

Morphodynamic changes of Hooghly River and reorientation of Chakdaha settlement: a perspective of urban evolution (WB, India)

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Abstract Association of human settlements with river is a historical phenomenon; their imprints upon present-day human organizations are quite visible. The shifting of river channels sometimes creates tremendous locational hazards to the human settlements, for instance shifting of Hooghly River course resulted in the obliteration of old and emergence of new settlements. The present work is a modest attempt to investigate the morphodynamic effect of Hooghly River on a historical Chakdaha settlement. The erstwhile ‘Chakradaha’ an agro-based rural settlement came to exist as ‘Chakdaha’ town sometimes in the nineteenth century; presently, it is located in Nadia district of West Bengal, India. The ever-changing meandering course of Hooghly River in Bengal basin made a gigantic interference in the formation and deformation of settlement boundary of Chakdaha. Due to the westward shifting, remains of Hooghly River can be seen in the present form of paleo-channels which were active river beds during fifteenth to seventeenth century. The natural levees were formed simultaneously. Such levees were withstanding in early time as highlands; now the same exist as linear human settlements, namely Noda-Durgapur, Malichaghar, Raninagar, Gangaprasadpur, Doardanga, Poradanga, etc., in Nadia district. Besides, these also mark the west boundary of Chakdaha town in some places.

Keywords Morphodynamic impact · Human settlement · Locational hazards · Shifting of river · Paleo-channels · Natural levees

1 Introduction

Meandering is one of the significant morphological systems, and it is associated with river course the changing pattern and associated flood plain through the continuous process of river erosion and deposition. The natural process of bank erosion and channel relocation

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affects the river-based urban settlements. The studies on such natural laws have become easy and relatively more authentic through the scientific process of image analysis and assessment. The river channels are very dynamic with respect to their actions in different geoenvironmental settings. The fluvio-geomorphic features and bank erosion are spatiotemporal as well as man-induced factors. Channel shifting has multipronged effect on the human life and their displacement; it has also snapped lives of men and animals (Bora and Kar 2013). One of the striking fluvio-dynamics of the deltaic Bengal of recent times is the state of decaying of its river channels (Basu and Chakraborty 1972). The process of meander formation begins with the bank erosion (Fridkin 1945). Bank erosion and channel shifting are natural as well as common phenomena of Hooghly River (Sanyan 2008). Traditionally, Hooghly River channel has a meandering tendency. The bank erosion and land reallocation is a longstanding problem along the banks of the Ganges. The erosion of gigantic stretches of land and subsequent emergence of *Chars* (riverine island emerges through the deposition process) has been in progress for the last 200 years or so (Rudra 2011). The process of channel shifting, bank erosion and land use change are interconnected, and it is a part of the fluvial system. Such a process is visible further downstream too (Islam 2013). High-enormity and sudden beginning of the floods generally induces intense kinematic water wave which enhances transportation capacity of huge amount of sediment and causes rapid river morphological change (Guan et al. 2015). This statement greatly contradicts the field evidence that river bed can be mobilized during floods and effect of channel morphology on flood dynamics has been basically unacknowledged although recent studies have determined the geomorphic impacts upon the outburst flows (Jenkins and Hanes 1998). Li et al. (2014) observed that the very strong erosion and the decrease in bed friction due to the bed change increase peak flow discharge within hyperconcentrated floods in the Yellow River (China). According to Walling (2009), the lower Yellow River in China, Chao Phraya River in Thailand and the upper Kolyma River in eastern Siberia are making a serious vulnerability along both banks. These rivers have a long history of lateral migration and avulsion. It is believed that the Bhagirathi was the main flow of the Ganga River once hundreds of years ago in India. The present channel of the Bhagirathi River, with its sacred traditions and ruined cities, witnesses an ancient course of the Ganga River (Laha 2015), while in West Bengal state of Indian, the Bhagirathi River joins Jalangi River at Mayapur (Hindu mythological holy place) of Nadia district (Sampat 1996). The combined flow of both rivers (Bhagirathi and Jalangi) is known as the Hooghly River. At Nrupur of Medinipur district of the same state, another mighty river, namely the Rupnarayan River, joins the Hooghly River and their combined flow discharges water to the Bay of Bengal (Fig. 1). Hooghly River system is a lifeline of the people of southern West Bengal, which makes static supply of water for irrigation, domestic and industry consumption. The channel of this river has highest sinuosity, and the parcels of acute meandering along the paleo-channel formations exist on its younger flood plain (Mallick 2016). The river shifting is a volatile natural process and accelerated due to the river bank erosion and channel shifting. Various scholars champion among them Rennell (1781), Colebrooke (1797), Sherwill (1858), Hunter (1876), Hirst (1915), Mukherjee (1938), Sanyan (2008), Rudra (2010), Islam (2013), Laha (2015), Roy (2015) and Mallick, (2016) have featured and scientifically analyzed the shifting nature of the Bhagirathi-Hooghly channel. Their scholarly works support the channel shifting of Bhagirathi-Hooghly River system. Their works encircle the morphodynamic nature of the Bhagirathi-Hooghly River.

