settlements at the forest fringes and near the coastal stretches are more vulnerable to the ravages of hazards. Drainage discontinuities and decay often increase the risks from the hazards experienced here. Both physical and anthropogenic stresses have led to decay of the rivers of Sundarban and their discontinuities from other river systems of Sundarban.

II Objectives

1. To identify the defunct and decaying stretches of the three river systems of Indian Sundarban.
2. To find out how these river systems can be revived.

III Methodology

The old routes of the three river systems were found out using Survey of India toposheets, scale 1:50,000 (base years 1918,1922-23, 1968, 1993) and vectors were prepared (WGS 84 datum, UTM 45N projection) using QGIS 2.8.9. software. These vectors were superimposed on Google Earth satellite imagery to find out the present status of degeneration and to find out alternate route so that these river systems can be revived.

IV Physiography of Indian Sundarban

A general slope towards south and south east with height ranging from 3-6 m above mean sea level is observed. Silt deposition is brought about by tidal water and sedimentation brought about by tidal spill decreases with increase in distance from the riverbanks, leading to a depression like topography.

Factors like dynamic depositional surfaces, Bengal basin tectonics, fluctuating sea level, dynamic sediment foci, development and subsequent decay of distributaries, channel avulsions, tidal influences and storm impacts characterize Indian Sundarban. The older delta surface of Hugli-Matla complex is slightly higher than Sundarban and is produced due to the extension of overlapping deltaic lobes of ancient distributary channels of Bhagirathi-Hugli in this region. A large backswamp of Hugli floodplain to the east of Calcutta, which was initially a large mangrove swamp has presently been silted up. Also, the upstream sections of Hugli-Matla have become silted up in forms of bars along the river beds. Sundarban coastal zone is influenced by macrotidal range and strong bi-directional currents. Elongated bodies of sand, found in shallow offshore zone, parallel to the north south extension of larger tidal mouths are indicative of the current dispersion of sediments [3].

V Drainage of Indian Sundarban

Delta building occurred in the quaternary period at the mouth of the distributaries of river Ganga. Separation of the distributaries from upstream sources have resulted in straightened courses joining the sea.

Anastomosing channel patterns, meander creeks, larger tidal mouths of ancient distributaries, bifurcation of channels, link channels, smaller tidal passes along the section of shoreline are the major drainage features of Sundarban. Hugli, Saptamukhi, Thakuran, Matla, Bidya, Gosaba and Jhilla- Raimongal are the principal rivers from west to east. The alluvial plain is dominated by fluvio marine and tidal environments, with course change of the rivers, alleviation of floodplains, decay of channels, erosion of riverbanks, sediment compaction with subsidence and upheaval in stretches.

Riverine ports (Chandraketugarh, Saptagram, Tamralipta and Calcutta) and riverine trade were controlled by the three parallel flows of the Ganga – Saraswati, Hugli and Jamuna near Triveni and the diversion of Hugli-Adi Ganga-Bidyadhari further downstream near Calcutta. In the prograding environment of Ganga delta, the distributary channel system got affected by channel switching, one of the causes of abandonment of the delta.

Sediment starvation is accentuated by bypass of sediments through the "Swatch of no ground" into the deep sea "Bengal fan". River system Hugli-Saraswati-Jamuna and Hugli-Adi Ganga-Bidyadhari were navigable from 2100 to 500 years before present. Further downstream of Tribeni, the southward and south eastward diversion of the channels of river Hugli were demarcated by rivers Adi Ganga and Bidyadhari rivers. The East Kolkata Wetlands and Salt Lake formed the spill areas and backswamps of river Hugli. Such wetland systems play critical roles in groundwater recharge and natural filtration, functions that are increasingly recognized in contemporary wetland studies [4]. Once connected with river Matla, Bidyadhari decayed post 1833 due to siltation of channel beds. Reduction in discharge was brought about by gradual decay of Bhagirathi-Hugli River as the main flow of Ganga got directed towards Padma [1].

VI Three river systems of Indian Sundarban

Adi Ganga, a southward diversion channel of Hugli from Calcutta was the actual route of river Ganga to the sea, which got abandoned around 1740 AD. Linear depressions and a series of elongated ponds at Kalighat, Tollygunge, Garia, Baruipur, Dakshin Barasat, Jaynagar-Majilpur, Mathurapur, Bishnupur and Chhatrabhog provide sufficient evidence of the existence of palaeochannel of Adi Ganga.

