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Degeneration of Jalangi River: An Investigation Based on Maps and Satellite Images

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Abstract

Jalangi is a distributary of the Padma River which has opened up within the last few hundred years to flow actively in the southern and south-western direction through the districts of Murshidabad and Nadia in West Bengal. Initially, its source was the original Jalangi offtake located near Jalangi village, Murshidabad district. Earlier, it used to meet Bhairab River at two different points 5 km apart. But due to irregular flow of water, this part of the Jalangi River has become a palaeochannel and the discharge through Jalangi River is now maintained by Bhairab River. So, the lower part of the Bhairab River is actually the present Jalangi River. It flows into the Bhagirathi-Hugli River near Mayapur in Nadia district. The part of Jalangi River in Nadia district is considered for this study which is representing the

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lower course of the river. Jalangi is active during the monsoon season and Nadia district is quite susceptible to the flooding of Jalangi and Bhagirathi-Hugli rivers. Jalangi River is otherwise suffering from lack of supply of water to maintain its flow during the drier part of the year. This study is an endeavor to map the behavior of the Jalangi River in the past two hundred years.

The database for detecting the changes in the Jalangi river course consists of J. Rennell's *Bengal Atlas* (1780), *Atlas of India* maps (1855-56), and topographical maps of 1: 63,360 scale (1914-18); satellite database includes Landsat (MSS, TM, ETM+) images (1973-2010) and LISS IV Mono images (2007). Discharge data of different periods have been used for identifying the variation of water flow through the main channel. The main channel of Jalangi is characterized by intense meandering and the channel has shifted a few times in the recent past. This fact is confirmed by the presence of ox-bow lakes, meander scars etc. near the main channel. It can also be found from the old maps of the 18th and 19th century that width of the Jalangi river channel—which was at a par with the Bhagirathi-Hugli river until a couple of centuries back— has been decreasing.

The main reason behind decreasing water flow in the Jalangi River is the shifting of the main channel of Ganga coupled with rapid siltation occurring at the off-take of Jalangi River. This prevents the discharge to enter through the course of Jalangi except during the monsoons. The other factors disturbing the main channel are sediment quarrying from the river bank and dry river bed, land-use changes, contamination of river water through the release of effluents into the river, garbage dumping etc. The presence of water hyacinth is a common phenomenon in the lower course of the river indicating eutrophication. The anthropogenic impact is mostly visible in the areas near Krishnanagar city. In spite of bankful and sometimes overbank discharge during the monsoon season, there is a possibility that the river could turn into an abandoned one in near future. Mitigation measures with proper planning should be implemented to regenerate the river environment.

Key words: Distributary, Offtake, Flooding, Palaeochannel, Meandering, Abandoned, Regenerate.

Introduction

The river Jalangi is a vital part of the Ganga-Brahmaputra Delta (GBD) system. The original offtake of the river is located near a village called Jalangi in the eastern part of the Murshidabad district, West Bengal. The river owes its name to the village Jalangi (Rennell, 1781). The initiation of the Jalangi river could be sourced to the course of presently non-active Bhairab river, which once flowed from the Padma river (main distributary of Ganga) across the present beds of Jalangi and Mathabhanga rivers in the south-easterly directions, and further eastwards towards Faridpur district of Bangladesh (Hirst, 1915). Since the main channel of Padma is shifting continuously, it might have affected the offtake of Bhairab in an adverse manner. Jalangi opened up long after the Bhairab ran as a strong stream. It is assumed that the Jalangi River opened up at about the end of 17th century, flowing south-west into the Bhagirathi-Hugli river and cutting across the Bhairab river flowing south-east (Reaks, 1919), although there is no direct evidence of this. During the greater part of 19th century, the discharge in this river has considerably diminished due to siltation of its offtake (Garrett, 1910).

The original offtake of Jalangi, though presently non-functional, is found to be at the north of the Jalangi village (24°11'01"N, 88°43'15"E), where Padma river takes a perpendicular bend towards east to enter Bangladesh. After initiation, the course of the river followed south-westerly direction and formed the boundary between Murshidabad and Nadia districts. On the way, Jalangi converges with Sialmari and Bhairab (opened up during early 20th century by capturing the upper course of the Kalkali river) rivers. The discharge through the Bhairab course is continuous and therefore it maintains the flow of the Jalangi River after the confluence. Jalangi, after meeting Bhairab, flows southward to enter Nadia district. It trailed in a tortuous manner towards south within Nadia until it reaches Ghurni near Krishnanagar town. From Ghurni, it proceeds due west up to Mayapur where it falls into the Bhagirathi-Hugli river (23°24'55"N, 88°23'48"E).

Previous Works

Although the decay of Jalangi River is appeared to be a major issue, it is surprising to note that documented research works highlighting the decay of Jalangi River are few. Initial works on Jalangi River include the reports prepared by Fergusson (1863), Garrett (1910), Hirst (1915), Addams-Williams (1919), Reaks (1919), and Stevenson, Moor et al. (1919). Those reports mainly emphasized on how Jalangi River was opened up during the course of the time. Even though there were a few mentions about how the general health of the river is deteriorating, a comprehensive account of the decaying river system is lacking. Moreover, the reports were compiled about a century ago. Therefore, the present condition of Jalangi River could not be successfully gauged by these reports.