Symbiotic relationship between the rivers and human settlements has a long history. Major imprints of river dynamism can be vividly visible on the human settlement. Human settlements tend to grow on either side of the river at best suited location and always try to

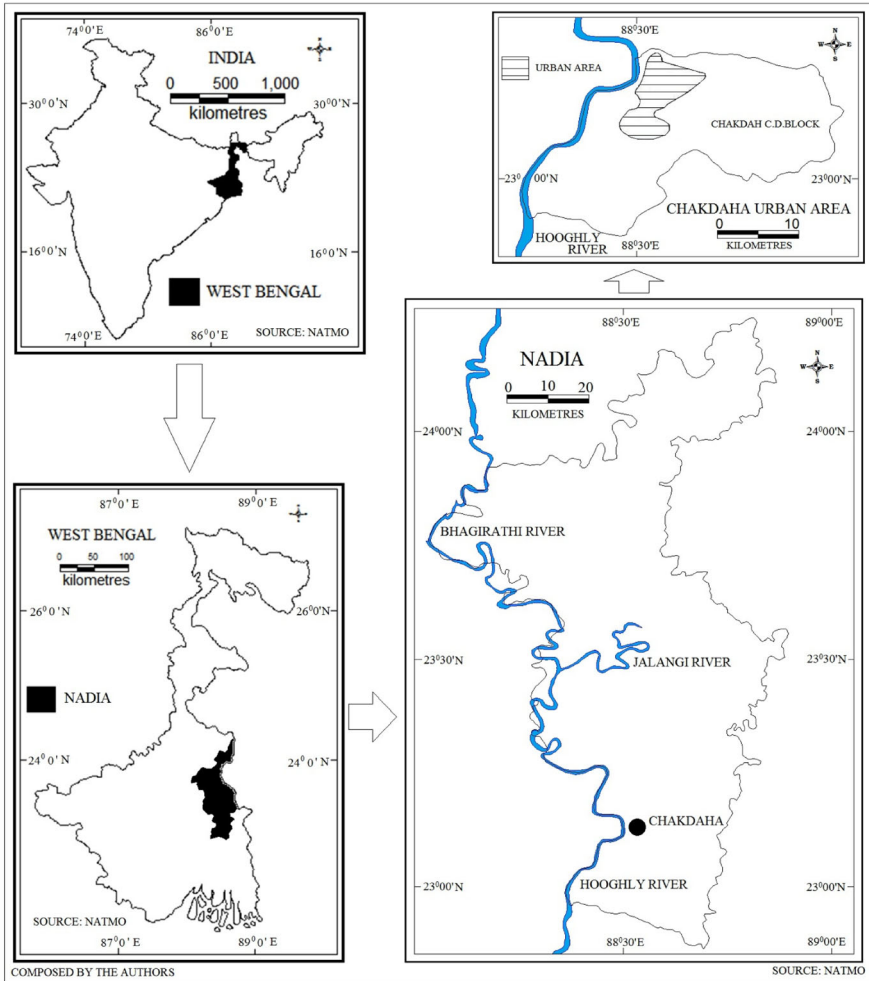


Fig. 1 Location map of Chakdaha town

adjust their position with shifting of the river course. The shifting nature of river channel sometimes creates tremendous locational hazards to human settlements. The river shifting causes socioeconomic problems to the people living along both banks of the Hooghly River since long past. Every year hectares of crop lands and habitable lands are submerged under the Hooghly River. The part of Nadia district is worst affected by the river shifting (Roy 2015). The Hooghly River, by its shifting nature, has obliterated old settlements; however, many settlements have grown up over time. ‘Chakdaha,’ the case study settlement presently, is an important municipal urban unit evolved out from an agro-based rural settlement sometimes before the nineteenth century (Nandy 1994). It was notorious for the Ganga pilgrimage at the time of development of Sukhsagar (presently submerged under the Hooghly River due to river sifting) during seventeenth century (Garrett 1910). Chakdaha settlement was evolved in the embankment of the Hooghly River. Rivers have always been the source of drinking water for the human being during the historical periods. The river

barrier in land route attributed to begin the use of ferry point which favored the emergence of river-based towns like ‘Chakdaha’ in Bengal. The ancient ‘Chakdaha’ settlement was established on the left bank (i.e., east bank) of the Hooghly River. The ever-changing meandering course of Hooghly River resulted in the reorientation of Chakdaha settlement boundary.

Urbanization is the manifestation of modern life of humans. It is not just population maximization and rather yields land use transformation in orderly, organized and planned manner. This paper aims to answer how the shifting of Hooghly River course causes the obliteration of old and emergence of new settlements. The present work is a modest attempt to investigate the morphodynamic effect of the Hooghly River on the evolution of Chakdaha settlement which initially came up as hamlet and later turned into a small town; now it is recognized as a Class-II Indian town. This study seeks to examine the process of reorientation of Chakdaha settlement boundary in response to the river shifting over the past few centuries. It also endeavors to analyze the reorientation of Chakdaha settlement using modern scientific tools like GIS and GPS.

2 Study area

‘Chakdaha’ is the study area of the present work; it is an urban unit in Nadia district of West Bengal (India). The Hooghly River flows along the west side of the Chakdaha town (Fig. 1). Chakdaha town has been developing, and presently it consists of 21 wards spreading over 15.56 sq. km area (as per municipality record). The Chakdaha town has recorded total population of 95,203 persons comprising 48,047 males and 47,156 females (Census of India 2011). It has recorded 90.95 percent literacy rate wherein 93.96 percent among male and 87.88 percent among female population. In the year 2011, it is recognized as Chakdaha Urban Agglomeration (UA) comprising Chakdaha town itself and nearest 04 census towns, i.e., Punglia, Lalpur, Chanduria and Simurali (Census of India 2011).

Chakdaha settlement from its very inception has been experiencing lose and gain of land over time due to the morphodynamic change of the Hooghly River. Its morphodynamic nature has posed a locational hazard to Chakdaha and resulted in the reorientation of its boundary. Through the process of land loss and land gain, Chakdaha turned from a simple hamlet (late eighteenth and early nineteenth century) into a present-day Chakdaha UA.