In the last 500 years, the original flow of Ganga was through Adi Ganga from Kolkata towards south east upto Bay of Bengal. Presently, it debouches from the river Bhagirathi-Hugli at Hastings and flows towards Kudghat to its south. In the 18th century, a westward canal was dug by the Dutch engineers under the supervision of Nawab Ali Vardi Khan linking a part of the river Ganga to the then dying river Saraswati of Howrah district. This led to gradual reduction of channel width and discharge of Ganga to south and south east, decaying Adi Ganga [5].

Major Tolly supervised the excavation of Adi Ganga in 1779 to link Adi Ganga with Bidyadhari and by this method, Adi Ganga was partially reclaimed. This flow extended upto the bank of Bidyadhari around Samukpota or Tardah, often connoted as Tolly's Nullah.

Ichhamati is dry near it's offtake point at Majdia. The gradual decrease of upstream discharge from Ganga to river Mathabhanga is another reason for the decay of river Ichhamati. River Jamuna can be demarcated upto some few km downstream from its offtake. River Jamuna got decayed as it lost its connection with Bhagirathi-Hugli River. The angular orientation of the channel at its offtake point has changed to obtuse angle restricting the flow of river Hugli into Jamuna.

Bidyadhari has been encroached by fisheries while the downstream stretch (40 km) upto its outfall has dried up. Excavation of Keshtopur canal in 1910 disconnected a portion of Salt Lake spill area and this led to a disequilibrium in the natural drainage from north and led to the decay of Bidyadhari river [6]. River Matla started decaying as the discharge from West Bidyadhari and the Karatia into the river Matla stopped. A number of lateral connections of the Matla River on and from inland side (like Belladona river, Kultala gang, Piyali-Nabipukur river, Chulkati gang etc) are presently in a decaying state, cutting off freshwater discharge to river Matla [5].

Civilization at Chandraketugarh had flourished along the bank of river Bidyadhari. According to historian, Nihar Ranjan Ray, international trade used to be carried using this river within the time span of 300 BC – 500 AD. The distributaries of river Bidyadhari are often collectively termed as Bidyadhari river system, the river Bidyadhari is known as Nonagang at its source, Gumar khal at Habra, Haroa gang at Haroa and Bidyadhari at its mouth. The actual source of river Bidyadhari is river Jamuna, debouching near Haringhata of Nadia district, about 10 km eastward from Tribeni of Hugli. Near Haroa, another branch of river Bidyadhari, went past Salt Lake and joined Matla after traversing a distance of 35.41 km beside the settlements Shamukpota, Kumarpukuria, Sangur, Nabhasan, Tardah, Kapasat, Sudia, Garanbere, Narayanpur, Homra-Palta, Sarengabad, Bagmari and Tambuldaha. The port of Tardah grew up at the confluence of Tolly's Nullah and Bidyadhari and was used by the Portuguese as a military base. The river Bidyadhari was active from 1830 to 1883 and its vigour got increased due to the construction of Circular Khal in 1833 and Kata khal in 1859 but it started decaying after the construction of Dhapa lock gate which got accentuated after the excavation of Bhangore Kata Khal of length 24.14 km from Bamanghata to Kulti. Further in 1897, two lock gates constructed at Bamanghata and Kulti restricted the flow of water into Bidyadhari thus leading to further decay. Krishnapur khal was constructed from 1908-1910 which led to permanent decay of this river.

Once the polluted waters of Kolkata took the route towards the Bay of Bengal via rivers Adi Ganga, Tolly's Nullah, Salt Lake, Beleghata, Kulti Gang, Dhapa lock gate, Krishnapur khal, Bhangore kata khal, Bidyadhari, Piali, Karatoya and Matla. The spill areas of Salt Lake were natural factors. Lord Bentinck had thought of reviving Salt Lake in 1830, but it couldn't be possible due to financial crisis. River Bidyadhari was very much active within 15^{th}-16^{th} century but owing to tectonic changes, the flow of river Ganga drifted eastwards towards river Padma and as a result the rivers Bidyadhari, Suti, Jamuna, Khardah Gang, Noai got dried up from 1795-1805.