Significant works related to the degeneration of GBD rivers progressed only after the independence of India. Initially, Basu and Chakraborty (1972) started the proceedings with the decaying Bhagirathi drainage system. Later, Sen and Basu (1974) mentioned that the bed of the offtake of Jalangi, like Bhagirathi is considerably higher than the low water level of the surface of Ganga (Sherwill, 1858). Therefore, the offtake could be left dry if the water level of Ganga (or Padma) recedes further. They highlighted that the angle (> 90°) at which Jalangi takes off from Padma river is awkward as it could prevent the required discharge of Padma to enter Jalangi. They had also pointed out the disproportion between the supply of water from Padma to the Jalangi river during the monsoon as well as in the dry season in this regard.

Standing on these premises, this paper endeavors to underscore the behavior of Jalangi River for the last couple of centuries using chronological maps and satellite images. It also aims at emphasizing the interference by the human agencies on the river.

Degeneration Scenario

Jalangi flows through the moribund portion of the southwestern GBD as found from the three-part division of southwestern GBD made by Bagchi (1944). Jalangi, along with Mathabhanga and Bhagirathi formed a network of moribund rivers in the concerned region for study and are still collectively known as the 'Nadia Rivers' (Hirst, 1915). These rivers were the most important means of communication until the advent of railways and were open for navigation throughout the year. It was first revealed by Rennell (1781) that these rivers were not usually navigable in the dry season. He stated that the Bhagirathi River was almost dry except monsoon months and Jalangi was non-navigable in some years during two or three months of the dry season, though a stream flowed through it perennially. He also showed that Jalangi was the only navigable river of the region. Later Colebrook (1801) revealed that Jalangi was not navigable during the dry season, though previously it used to be navigable during the whole or greater part of the year. For purely navigational purpose, the ruling British Government initiated some measures like dredging to resurge the moribund rivers in the early 19th century with only Jalangi responing positively. It was in favourable condition during late 1820's and was navigable for the medium sized boats throughout the year. In 1831, a devastating flood occurred in the Bhagirathi basin which opened up the Bhagirathi River for navigation. The flood water inundated a major portion of the moribund region and caused a northward shifting of the Jalangi offtake (Garrett, 1910). The upper course of the Jalangi River became sluggish after that and it failed to transport the silt which it received from Padma River. The shoaling behind the offtake continued for a long period and as a result the river remained unfavourable during the middle part of the 19th century. Lang (1851) monitored the entrance of the Jalangi from 1821 to 1847 and showed that it had shifted five times during this period in accordance with the shifting of Padma in order to keep itself active. Therefore, since the midway of the 19th century, upper part of the Jalangi is gradually transforming into a palaeochannel. The situation is different in the lower course after the confluence point of Bhairab and Jalangi Rivers. The Bhairab River started to open up in 1874 and during 1880's, it developed into the main entrance channel of Jalangi (Reaks, 1919). Since that time, the flow of Jalangi is maintained by Bhairab River and the river till now is navigable for the small and mid-sized boats throughout the year. After the meeting point, Jalangi follows a winding path to course through the Nadia district up to its confluence with Bhagirathi near Nabadwip town. The most remarkable feature of this lower course is that the meandering curves are well preserved and their variability in different times seems to be minimal. This section gives an appearance of a river with well established banks in most places, probably made up of stiffer materials and therefore less subject to erosion (Reaks, 1919).

Methodology

Details of the maps and satellite images studied for the current paper are presented in Table 1. The graticules and reasonably stable cultural features like road junctions, bridges, embankments etc. were used as the references for matching the maps and satellite images with one another. The distortions in the final output are likely to be insignificant here as the maps and satellite images were reduced, rather than enlarged, in scale. The results are supported by the Ground Truth Verifications done on the field by taking some strategic Ground Control Points (GCP's) using Global Positioning System (GPS).

Findings

The obtained results are the outcomes of the comparative study of the maps and satellite images of the *moribund* delta. They are recapitulated in Fig. 2-6 and in Table 2. They reveal the changes in the Jalangi river course for the last two centuries with some evident development.

- The offtake of the Jalangi River has shifted over different periods with the shifting thalweg of Padma. The original offtake is non-functional now. It is a real challenge to locate the original offtake in the field as well as in the contemporary satellite images.
- Significant changes in the general health of the channel occurred in the upper course of Jalangi and that part has become a palaeochannel during the course of time.
- The discharge of Bhairab River helps the flow of Jalangi River to continue up to its convergence with Bhagirathi-Hugli River. Otherwise the entire course of Jalangi would have become a palaeochannel.
- During the last century or so, major changes in the morphological character of the lower course of Jalangi could not be traced.
- The channel width of Jalangi River is decreasing continuously.