3 Database

The impact of morphodynamic change of the Hooghly River on the reorientation of Chakdaha town has been analyzed on the basis of primary and secondary data. The Census of India, District Statistical Handbook, old testimonies and official records of Chakdaha municipality are important sources of secondary data. The entire work focuses on the spatiotemporal changes of riverine land area, which analyzes the current satellite imageries. Satellite images have facilitated in the change detection analysis and helped in the identification of river bank position as well as urban boundary at particular latitude and longitude. The shifting position then cross-verified empirically with GPS device (model no. ‘Garmin-010-00780-02, eTrex Vista H, Pac’) at different wisely selected points.

4 Methodological principle

This is an inferential work that focuses on how far channel shifting impacts the spatial diffusion of population. The work is based on what went before, but the same has been rectified by empirical investigation (Fig. 3). A comprehensive study on the Hooghly River shifting near the southwestern part of Nadia district has been pursued using the maps of 1776 (Rennell map), 1857 (Sherwill map), 1925 (Toposheet 79 A/8 & 12) and 2010 (Block map) which is in detail presented in Fig. 2.

Change detection across the referenced time points has been studied considering 1776 as the base year. Selected 4 types of maps (1776, 1857, 1925 and 2010) are rectified (ERDAS IMAGINE-9.0) and registered (ERDAS IMAGINE-9.0) with the help of UTM Map Projection and WGS84 datum surface (ERDAS IMAGINE-9.0) taking several ground points (Fig. 2) derived from the Google Earth images 2015. Subsequently, the images are subset (ERDAS IMAGINE-9.0 and MapInfo 7.0) to delineate the study area. Once the Hooghly River is subset from the four images, the water body, old road and rail crossing are then masked from the subset images (ERDAS IMAGINE-9.0). This composite map is registered in the MapInfo 7.0 and finally reprojected into a uniform datum and projection system. Lastly, the bank-line positions (for the years 1776, 1857, 1925 and 2010) of the Hooghly River are superimposed into the uniform datum (WGS 84) and the projection system (UTM). Further these images were authenticated by the cross-verification with some selected empirical observation points with GPS measurement (model no. ‘Garmin-010-00780-02, eTrex Vista H, Pac’), which made the study more scientific and worthy (Fig. 3).

In the next step, the river is digitized from Toposheet 1925 (MapInfo 7.0), Block map 2010 (MapInfo 7.0), Sherwill map 1857 (MapInfo 7.0), Rennell map 1776 (MapInfo 7.0) and image Google Earth (2015) (MapInfo 7.0). Then, all layers of the river are superimposed and major changes have also been digitized with the help of MapInfo software 7.0. Further, RS & GIS tools have been applied for measuring the length of the river and bars, also for data extraction. Besides the map analysis, inferential quantitative