The excavation of Tolly's Nullah (from Hastings to Shamukpota, on the western bank of river Bidyadhari), Old Eastern Canal and Entally – Beleghata (1880), Circular Canal (from Chitpur to Entally-Beleghata Canal) in 1820, New Cut Canal (from Ultadanga to Dhapa lock gate – 1850), Dhapa lock gate and Chitpur lock (1880-81), Bhangore kata khal (1895-97), Krishnapur khal (1908-1910), connection between Kulti Gang and new cut canal, circular canal and construction of Bamanghata lock gate in 1935 were done in order to protect Kolkata. Development of fisheries, sewage and polluted water reaching Kulti Gang and Tolly's Nullah led to decay of these canals and also to the decay of river Bidyadhari.

Sundarban Delta Project: Engineer Dr. B.N. De developed Kulti Outfall Scheme under which two canals of length of 33.796 km were cut from Tapsia to Kulti. These canals were named as Storm Water Canal and Dry Weather Flow. He had also constructed sedimentation tanks on 40 bigha land area of Bantala. The sedimentation tanks were of 13 feet depth and radius of 260 feet each. The water holding capacity was about 37.5 lakh gallon, costing 13 lakh rupees at that time. The sedimented water used to be filtered and the filtered water used to be emptied in Kulti Gang and the sediment was pumped into 7 ponds or lagoons. This sediment was indeed fertile and was distributed in other districts. Also, there was a system of dredging at the mouth of sluice gate of Kulti Gang near Ghushighata but this scheme became obsolete in 35 years. In 1958, the then Chief Minister of West Bengal, Dr. Bidhan Chandra Roy visited Netherlands and witnessed the successful implementation of the Dutch Delta Programme. He also noted that there are indeed some resemblances between West Bengal coast and coastal stretches of Holland. The Sundarban Delta Project was formulated by Mr. Nedoko, famous Dutch river scientist in the year 1962. This project had 3 stages. In the 1^{st} stage, one embankment was to be constructed in a transverse manner on river Saptamukhi, at a distance of 19 km landward. A series of embankments were also to be built on river Hugli, Namkhana estuary, Saptamukhi river, Eastern gully, Walsh creek, Kalchara, Gobadia Gang and these embankments were to join the previous embankment on Saptamukhi. In the next two stages, it was planned that other embankments like that on Saptamukhi would be constructed on rivers Thakuran and Kalchara. Both sides of this embankment would be joined with other embankments as well. Also, Gangasagar and Mousuni islands were decided to be encircled with embankments. The major objective of Sundarban Delta Project was to connect the sea dykes along coastal stretches with the embankments on the estuaries. The area between rivers Hugli and Matla was under this programme. This programme was considered as a protective measure to protect Sundarban from saltwater flooding as a result of cyclones. However, it was a challenging task to protect the sea dykes from the strong sea waves and so it was decided that estuarine embankments would be constructed first and slowly these would be proceeded seawards. The cost of this programme amounted to 18.75 crore rupees in the year 1967. This programme would lead to improvement of drainage, provide assistance to production of crops and improve fisheries too but this programme couldn't be implemented. Also, a programme of construction of an irrigation canal of length 215 km from Minakhan to Basanti was decided upon in 1980, which would bring dual cropping in Canning, Basanti and Minakhan. Another canal of 10 km length would be cut with a reservoir of capacity of 113 cusecs at the confluence of Kulti Gang and Ghaghramari but it was not constructed [7,8].

VII Condition of deltaic distributaries of Ganga

Inception of 19^{th} century saw Bhagirathi to get seasonably cut off from Ganga [9] and emergence of Padma as the most important deltaic distributary of the river. Offtake of Bhagirathi from Ganga at Suti has degenerated to such an extent that during "low stage" parts of the year, water flows towards Ganga instead of entering into it [10]. The lower course of the river is maintained by tides (entering

290 km upstream from the confluence) apart from contribution by rivers from western plateau region and diversion of water from Ganga during lean season (January-May) by Farakka barrage.

Shift of primary discharge to Padma probably got initiated from 4 ka BP with eastward growth of the delta [11]. Offtake of river Bhagirathi at Suti was observed to be non-navigable during the lean season of January 1666 [12]. Discharge through Bhagirathi-Hugli was less than that in Ganga, the proportion being 1:6; being almost dry from October – May at its headwaters [13]. Sherwill in 1858 [14] identified that the general slope of the land towards south east or the centre of the basin aids Ganga to proceed straight instead of entering into Bhagirathi.