- Flood appears to be a major threat for the region during the monsoon season and a substantial proportion of land remains inundated for a long time if a major flood occurs. But even a high intensity extreme flood event may not bring about long term changes in the channel morphology of Jalangi.
- Location and arrangement of the brick fields, occurrence of water hyacinth, usage of river water for sanitation purpose etc. further degrade the health of Jalangi River.

Discussion

Shifting Offtake of Jalangi River

As a part of the active GBD system, opening of Jalangi River from Padma could be traced on the evolution of the distributaries of the GBD throughout the geological History. In this regard, Oldham (1870) and Bagchi (1944) considered that switchover from one distributary to another is a normal part of the delta building process. Therefore, it indicates that the opening up and shifting of the offtakes is a common phenomenon in a dynamic delta like GBD. Later Mukerjee (1938) mentioned about rising as well as subsidence of land in some parts of the delta which affected the opening or choking up of the main distributary sources. But Stevenson-Moor et al. (1919) reported earlier that there is no evidence to justify the elevation and subsidence of the delta though they admit that those processes are determining forces behind the drainage development of the delta. Afterwards, Morgan and McIntire (1959), Basu and Chakraborty (1972), Khandelkar (1984), Khan (1991) and more recently Goodbred et al. (2003) held faulting as the responsible factor for the shifting of Ganga distributaries.

According to Banerjee and Saha (1972), the gradual decay of the Jalangi source region could be attributed to a negative change in the base level for the Ganga distributaries in recent times. Sengupta (1966) stated that due to the mobility of the basement complex of the Bengal basin the sea-face has receded towards south-eastern part and expectedly this movement is widest in the eastern part of the GBD. As a result, knick points produced in the western distributaries of Ganga-Padma would be located further from their offtake points as compared to the eastern distributaries. This theory is applicable to the parent river also. Since headwater migration of the knick point is proportional to the volume of discharge through the channel, Padma River, which carries the lion's share of discharge, experience the most frequent migration of its own knick point resulting into regular shifting of its thalweg. Consequently, it beheads the offtakes of the distributaries and therefore the bed of the offtakes lies higher than the water level of the parent river Padma, forming a hanging valley relationship. The status of the offtake of Jalangi signifies the same scenario. The theory of the mobility of the basement complex of the Bengal basin to the eastern and south-eastern direction is actually substantiated by many workers viz. Oldham (1870), Reaks (1919), Fox (1938), Bagchi (1944), Bakr (1971), Basu and Chakraborty (1972), Niyogi (1975, 1989), Bagchi and Mukherjee (1978),Choudhury (1978), Chattopadhyay (1985), Rudra (1987). They suggested that the delta building procedure occurs to be in the east or south-east direction by throwing successive overlapping deltaic lobes relating to the different distributaries which came into prominence and lost importance one after another (Bandyopadhyay, 2007).

Sen and Basu (1974) forwarded that Jalangi, with its decaying head, would be in an awkward position to receive the incoming discharge from the Padma river. The variability in the discharge of Padma in different seasons played an important role here. During monsoon, offtake of Jalangi used to become active with greater amount of discharge. But as soon as the discharge used to make an entry into the Jalangi course, the flow would become sluggish since by then it would lose its kinetic energy so much so that the sediment it carried along would settle down at the bed of Jalangi. Therefore in the drier times and even in the wet season afterwards, it was practically impossible for Jalangi offtake to receive a substantial amount of water to maintain its flow. As a result, it became abandoned about a century ago and the stream behind it transformed into a palaeochannel. In this context, they put forward the noble concept of obtuse angular offtake of Jalangi which might have formed in order to cope up with the continuously shifting Padma thalweg.

The abnormal supply of discharge from Padma to Jalangi was also mentioned by Lang (1854). He calculated that the discharge of Padma stood at 118,304 cusecs in January 1853 and

13,55,707 cusecs during flood season of 1853 at Sarda (located in Bangladesh, about 18km. north of the original offtake of Jalangi). Though the amount of discharge received by the Jalangi offtake was not mentioned, he observed that the least depth of the water column at the entrance of Jalangi in dry season was 0 ft. and greatest depth in flood season was 22 ft. It was further stated by him that Jalangi was non-navigable in the month of February. The records between 1840 and 1853 showed that the greatest depth of water column at the entrance of Jalangi during floods was usually more than 20 ft., but the least depth in dry season rarely crossed 1 ft. indicating variability of water supply in Jalangi river. The discharge records of Jalangi at Punditpur, Nadia for 1915 confirmed the same situation as the discharge recorded for September was 75,000 cusec (using Kutter's formula) and for February it was only 2,780 cusec. The records of 1914, 1916 and 1917 marked the same degree of variability in the discharge amount of Jalangi in flood and dry seasons (Stevenson, Moor et al., 1919).

In the current study, the 1780 Map of Cossimbuzar Island revealed that the original offtake of Jalangi was adjacent to the Jalangi village, Murshidabad. But 1855 Atlas of India map indicated that afterwards it shifted by 3 km. to the north of Jalangi village. The offtake existed even in the first half of the 20th century. But in the recent maps and images, the absence of the Jalangi offtake is noticeable, although the parent river Padma have shifted quite a few times.