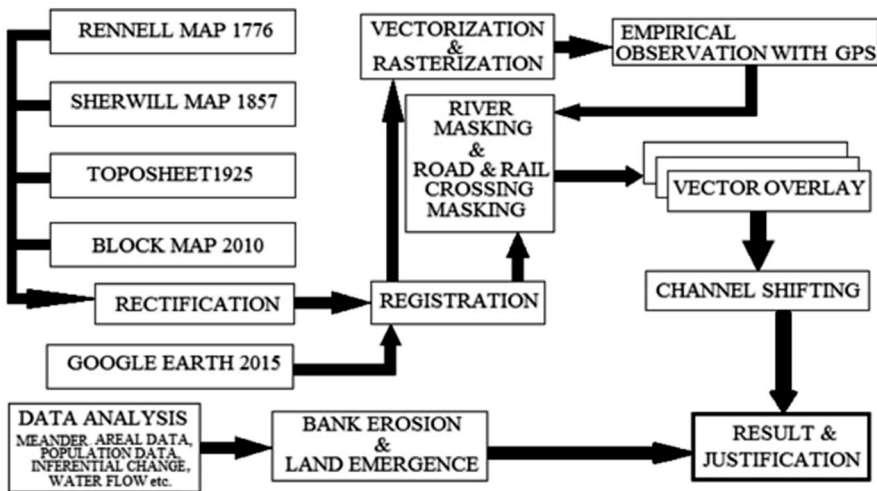


Fig. 2 Flowchart of methodology

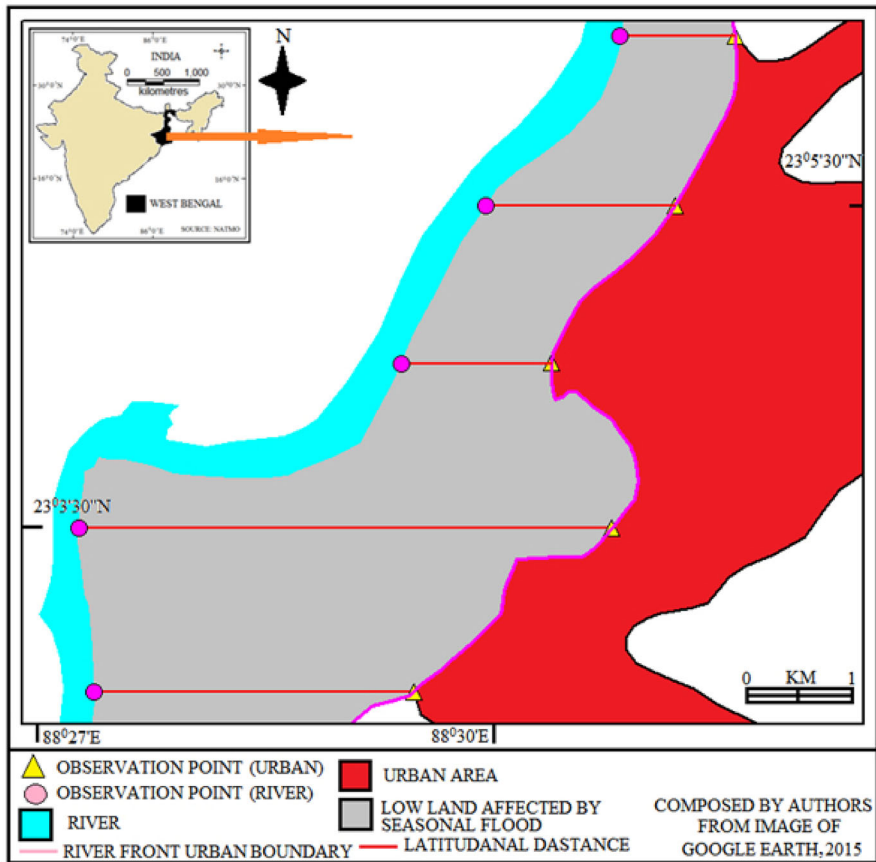


Fig. 3 Location of ground control points in the study area

techniques (i.e., linear regression and ‘t’ test) have been applied for drawing inferences on geographical analysis of urbanization.

5 Analysis and description

5.1 Meander geometry of Hooghly River along Chakdaha town

The analysis of river meandering through an important morphological system is lacking of the data on changing channel pattern and associated phenomena of erosion, deposition as well as the formation of flood plain. However, the advent of modern techniques like GPS and GIS made the same quite easy through the image processing, which therefore helps in construction of realistic models of meandering stream evolution (Panda and Bandyopadhyay 2011). Channel instability is a continuous process; its analysis considers geological, hydrological, channels morphology and geotechnique activities (Parua 1992). Rivers maintain the dynamic equilibrium between their sediment loads and the energy generated from stream flow to perform its erosion activities and also to transport the sediment load.

The meander geometry of rivers always provides for the dissipation of energy from moving water and sediment transportation. Rivers exhibit continual adjustments with channel length that result in maintaining a slope such that the stream system neither degrades nor aggrades. Changing river alignment due to reducing natural sinuosity consequences the decreasing reach length, increasing local slope, and setting in motion a series of channel adjustments (Rosgen 1996). The meandering river system is characterized by the recurrent river *planform* (river structure related to its geometry) patterns. The consistency of meander magnitude suggests the normal operation of physical processes of deposition and erosion in the river system. Meandering is the result of the operation of two counteracting processes under the local geometrical control wherein lateral migration and cutoffs of river act in the increasing and decreasing of sinuosity, respectively. Lateral migration resulted from the bend erosion and deposition. Cutoffs appear from a local geometry as a consequence of lateral migration process (Stolum 1996).

A stream travel is perfectly following the surface slope naturally in a non-straight path for long distance. Inevitably, river bends are also being produced by any obstacle in its path, like a tree, a rock, a fallen log. As the water in a stream arcs around an obstacle or a bend, it moves in a quite higher speed outside and quite slower rate along the inside bend. River having higher velocity and kinetic energy erode the river bank quite severely and that result more widen and deep outside turn of the river bank. The river however carries the eroded sediments and deposits them along the inside of another bend. The slow-moving water along the inside bend is quite unable to carry more materials causing sedimentation here. Therefore, the inside bend acquires sediment deposition supplied by the fast-moving upstream water of outside bend. Erosion on the outside upstream and deposition on inside downstream result in the gradual increase in stream sinuosity over time (Craghan 2003). Hooghly River along the Chakdaha settlement has been following exactly the same processes of erosion and deposition. The evolution of Chakdaha settlement, its growth and reorientation of boundary bears the testimony of what river shapes the surrounding landscapes by its continuous morphodynamic processes (Majumder 2009).

The Hooghly River is the main river of West Bengal flowing across the important cities like Murshidabad, Berhampur, Nabadwip, Chakdaha, Chinsurah, Chandannagar, Serampore, Howrah, Kolkata, Diamond Harbour and Haldia. Bhagirathi-Hooghly is one of the ancient channels of central part of the West Bengal state of India, and its ever-changing nature has been creating tremendous locational hazards to the settlement laying both banks.

According to the survey of James Rennell, during 1770–1776 the Hooghly River was flowing from the east of Kalna town in a north–south direction (Rennell 1781); then, it took turn to move in northwest to southeast direction (Rennell 1781). After a very short run, it formed two massive meanders one in the west of historical ‘Phulia’ village (the birth place of Krittibush Ojha who wrote ‘Ramayana’) of the Nadia district and another in the east of ‘Rusitpour’ village of Burdwan district. Again after a short meandering the river moves in northwest to southeast direction to confluence with ‘Churni’ river near ‘Shibpur’ settlement located in the northwest of Chakdaha Community Development Block. At this confluence the Hooghly River has created two massive riverine islands (Fig. 4A ‘a’ & ‘b’) which Das has discussed (Das 1995). Over the time both riverine islands were separated by two different flows of water near Chakdaha, one very active flow along the east bank (i.e., east channel) and another inactive flow along the west bank (i.e., west channel) (Fig. 4B).