Bhairab Jalangi and Mathabhanga Churni fall into Bhagirathi-Hugli from east but neither of these rivers receive any water from Ganga during the non-monsoon months, owing to sedimentation at the offtake points, maintained mostly by groundwater. Average annual and peak discharge of the month of September at Churni are estimated to be 60 and 156 cumecs respectively. These are not much different from those of river Jalangi. During dry season the beds of Bhairab-Jalangi, Mathabhanga-Churni are covered to farmlands. During the flood of September 2000, water took more than a week to get drained out through the channels like Ichhamati and Kulti Gang as these were occupied by embanked aquaculture ponds and silt collection pits for brick kilns [15].

Table 1: Pollution parameters of some rivers of West Bengal

Rivers	Biochemical Oxygen Demand (mg/l)	Dissolved Oxygen (mg/l)	Maximum Coliform Count (MPN/100 ml)	pH	Dissolved Solids
Bhagirathi (Berhampore)	3.2	8.2	110000	8.33	2
Hugli (Garden Reach)	3.5	6.9	1400000	8.11	488
Hugli (Diamond Harbour)	3.2	7.1	110000	7.96	2838
Jalangi (Krishnanagar)	1.2	7.0	–	8.10	325

The Ganga Brahmaputra delta system encompasses vital rivers like Bhagirathi, Bhairab, Jalangi, Mathabhanga. Originally emanating from Ganga- Padma flow, Jalangi takes its name from the village Jalangi to the east of Murshidabad district of West Bengal which is in close proximity to its original offtake [13]. River Bhairab which can be cited as the initiation of Jalangi has now turned inactive. This river once flowed from Padma (main distributary of river Ganga) across the present beds of Jalangi and Mathabhanga in southeast direction. The river moved further east towards Faridpur of Bangladesh [16]. According to Reaks [17], Jalangi could have opened up at the end of 17th century, flowing south west into Bhagirathi-Hugli system, cutting across Bhairab flowing south east. Heavy siltation at its offtake has led to decreasing flow in river Jalangi.

The original offtake of Jalangi has turned non functional at present. After getting initiated, the river follows a south west course, forming the boundary between Murshidabad and Nadia districts. Jalangi also converges with Sialmari and Bhairab. Jalangi then flows south to enter into Nadia. Trailing tortously towards south in Nadia, it proceeds towards west upto Mayapur where Jalangi empties into Bhagirathi-Hugli rivers.

Bed of the offtake of Jalangi is observed to be higher than the low water level of the surface of Ganga [14]. The angle of the offtake is obtuse preventing the required discharge of Padma to enter Jalangi. Collectively known as the 'Nadia rivers', Jalangi alongwith Bhagirathi and Mathabhanga formed a network of moribund rivers [16]. These rivers were non navigable in the dry season as early as 1781, as suggested by Rennell [13]. Colebrook in 1801 [9] suggested refuting Rennell's claim of a navigable Jalangi, that Jalangi was not navigable during the dry season though it used to be navigable during the whole or greater part of the year. River engineering works such as dredging were carried to ensure navigability. Jalangi was navigable for medium sized boats throughout the year in late 1820s.

A northward shift of the Jalangi offtake due to devastating flood of 1831 was observed [18]. Post flood, the upper course of Jalangi grew sluggish as it failed to transport the silt received from Padma. Within 1821 and 1847, Jalangi had shifted 5 times according to the shift of Padma to keep itself active. Since 1880s, the flow of Jalangi is maintained by Bhairab and the river is navigable till now for small and medium sized boats. The general health of Jalangi in its upper course has changed significantly, leading this part to become a palaeochannel over time. Also, the channel width has been decreasing continuously. Floods during monsoons still are commonplace. Location of brick fields, occurrence of water hyacinths, pose considerable threat to river health. These anthropogenic pressures mirror findings from other Indian river systems, where agricultural expansion, urbanization, and infrastructure development have been identified as primary drivers of environmental degradation [19]. Switchover from one distributary to another is a normal phenomenon in delta building process according to Oldham [20] and Bagchi [2].

According to Mukherjee [21], rising and subsidence of land in some parts of the delta affected the opening up and choking up of the main distributary sources; though Stevenson-Moor et al. [22] reported earlier that there is no evidence to justify elevation or subsidence of land. Morgan and McIntire [23], Basu and Chakraborty [10], Khandelkar [24], Khan [25], Goodbred et al. [11] held faulting responsible for shift of the distributaries of Ganga. Sengupta [26] observed that the mobility of the basement complex of Bengal basin led to recession towards south east part with this movement being widest in the eastern part of Ganga Brahmaputra delta. As a result, knick points produced in western Ganga – Padma distributaries would be located far from their offtake points. As headward migration of the knick point is proportional to the volume of discharge through the channel, Padma river carrying maximum discharge goes through the most frequent migration of its own knick point resulting in shift of thalweg. The offtakes of the distributaries are beheaded. Seasonal variability of discharge in Padma leads to sedimentation on the channel bed of Jalangi itself, as loss of kinetic energy with the entry of monsoonal discharge into Jalangi would lead to settling of sediments on the channel bed itself [15].