Shifting Offtake of Bhairab River

Rennell (1780), in his map of Cossimbuzar Island, pointed out Bhairab as a small stream drained out of the Kalkali River towards south near Akheriganj and followed the course of Suti Nadi (Reaks, 1919). But in the latter half of the 19th century, it opened up only to capture the upper course of the Kalkali River. Reaks (1919) also stated that in 1914, Bhairab had completely appropriated the upper course of Kalkali and took off the Ganga about 15 km. west of Akheriganj. It then took a perpendicular bend towards south near Akheriganj to follow the course mentioned by Rennell up to Banti where it started to follow a new course leaving old Bhairab. As a result the connection between Kalkali and Sialmari was lost and subsequently at the start of 20th century, the offtake of Sialmari shifted 5 km. north of

Akheriganj. From the image of 1973, it is very clear that the Padma channel is working southward near Akheriganj and eventually after 1978 flood it swallowed the entire upper course of Bhairab. Therefore, the presently the offtake of Bhairab river can be seen near Akheriganj. This entire sequence of events has badly affected the Sialmari River as its offtake was wiped out and ultimately in due course of time, it has become a palaeo-distributary. Since opening up, Bhairab River acts as the main entrance of Jalangi River as the older upper course of Jalangi has silted up and only operates as a flood spill channel.

Confluence of Jalangi and Bhairab

With the emergence of Bhairab as a strong stream in 19th century, Jalangi River had revived in the downstream portion after confluence with Bhairab near Madhupur in Nadia. Until the first half of the 20th century, the confluence was quite active as Bhairab used to flow effortlessly and Jalangi used to receive a substantial amount of discharge from Sialmari to maintain its upper course. The scenario changed afterwards as the Jalangi channel has silted up due to the sluggish flow caused by the degeneration of Sialmari. After 1978 flood, Jalangi re-energized temporarily due to the surfacing of a new spill channel which left the older channel near Garibpur in Nadia to converge with the Bhairab River at about 5 km. north of the older confluence. But it also degenerated within a few years in the same manner of the older course. The beds of both channels of Jalangi are positioned at the confluences in such a way that the concept of hanging valley at the offtakes put forward by Sengupta (1966) could again be evoked.

Changing Width of Jalangi

It is very obvious from the maps and satellite images that the width of the channel of Jalangi has been decreasing with time. The changing dimension of thalweg is basically caused by the variability of discharge in different years as well as different seasons. In the upper course, the effect is severe as in some parts, the channel discontinued leaving no mark of the once existing thalweg. Even in the lower reaches, decreasing width of the river is quite evident. Therefore, it could be asserted that the regime of the Bhairab River which contributes to the lower course of

Jalangi is becoming lethargic day by day and in the coming years, both the rivers would be converted into abandoned streams like the upper course of Jalangi. In Table 2, it is shown how the width of the Jalangi River has been altering in the last two centuries. To estimate the earlier condition of Jalangi, a couple of abandoned cut-offs have also been referred. It is found that the width of the current Jalangi channel is about one third of those cut-offs indicating that in earlier times, Jalangi was indeed a healthy distributary of GBD system. However the age of those cut-offs is unknown as it is not very clear from the available maps and images.

Absence of Significant Morphological Alterations in Jalangi Watershed

Except one or two cut-offs, major morphological changes could not be detected in the entire Bhairab-Jalangi tract. Bagchi (1944), in his evaluation of the geomorphic division of the GBD, classified this area as a part of ineffectual moribund delta. However, Bandyopadhyay (2007) countered Bagchi's view by stating that the area gets flooded at regular intervals and as a result vertical accretion occurs regularly by depositing silt layers. The channel pursues a meandering path all along and the direction of movement is mainly southward and south-westward. Though such a course is common in GBD, alteration in the channel orientation of Jalangi is a rare thing which is not expected for a river flowing in the supposedly active delta region. This indicates that the materials of the river bank are so rigid that the bank has become less susceptible to erosion. Therefore, it could further suggest the geomorphological stability of the region. In Table 2, it is shown that the sinuosity index of the river has not changed significantly in the last century. The features like natural levee, backswamp, floodplain and oxbow lakes are well established here. Almost all these features came into existence long ago and from the available data source, it is impossible to even guess their actual age. But it is evident that the river was quite active in the initial years. However, the channel takes an unusual westward turn near a place called Ghurni which may be doctored by the subsidence of Nadia region mentioned by Hirst (1915).