During the year 1780–1860 the entire scenario of the Hooghly River near Chakdaha got transformed upon the westward shifting of the inactive flow. This shifting was associated with the changing hydraulic geometry and channel geometry. The Hooghly River has destroyed the west boundary of Chakdaha settlement just below the 23°04′30″N latitude

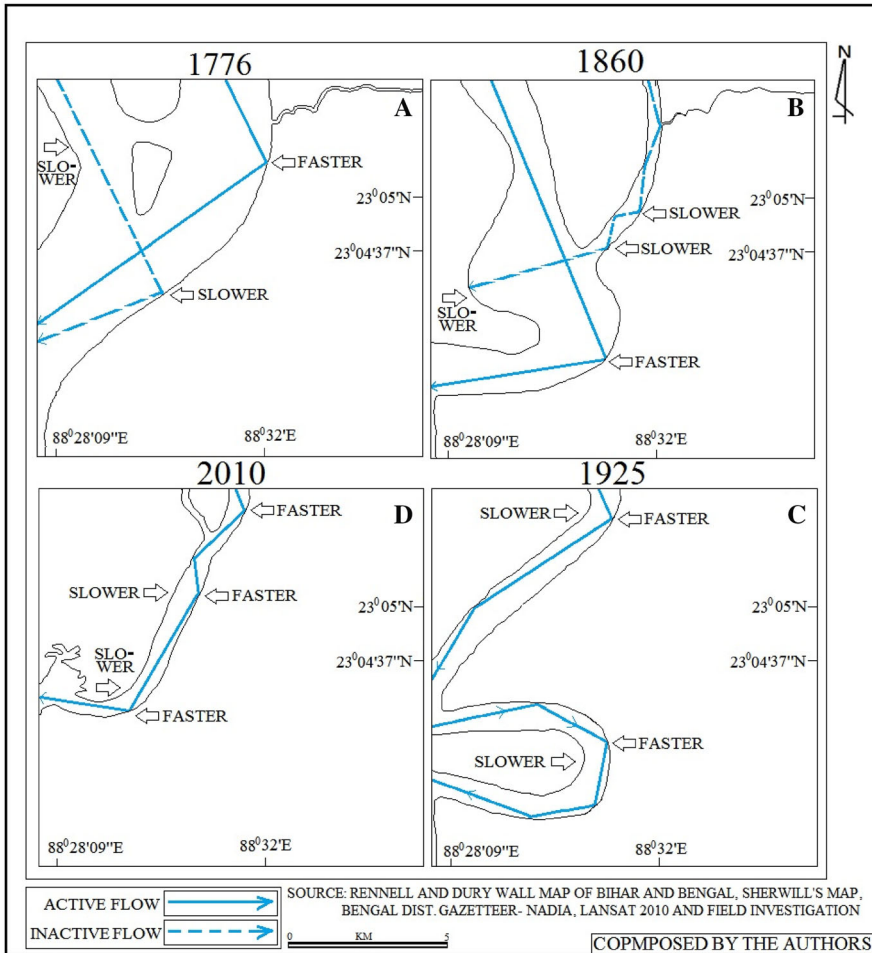


Fig. 4 Stream meandering of Hooghly River along Chakdaha town

due to the eastward movement of the river which occurred between $23^{\circ}04'30''\text{N}$ and $23^{\circ}02'30''\text{N}$ latitude (Fig. 4B). At the $23^{\circ}03'30''\text{N}$ latitude, the river was shifted eastward by 3.44 km (shifting from $88^{\circ}29'16''\text{E}$ to $88^{\circ}31'17''\text{E}$ longitude) from its previous location (Table 1).

During the period 1860–1925, the inactive flow along the east bank (i.e., west channel) of the Hooghly River was quite dead and gradually became isolated from the main flow; however, the active flow (i.e., east channel) was also reduced into a small creek locally known as Buriganga which is still flowing along the west boundary of the Chakdaha municipality. The west channel started flowing as main channel of Hooghly River along Chakdaha settlement. During the said time period (1860–1925), the Hooghly channel further shifted westward by 2.19 km at $23^{\circ}06'30''\text{N}$, by 3.96 km at $23^{\circ}05'30''\text{N}$ and by 4.60 km at $23^{\circ}04'30''\text{N}$ and another part of Hooghly River shifted eastward by about 2.88 km at $23^{\circ}03'30''\text{N}$ and by 4.64 km at $23^{\circ}02'30''\text{N}$ (Table 1, Figs. 4C, 5).

Table 1 Shifting of east bank of Hooghly River along fixed latitudinal points to variable longitudinal points, near Chakdaha town, 1776–2015

Base latitude (fixed)	1776 (base year or B.P.) Rennell map		1860 Sherwill's map		1925 Topographical map		2010 Block map		2015 (empirical observation with GPS)	
	Longitude	Shifting (km)	Longitude	Shifting (km)	Longitude	Shifting (km)	Longitude	Shifting (km)	Longitude	Shifting (km)
23°06'30" North	88°32'06" East	0.0	88°32'08" East	0.07 (Eastward from BP)	88°30'31" East	2.19 (Westward from BP)	88°30'52" East	1.58 (Westward from BP)	88°30'59" East	1.33 E (Westward from BP)
23°05'30" North	88°31'52" East	0.0	88°31'52" East	0.00 (Static)	88°29'33" East	3.96 (Westward from BP)	88°30'14" East	2.79 (Westward from BP)	88°30'09" East	2.97 D (Westward from BP)
23°04'30" North	88°30'59" East	0.0	88°30'55" East	0.10 (Westward from BP)	88°28'19" East	4.60 (Westward from BP)	88°29'40" East	2.25 (Westward from BP)	88°29'32" East	2.53 D (Westward from BP)
23°03'30" North	88°29'16" East	0.0	88°31'17" East	3.44 (Eastward from BP)	88°30'58" East	2.88 (Eastward from BP)	88°27'32" East	2.92 (Westward from BP)	88°27'26" East	3.13 D (Westward from BP)
23°02'30" North	88°28'08" East	0.0	88°27'54" East	0.37 (Westward from BP)	88°30'50" East	4.64 (Eastward from BP)	88°27'25" East	1.20 (Westward from BP)	88°27'29" East	1.06 E (Westward from BP)