Rennell in 1780 [13] observed Bhairab as a small stream draining out of Kalkali river towards south near Akheriganj, following the course of Suti nadi [17]. In 1914, Bhairab had completely captured the upper course of Kalkali taking off the Ganga about 15 km west of Akheriganj. It changed its course leaving the old Bhairab resulting in separation of Kalkali and Sialmari. At the start of 20^{th} century, offtake of Sialmari shifted 5 km north of Akheriganj. The flood of 1978 swallowed the entire upper course of Bhairab. The offtake of Sialmari river was wiped out and over the years it has become a palaeodistributary. Bhairab acts as the main entrance of Jalangi as the upper course suffers from siltation and only operates as a flood spill channel. Width of the current channel of Jalangi is about $1/3^{rd}$ of the abandoned cutoffs [15].

In 12^{th} century, distributary Jamuna was a navigable channel connected with river Bhagirathi-Hugli ([27], [28]). At present, this river is disconnected from Bhagirathi-Hugli. The average width of Jamuna in 1956 was 319.81 m. Large cutoffs like Mathura bil and Maricha bil were observed in 1922. An abrupt change of river geometry was brought up after losing the connectivity of Jamuna river with Bhagirathi-Hugli. Width of the channel confluence at Tipi Ghat has reduced drastically.

Human encroachment of meander loop and excavation of canal for straightening the channel were observed. Channelization has led to confinement of the river. Reduction of carrying capacity was observed due to excessive siltation and low discharge. Excessive siltation of the channel bed has increased its height. The geomorphological units of the floodplain are largely encroached and modified by humans. Flood occurences have also greatly influenced the morphological condition of channel through lateral shifts by erosion accretion. Also, conversion of channel bed into paddy field and river water pollution have taken heavy tolls on river health of Jamuna [29].