Flooding in the Jalangi Basin

This portion of GBD gets flooded at regular intervals. The terrain is almost flat and general topography is only characterized by natural levee systems and earthen embankments alongside the river channel. In the present form, Jalangi has not been unable to contain the monsoon discharge within its banks and therefore the region becomes susceptible to floods almost every year. The last of the major floods occurred here in 2000 and that was the worst in living memory (The gauge height reading of Swarupganj station near Bhagirathi confluence on 24th September, 2000 was 11.92m. while the extreme danger level of water is still marked at 9.05 m. Data Source: West Bengal Irrigation and Waterways Department). In some parts, the levees and dykes often act as barriers and prevent the water from getting back into the main channel causing stagnation of floodwater till it is percolated down or drained out using some palaeochannels. Moreover, it is important to know whether the morphological features of the region would withstand a given level of flood. But the threshold flood magnitude (discharge and stage) required for bringing about a detectable change in the morphology of the area is not very certain. Significant alterations are hardly there in the channel orientations. Features associated with the floodplain morphology haven't changed too much either. Therefore, it can be understood that flood appears to be a major problem during the monsoon season and a substantial proportion of land remains inundated for a long time. But a high intensity flood event may not bring about long term changes in the fluvial morphology. The existing morphological characteristics might be the outcomes of relatively slower and less devastating ongoing fluvial processes.

Anthropogenic Interferences

Interference of human agencies should be mentioned in the context of the degenerating Jalangi River. Activities like brick making, sediment quarrying from the river bank and dry river bed, release of industrial and household effluents into the river, garbage dumping etc. have caused the degradation of Jalangi River in the recent past.

The unwanted consequences of the brick making industry positioned near the river were first mentioned by Hirst (1915).

In order to make bricks, the brick field authorities cut pits across the bank up to the brick-field so that during monsoon, the sediment-filled water could passage into the brick-field. This water then evaporates and percolates down in due course of time so that during the dry season, only the silt is left to be used in the brick-making process. As these brick-fields are located very close to the main channel, the normal flow of the river gets disturbed which deteriorate the health of the river. According to West Bengal Irrigation Department officials, every brick-field should be located at least 100 m. away from the Jalangi channel. However, in reality, most of them violate the government order and some of those brick-manufacturing units don't even possess any kind of permit.

A few industries are located near populous Krishnanagar town which is the district headquarter of Nadia. Waste matters released from those industries and other sources drain out of the city environment to the Jalangi River. Also, the river water is used for sanitation purposes. These, altogether degrades the condition of Jalangi.

The presence of water hyacinth is a common phenomenon in the lower course of the river indicating eutrophication. Impacted by human activities (both agricultural and industrial), the nutrient supply have been increasing in the Jalangi river and as a result water hyacinth invades the Jalangi course especially during monsoons, resulting into a choked up channel in few parts. These plants, known locally as *Kochuripana*, can unbalance natural lifecycles in a river like Jalangi which generally receives large amounts of nutrients.

Conclusion

Jalangi River still acts as a necessary component for the people of Nadia district. Human beings carry out different activities depending solely upon this river. From this study, it is revealed that the alterations in the physical landscape are very few in the areas through which the river continues to flow, further evoking the notion of moribund region suggested by Bagchi (1944). However, gradually the channel is shrinking and the water is getting polluted by different agents.

So, even though the discharge through Jalangi is satisfactory during the monsoon season, there is every chance that the river could turn into an abandoned one in the near future. The consequences could be really hazardous and could severely disrupt the eco-systems in the region. The curative measures with proper planning and management could be suggested to regenerate the river environment.

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Table 1. Degeneration of the Jalangi River in Nadia Districts: Data Source

Producing Authority	*Details of the map/ satellite image*	*Year of survey/ Date of pass*	*Scale/Spatial Resolution*
East India Company	J. Rennell's 1780 *Cossimbuzar Island* Map	circa 1770's	1: 760 320
SoI	Map no. 120 of Atlas of India	1851-55	1: 253,440
SoI	Map no. 121 of Atlas of India	1851-55	1: 253,440
SoI	Map no. 78 D	1847-68	1: 253,440
SoI	Map no. 78 D/8	1914-16	1: 63,360
SoI	Map no. 78 A/7	1916-18	1: 63,360
SoI	Map no. 78 A/9	1916-18	1: 63,360
SoI	Map no. 78 A/10	1917-18	1: 63,360
USGS	Landsat MSS, P148R043	22/02/1973	60 m.
USGS	Landsat MSS, P148R044	16/01/1973	60m.
USGS	Landsat 4TM, P138R043	11/11/1989	30m.
USGS	Landsat 4TM, P138R044	19/01/1989	30m.
USGS	Landsat ETM, P138R043	30/09/2000	30m.

USGS	Landsat ETM, P138R044	30/09/2000	30m.
USGS	Landsat ETM, P138R043	21/01/2010	30m.
USGS	Landsat ETM, P138R044	21/01/2010	30m.
NRSC	IRS P-6 LISS 4 Mono P108R055Q-A26/12/2007		5.8m.
NRSC	IRS P-6 LISS 4 Mono P108R055Q-C26/12/2007		5.8m.

SoI: Survey of India
USGS: United States Geological Survey
NRSC: National Remote Sensing Centre.