BP base point, E erosion point, D deposition point, base latitudes have been marked along the east bank of Hooghly River

During the period 1925–2010, Hooghly River has recorded to shift in every observation points (Table 1). An empirical measurement has been done for studying about how far the bank-line movement along the west of Chakdaha town was occurred in the recent past (Table 2). As far as the sinuosity of the Hooghly River is concerned, the index of sinuosity (SI = meandering length/straight length) near the Chakdaha settlement is estimated to be 2.0518 in 1925 which reveals a highest meandering till date (Table 3). During the same time, the Hooghly River was suffering from an inadequacy of water supply over decades mainly in the dry season and gradually a siltation on the river bed was taking place. Subsequently, the river was reduced to appear as thin veins of water amidst masses of sandbars and islands in its some parts. Salvation from this critical hydrological problem could be possible by the construction of Farakka barrage in the year 1971 on the river Ganga at Farakka in the state of West Bengal near Indo-Bangladesh border (Mazumder 2012). The purpose of its construction was to forcibly divert about 1135 cumec fresh upland water of the Ganga River to its tributary Hooghly River through the feeder canal (man-made channel). The Hooghly River is supposed to be the lifeline of Kolkata city as well as many other cities including large industrial complex on its banks (Rudra 2011). Water supply through the feeder channel solved the water scarcity problem, but Farakka barrage construction posed a counter problem of siltation in the Hooghly River.

Again during the period 1925–2010, the scenario of Hooghly River near Chakdaha settlement got a drastic change. During the same time, a mature meander near the southwest of Chakdaha settlement was decayed because the erosion process pushed the bends outward, and sections of the meander came closer one another. It made possible for the stream to breakthrough a narrow neck separating its parts. If a breakthrough happens, it is called a cutoff and the main flow follows the shorter as well as steeper path. Presently, the meander is completely separated from the Hooghly River to emerge as land which is known as *Char Srikrishnapur* (Fig. 4C.a). Figure 4 clearly depicts that the Hooghly River near Chakdaha town appears to be narrowing until the nineteenth century, but during the last few decades the river morphology is changed which proves to be a quite active fluvial

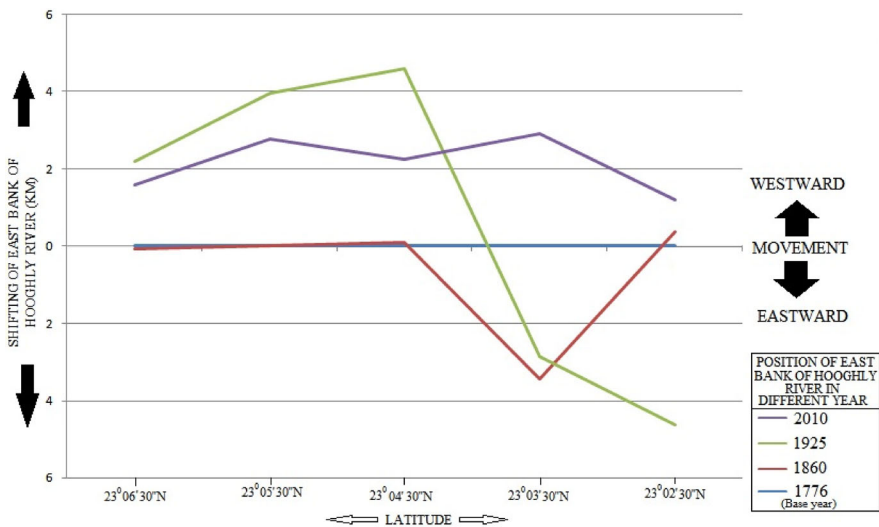


Fig. 5 Longitudinal shifting of east bank of Hooghly River at latitudinal positions near the Chakdaha town, 1776 (base year) to 2010

Table 2 Land adjustment of Hooghly River along west boundary of Chakdaha town, 2010–2015

Base latitudes— north (fixed)	Land alteration in the last 5 years			Remarks
	Longitudes—east 2010	Longitudes—east 2015	Bank movement (km)	
23°06'30"	88°30'52"	88°30'59"	0.25	Erosion
23°05'30"	88°30'14"	88°30'09"	0.18	Deposition
23°04'30"	88°29'40"	88°29'32"	0.28	Deposition
23°03'30"	88°27'32"	88°27'26"	0.21	Deposition
23°02'30"	88°27'25"	88°27'29"	0.14	Erosion

Table 3 Sinuosity index of Hooghly River along Chakdaha town from 1776 to 2010

Years	Channel length (km)	Straight length (km)	Sinuosity index
1776	7.2234	6.2110	1.1630
1860	9.8087	7.4015	1.3252
1925	16.0124	7.8038	2.0518
2010	7.4131	6.2813	1.1801

process therein. Such a morphological process results in the taking place of erosion in some parts, simultaneously a deposition on the counter part of the river bank.

The sync of the aforesaid discussion is that the Hooghly River has been extremely a dynamic particularly along the west side of the Chakdaha town. In every year, the river bank is retreating by few meters somewhere along the west boundary of Chakdaha town due to the bank failure; however, land mass acceleration takes place through the sediment deposition elsewhere. It can be said that both of the processes go on at different points of the west boundary of Chakdaha town, which result in the urban boundary reorientation in compliance with the natural law of land loss and land gain (Table 2).