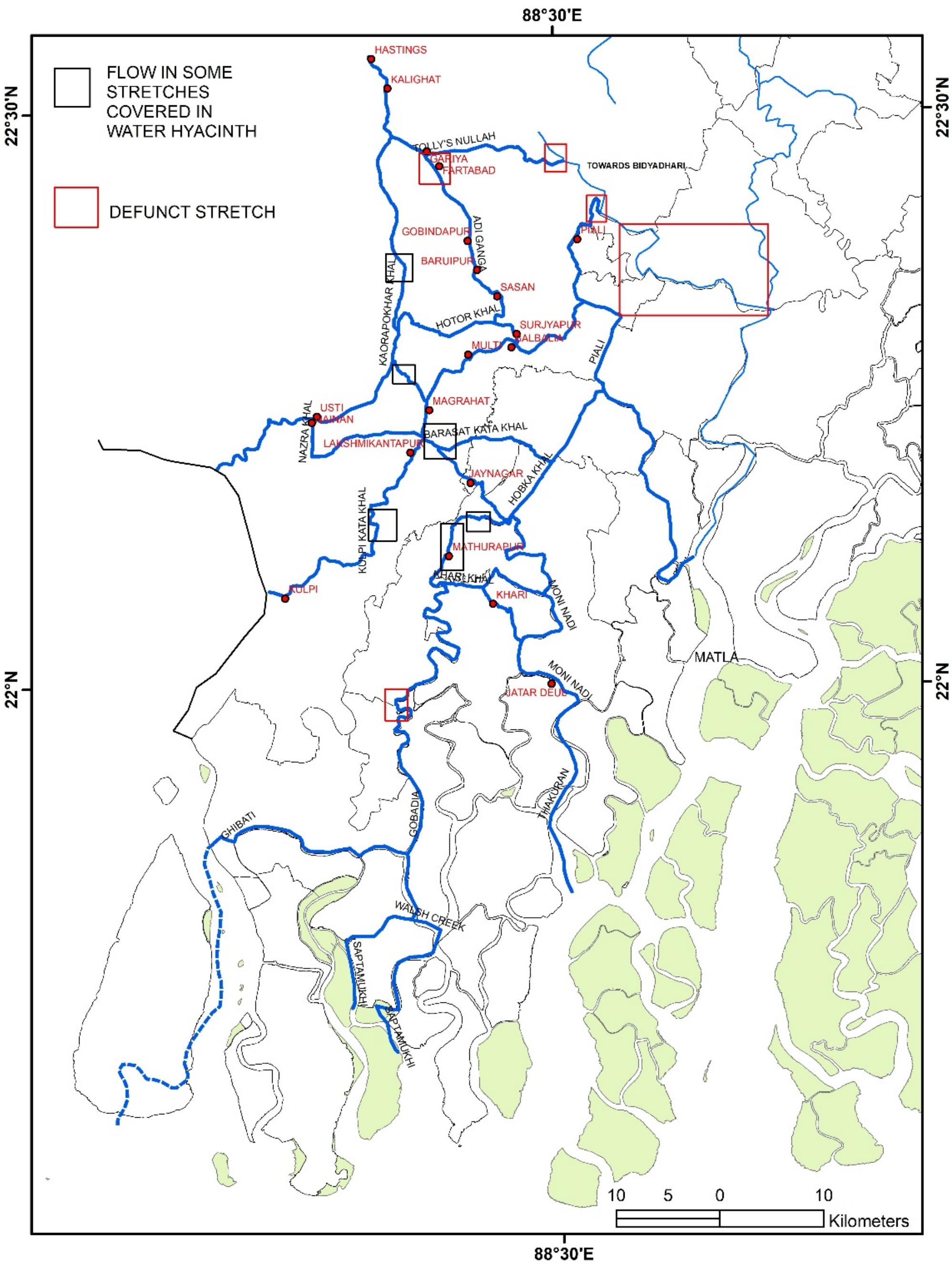

Figure 1: Old and probable route for reviving Adi Ganga (old route to Sagar Island is shown in dotted blue line)