Table 2. Channel Pattern Observations of Jalangi River

Year	*Length* of the channel (in km.)*	*Sinuosity Index*	*Area covered by the river width (in sq. km.)*
1780	155.25	2.39	52.45
1855	170.05	2.62	28.16
1916	177.78	2.74	21.84
1973	185.50	2.86	17.77
1989	183.21	2.82	17.51
2007	183.57	2.83	14.74

*Lengths were calculated from the confluence of Bhairab-Jalangi up to the confluence of Jalangi-Bhagirathi.

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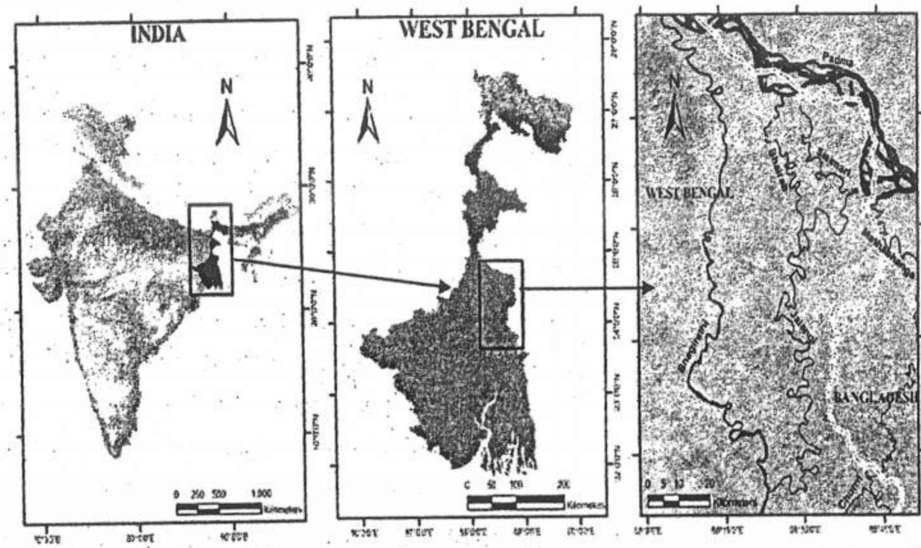

Fig. 1. The Jalangi River and other major distributaries of Upper Ganga-Brahmaputra Delta (GBD).

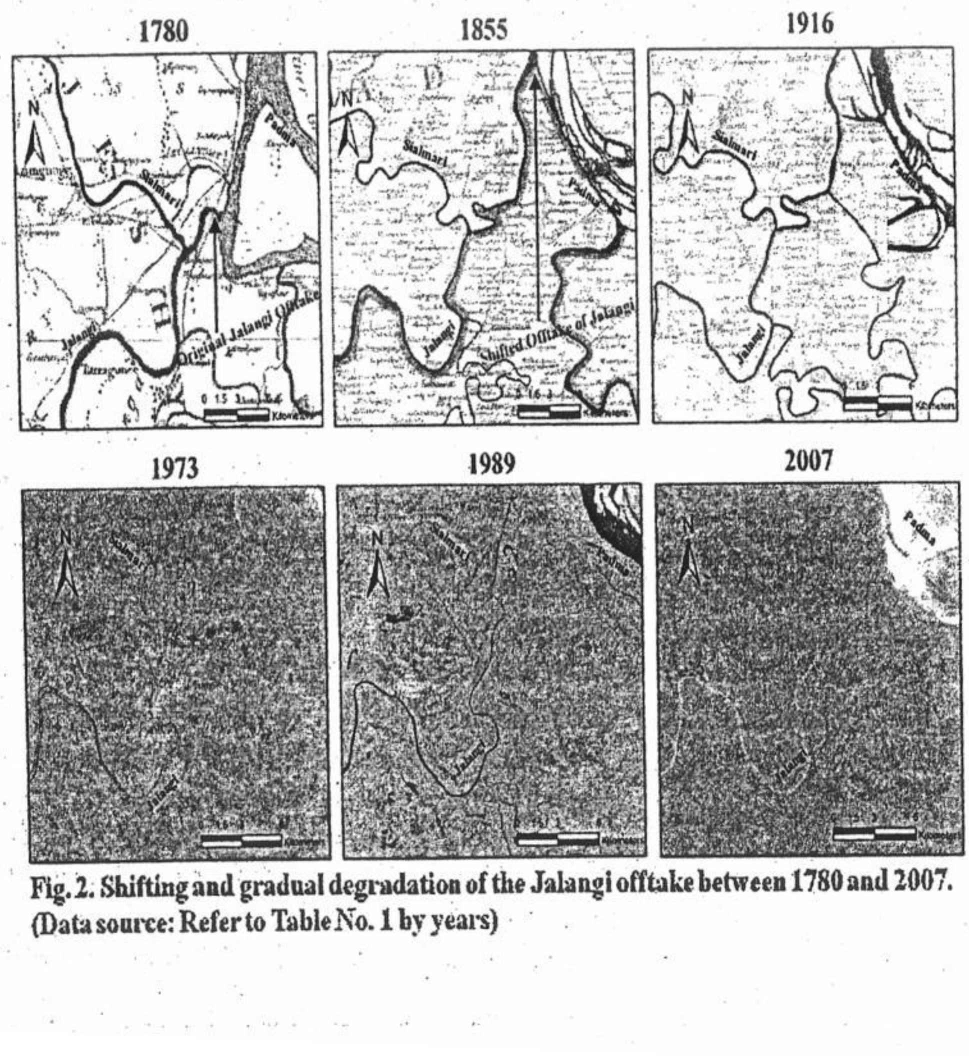

Fig. 2. Shifting and gradual degradation of the Jalangi offtake between 1780 and 2007.
(Data source: Refer to Table No. 1 by years)