6 Rural to urban transformation of Chakdaha settlement

The evolution of settlements in river proximity has a long tradition and also has a vulnerability of being destructed by the erosive power of the river. Simultaneously, river has constructive power too, by the process of sediment deposition. The rivers are extremely dynamic, by their shifting of course possessing tremendous locational hazard to the human settlements. Valley civilization along the Ganges basin dates back several thousand years. The way of living of the people of river-based settlements manifests a decisive power of the river through the time immemorial (Basu 2012).

The dynamic nature of Hooghly course has resulted in the extinction of old settlements and emergence of new settlements. Chakdaha settlement was evolved on the east bank of Hooghly River in the southwest part of Nadia district at 23°05'N and 88°32'E. In the year 1770, 'Chakdaha' settlement emerged as an agro-based rural settlement (Nandy 1994). Since then the settlement formed and reformed through the orientation and reorientation of

its boundary finally to achieve present shape, size and identity as Chakdaha municipal town, a Class-II town of India national (Census of India 2011) after about 240 years of its inception. Before the year 1770, Chakdaha was locally known as *Chogda* (Nandy 1994), a well-developed rural settlement. The *Chogda* was mainly evolved based on the riverine port of Anandaganj which is now the ward no. 11 of Chakdaha municipality. Another contemporary settlement, namely ‘Sukhsagar,’ was evolved based on Sukhsagar port though obliterated during the year 1850–1860. The erosive nature of the Hooghly River has destroyed the base of both ports until 1860. The Hooghly River course was shifted westward from the Anandaganj port, and its erosive power has demolished Sukhsagar port.

Anandaganj of those time provided base for the foundation of present-day Chakdaha town. Chakdaha from a simple hamlet of late eighteenth and early nineteenth century turned into a *Panchayat* head quarter (rural local self-government) by the year 1885 and finally into a municipality (urban local self-government) in the year 1886.

Anandaganj port was heart of the village of contemporary time as a river-based trade center. Some other villages too were developed encircling the Anandaganj port, namely Kanthalpully, Jashra, Panchnur, etc. The Sukhsagar port was positioned probably at $88^{\circ}28'52''\text{E}$, $23^{\circ}03'53''\text{N}$. Some other villages and hamlets were originated along the connecting road between Anandaganj and Sukhsagar. Such roads still exist and known as Sukhsagar road between Chakdaha and Simurali settlements. The Hooghly River has been flowing along the west of Chakdaha since inception when it was extended over nearly half sq. km area. East bank of the river was quite touching the west boundary of Chakdaha town (Fig. 6a, b). But the meandering nature of the same river posed a locational hazard and destroyed the geographical location of Chakdaha.

Gone are the days when Sukhsagar port and adjoining vast areas were destroyed by the destructive power of the Hooghly River. However, contemporary Anandaganj port and adjoining land were comparably saved. During the year 1776–1860, a huge land estimating about 3.44 km in the west of Chakdaha settlement was eroded at $23^{\circ}03'30''\text{N}$ latitude due to the eastward shifting of the Hooghly River (Table 1) and people wisely looked to settle quite away of previous location. It was 1860 when Chakdaha settlement was spreading over 01 sq. km only and its west boundary was quite touching the east bank of the Hooghly River. Initially, the Chakdaha was evolved as an urban settlement based upon the water transport facilities offered by the Hooghly River. But the volatile meandering course of the river made an immense impact upon transportation system. During the rural to urban land use transformation of Chakdaha, its west side was shaped by the old paleo-channel named Buriganga and the urban boundary was situated at 4.25 km distance (Fig. 6c). The evolution of *Chogda*, its transformation into Chakdaha municipality and the reorientation of its settlement boundary over time bear a testimony of the destructive as well as creative power of the Hooghly River. In the year 1925 west boundary of Chakdaha town was situated at 4.25 km distance from the east bank of the river (Fig. 6c). In the year 2010 the landscape got transformed drastically. The Hooghly River moved a little bit west; though the meanders were found to be connected till 1925 (Fig. 6c), it was dissected in the year 2010 (Fig. 6d).

Table 4 infers the reorientation of boundary of Chakdaha town over centuries and therefore physical extension of the town. The Census of India 2011 has recognized few census towns in the east and south of Chakdaha town. Entire urban area consisting of Chakdaha municipality and four census towns is documented as Chakdaha Urban Agglomeration (Census of India 2011). Reorientation of the west boundary of Chakdaha town manifests the shifting of Hooghly River; however, the east and south boundary reorientation is attributed to the development of road and railway. Further it is worth

Table 4 Latitudinal and longitudinal extension of Chakdaha town at selected points, 1776–2010

Outermost point of the town boundary	1770		1860		1925		2010	
	Position	Boundary extended by	Position	Boundary extended by	Position	Boundary extended by	Position	Boundary extended by
North boundary	23°05'33"N	–	23°05'41"N	00'08"	23°06'55"N	01'14"	23°06'55"N	00'00"
South boundary	23°05'06"N	–	23°04'47"N	00'19"	23°03'20"N	01'27"	23°02'04"N	01'16"
East boundary	88°31'46"E	–	88°31'55"E	00'09"	88°32'37"E	00'42"	88°34'05"E	01'28"
West boundary	88°31'12"E	–	88°31'02"E	00'10"	88°30'32"E	00'30"	88°30'22"E	00'10"