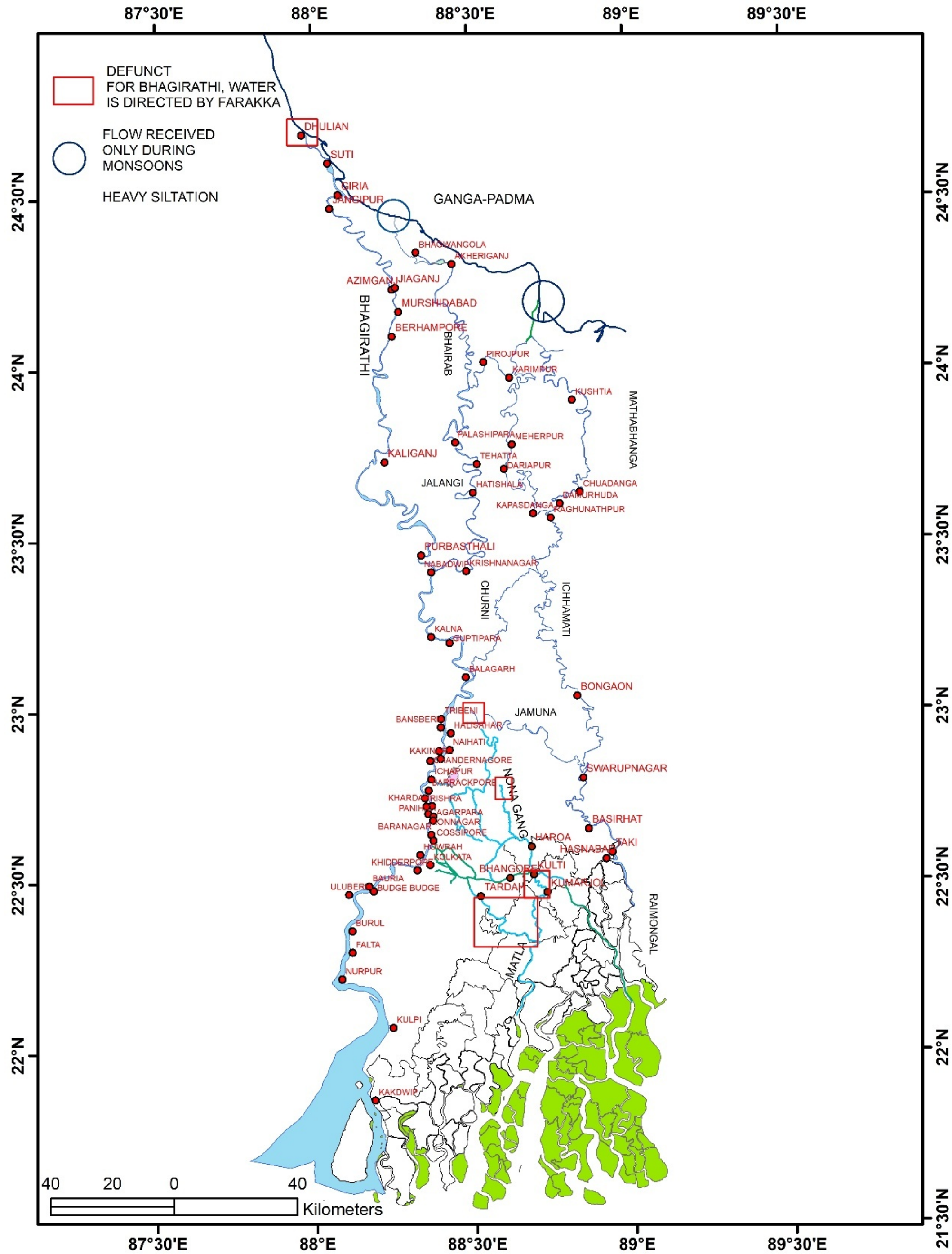

Figure 2: Headwaters feeding Adi Ganga, Bidyadhari and Ichhamati river systems

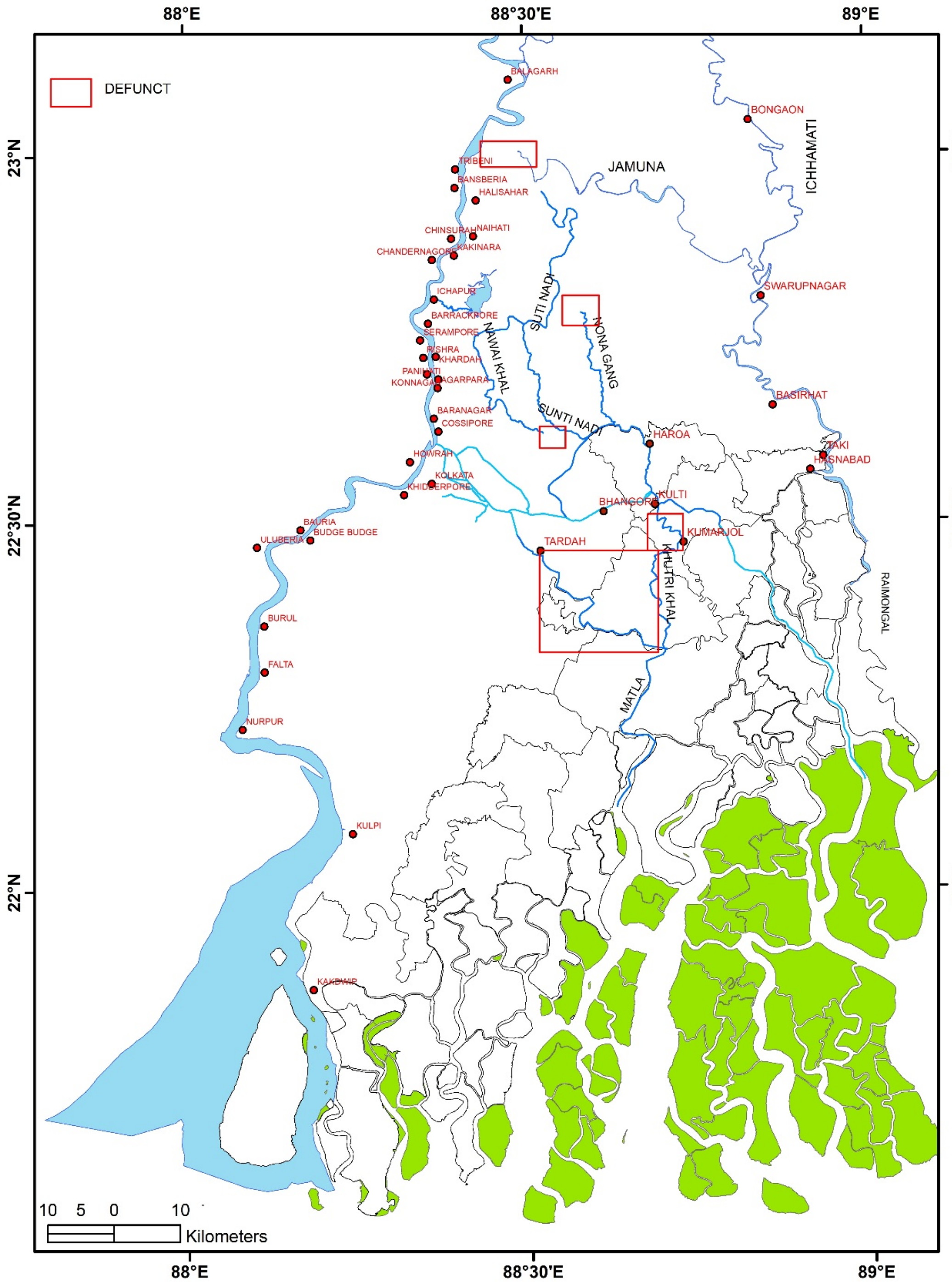

Figure 3: Probable route for revival of Bidyadhari and Ichhamati systems

VIII Probable routes of three river systems of Indian Sundarban

Five probable routes in and out of Adi Ganga can be traced in all probability. Outfalls can be traced to river Hugli via Diamond Harbour and Kulpi, to Saptamukhi estuary, Thakuran estuary and river Matla.

Diamond Harbour route: Kaorapukur khal (29.005 km) can be used as it emanates from Adi Ganga near Kudghat. Then as it connects with Usthi Nainan outfall channel (10.435 km), the accumulated water is directed towards Diamond Harbour creek (14.531 km) which empties into Hugli River. Also, the same route can be accessed from Surjyapur using Hotor khal (12.305 km).

Kulpi route: Water of Adi Ganga can be directed from Surjyapur along settlements Multi, Magrahat and Lakshmikantapur using the canals Surjyapur khal (10.215 km), Magra Jaynagar khal (14.647 km) and Kulpi kata khal (19.039 km) towards Kulpi. Alternatively, water can be directed towards Kulpi kata khal using Nazra khal and Sangrampur Outfall channel.

Route towards Saptamukhi estuary: From Surjyapur, a westward route along Multi using Surjyapur khal (10.215 km) can be followed, upto Magra Jaynagar Khal (14.647 km), flowing past Jaynagar Majilpur. From there, using Burar khal (2.035 km) and Chitraganja khal (5.324 km), the palaeochannel of Adi Ganga can be accessed upto Sudhirghat. From the settlement of Chandbhasa, Banstala khal (16.658 km) can be accessed. Chora Gangadora khal (5.463 km) can be accessed from the settlement of Bakultala. The rivers Kaloa, Gobadia (18.102 km), Barchara and Walsh creek can then be used to direct the water towards Saptamukhi estuary, though Kaloa river has got decayed at present. Alternatively, Curzon creek also can be used to direct the water towards Saptamukhi estuary.