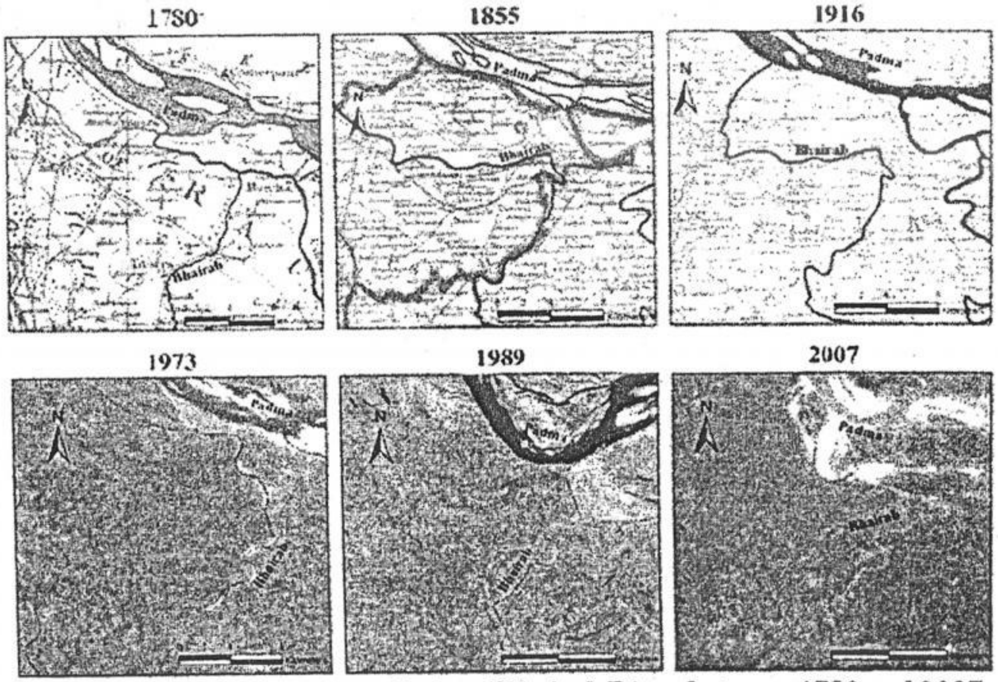

Fig. 3. Frequently changing offtake of Bhairab River between 1780 and 2007. (Data source: Refer to Table No. 1 by years)

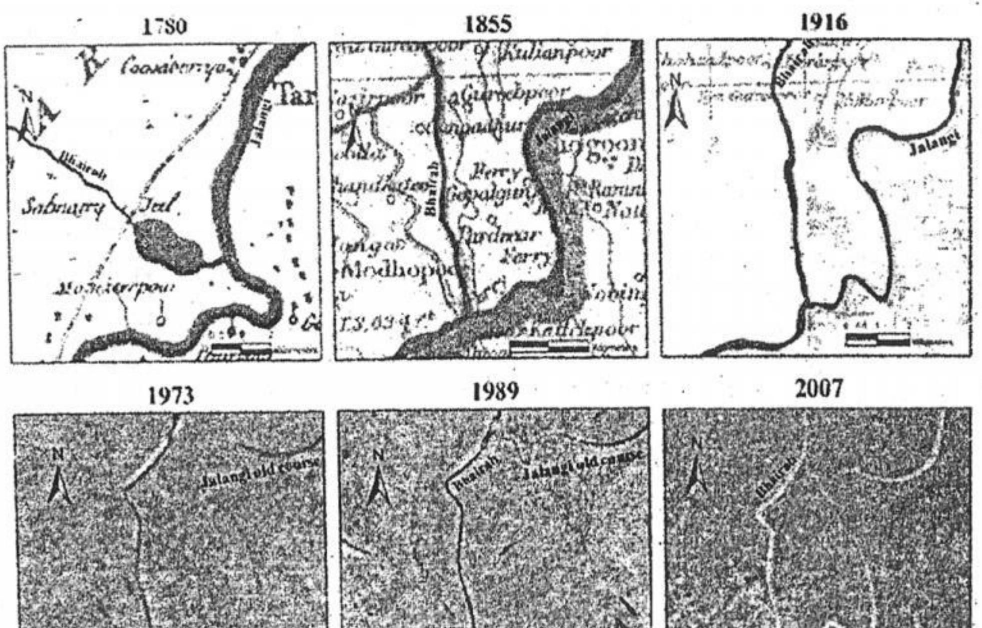

Fig. 4. Condition of the confluence of Jalangi and Bhairab Rivers between 1780 and 2007. (Data source: Refer to Table No. 1 by years)