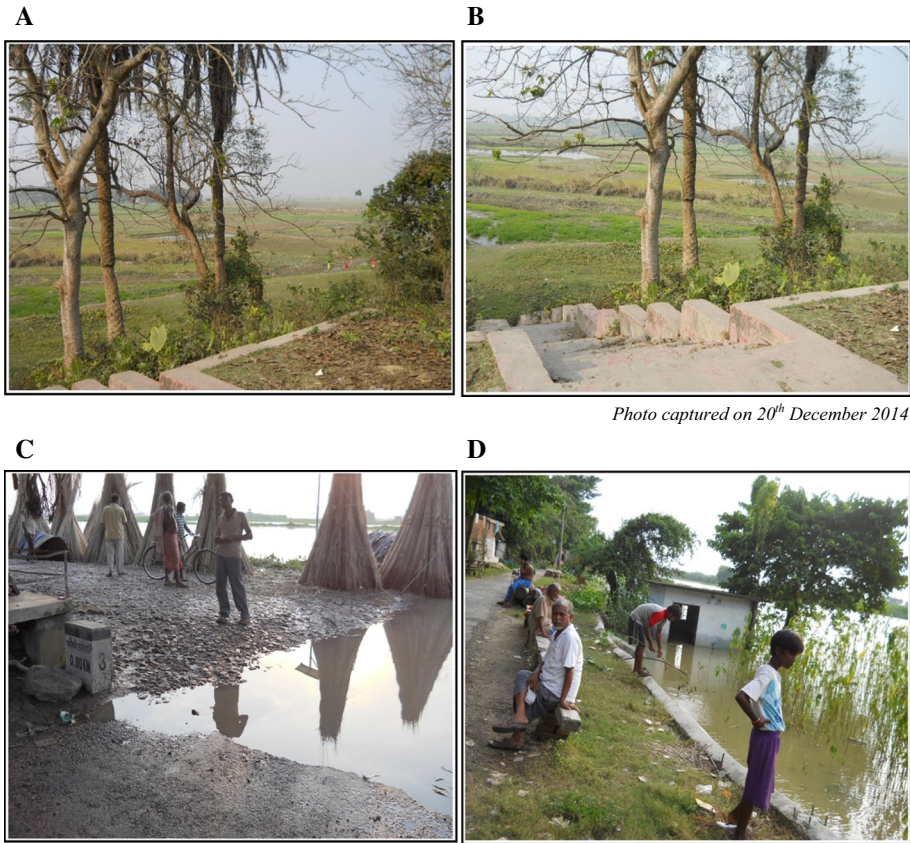


Photo captured on 20th December 2014

Photo captured on 5th August 2015

Fig. 7 Western boundary of Chakdaha municipality along Hooghly River during off and on monsoon. **a** Off-monsoon western boundary along southwest. **b** Off-monsoon western boundary along northwest. **c** On-monsoon western boundary along southwest. **d** On-monsoon western boundary along northwest

the town; however, a quite free of natural hazards along east side results in the continuous extension. It is evident that emergence and spreading of Chakdaha town is associated with morphodynamic changes of the Hooghly River.

Anandaganj of the then time provided a base for the foundation and evolvement into the present-day Chakdaha town. Chakdaha from a simple hamlet gradually turned into a Panchayat (local self-government at village level) with a population above 5000 persons, in the year 1885 under the British rule (Chakdaha Municipality DDP, 2013). In the year 1886 under the initiative of a British Architectural Engineer—John Beglar, Chakdaha was declared as Municipality on May Day (1 May). After the formation of municipality, different types of planning and land use policies were implemented for land use development. As per the Census of India 2011, a total population of Chakdaha was accounted for 95,203 persons. Growth of urban population is quite fairly in a linear between 1940 and 2011 (Table 5). Highest 179 percent growth of population was recorded during 1941–1951 followed by 128.27 percent during 1951–1961. Growth of urban population found to be

Table 5 Decadal growth rate of population of Chakdaha municipality, 1901–2011. *Source:* Census of India 1991, 2001 and 2011

Census year	Population (person)	Decadal growth rate (%)
1901	5482	0
1911	4931	– 10
1921	5216	6
1931	3986	– 24
1941	5494	38
1951	15,372	180
1961	35,089	128
1971	46,345	32
1981	59,308	28
1991	74,769	26
2001	86,999	16
2011	95,203	9

quite declining during each progressive decade (Table 5). In every flood year since the wetted perimeter of Hooghly river touches the Chakdaha municipality boundary, the westward urban extension is restricted. However, east boundary is free from the seasonal flood.

7 Conclusion

History conveys world's human civilization grown on the suitable geographical position along the rivers; however, mighty nature of it has destroyed some of them. River always tries to establish her supremacy on human settlement; simultaneously technologically empowered man also tries to protect themselves. Like other cities Chakdaha town evolved along the Hooghly River. Chakdaha urban settlement emerged and shaped by the order of Hooghly River along its east bank of concave structure of the meander. Shifting of the Hooghly River has destroyed 'Shibpur' (once located at 04 km in the north from the Anandaganj port) and Sukhsagar (once located at 08 km in the south from Anandaganj port) settlements as they were positioned on convex structure of the river meander. Geographical position of Chakdaha on concave side of meander receives sediment deposits which facilitated to its survival and continuous growth to become a Class-II town in 2011 with spatial extension of 15 sq. km from that 0.5 sq. km only in its very inception. Mightiness of river simultaneously destroys as well as builds human structure; otherwise, human structures would have been perished completely. The evolution, growth and present shape of Chakdaha settlement are the manifestation of constructive nature of the river. The trend of urbanization of Chakdaha is rapid and linear over the time and expectedly may spread over west side of the municipal boundary, if technological man can control over flood vulnerability. The natural process of losing and gaining of land will go on forever by the natural law of the river simultaneously the urban planners as well as the technologically empowered men will continuously try to adjust with nature through planning the human habitat.

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