Route towards Thakuran estuary: The same route can be followed upto Burar khal, then the water can be directed to Moni nadi. Alternatively, Khari khal can be used past Chandbhasa and the water can be directed towards Thakuran via Moni nadi.

Route towards Matla: Water from Adi Ganga can be directed towards Matla River using Surjyapur khal and Piali river.

Alternate route through river Bidyadhari: As the Bidyadhari system has become defunct at most of the stretch, water from river Hugli can be directed towards Ichapur khal, which also needs to be revived at stretches. Water from Ichapur khal can be directed towards Bidyadhari river via Nawai khal and Suti nadi. This flow can be continued upto Haroa Gang upto Malancha. At Malancha this flow gets bifurcated, the water flow can be then directed towards Bidyadhari, Bermajur nadi, Kalagachi gang along Atapur and finally to Raimongal river.

Alternative route through river Ichhamati: River Ichhamati is observed in a decayed stretch near its origin from the river Mathabhanga at Majhdia. Thus if the river flow of Jamuna originating from Tribeni can be restored, this flow can be directed towards Ichhamati, just north of Swarupnagar.

IX Conclusion

Rejuvenation of defunct riverine stretches of Indian Sundarban is the need of the hour in order to supply sediments in an already sediment starved retrograding environment. Also, revival of the headwaters is necessary for this to materialise. However, with the gradual siltation and obliteration of offtake points, it is necessary to trace out alternative routes of freshwater influx. This can involve dredging, along with restoration of natural connections of separated tidal channels which have become clogged. In channel sedimentation has reduced tidal prism and restoration of tidal flow is necessary to combat this morphologic inequilibrium.

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