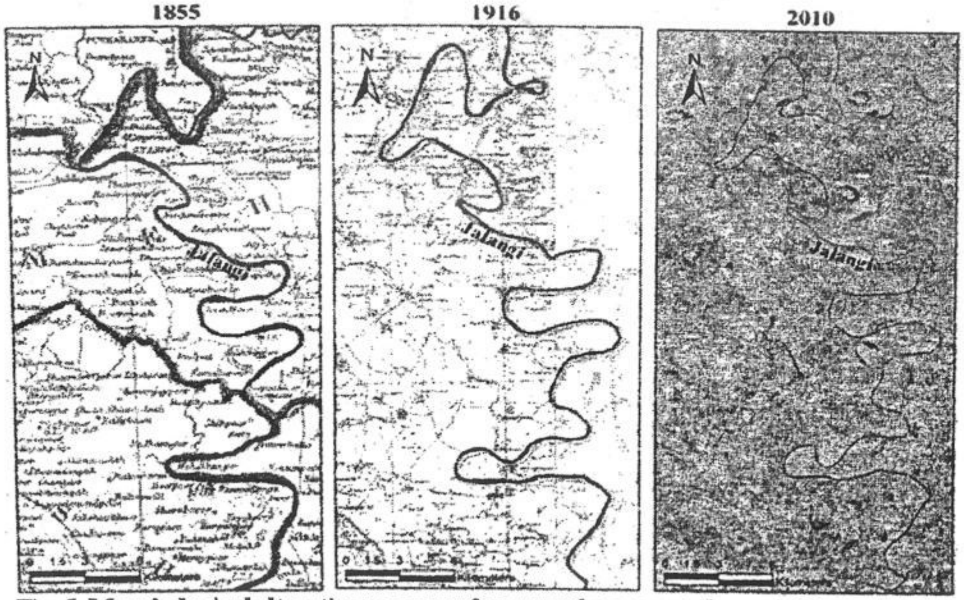

Fig. 5. Morphological alterations are very few near the present channel of Jalangi in the last couple of centuries. (Data source: Refer to Table No. 1 by years)

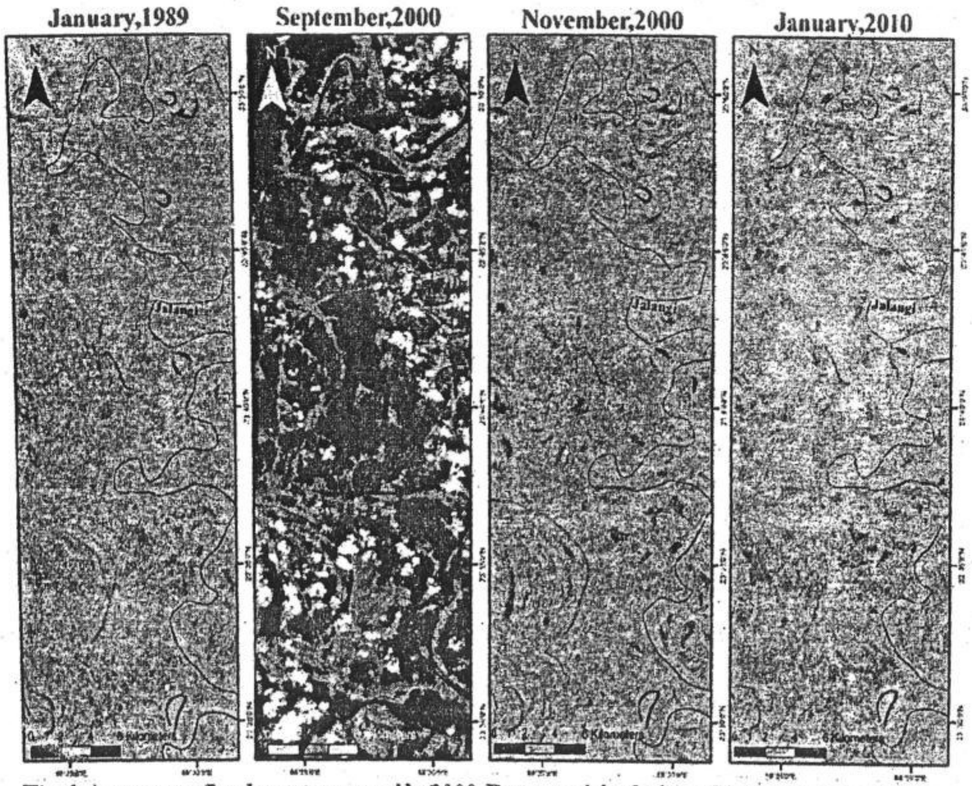

Fig. 6. An extreme flood event occurred in 2000. But surprisingly, it could not enforce any change in the channel morphology. (Data source: Refer to Table No. 1 by years)