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ORIGINAL ARTICLE

Quantitative study on shoreline changes and Erosion Hazard assessment: case study in Muriganga–Saptamukhi interfluve, Sundarban, India

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Abstract Quantitative techniques, statistical methods and mathematical rules make the geospatial analysis more systematic, accurate and precise. In order to measure the intensity of the ongoing processes on the earth surface, evaluate the spatio—temporal changes in geographical attributes, highlight the principal factors for any geographic events and to identify the future possibilities, quantitative techniques are for most dependable. In the present article sequential changes of the shoreline, spatio—temporal extent of erosion and depositional processes of Sundarban region, West Bengal, India, have been measured following the selected quantitative techniques. The Sundarban is one of the most dynamic geomorphic units in the earth surface, situated in the northern apex of Bay of Bengal. The region has formed, sculptured and modified due to continuous sedimentation of the Ganga and the Brahmaputra systems, intense tidal hydro dynamic behavior, climatic disturbances and anthropogenic activities. In the last two century most of the parts of the active Sundarban delta has being reclaimed and occupied with dense rural settlements, most of the peoples are engaged in agriculture based rural economy, hence substantial erosion and successive regressive changes in the area have an unconstructive impact on the dwelling communities. In order to examine the net shoreline changes, average rate of end point changes and extent of erosion and depositional processes Survey of India toposheets of 1920, 1921, 1922, 1923, US Army toposheets of 1955, Survey of India toposheets of 1967, 1968, 1969 and IRS P6 LISS IV satellite images of 2014 have been used. Finally erosion hazard zones have been identified will help of net area changes of the each geomorphic units to access the spatial variation of erosion hazard intensity. Quantitative model has been prepared on the basis of multi temporal data of Muriganga–Saptamukhi interfluve area of western Sundarban which can be applied to the other parts of Sundarban region.

Keywords Deposition · Erosion · Erosion hazard assessment · Estuary · Shoreline changes · Sundarban

Introduction

Sundarban is a vast active deltaic tract of Asia. Geomorphological attributes, hydrological behavior that configures this mysterious landscape is very dynamic and sensitive. Morphologically this landscape is the product of successive deposition by the Ganga and Brahmaputra River. Since the formation of this geomorphic region the area especially its marginal parts are getting affected by regional tectonic set up, fluvial and coastal hydrodynamic behaviors, climatic extremities and human interferences. Strong tidal activities, long shore current and wave have constantly been modified, shaped and reshaped the marginal shorelines in this active estuarine delta through hydro-geomorphological processes like erosion and deposition (Chakrabarti 1995; Bandyopadhyay et al. 2004; Raju et al. 2010; Jana et al. 2012; Chakraborty 2013; Das et al. 2013; Addo 2015). Once it was marshy forested immature low land, successively has evolved by hydrological processes but later through consequential phases of reclamation present Sundarban, became the home of

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millions (Mukherjee, 2002). In this fatal platform, dwellers are living in a misconception with nature in vulnerable condition in the form of erosion and rapid embankment breaching. Sundarban region is demarcated by the river Hooghly on the West, the Bay of Bengal on the South, and the Ichamati-Kalindi-Raimongal Rivers on the east and the Dampier-Hodges line on the North. Sundarban region comprises of nineteen administrative blocks (sixteen police stations) of North 24-Parganas and South 24-Parganas Districts of the State of West Bengal. The land area measures about 9629^2 km , of which 4493^2 km is inhabited by people and the rest is Reserve Forest. Approximate population of Sundarban region is 45 lakhs. About 80 % of the population in Sundarbans is based on agriculture (Hazra et al. 2010; Danda et al. 2011; Ghosh 2012). So the progressive land losses become economic hindrance for their sustenance (Jana et al. 2012; Das et al. 2013; Chakraborty 2013; Bandyopadhyay et al. 2014).

Geo-tectonic setup of the Bengal basin

The Sundarban region is the tidally active and one of the most dynamic deltaic regions in the world. Flat sandy beach, tidal marsh, mud flat, creeks are the geomorphic signatures of this landscape (Paul 2002; Das 2006; Rahman 2012; Udo-Akuaibit 2014; Weichselgartner and Pigeon 2015). The region is situated in the northern apex of Bay of Bengal. The area has been successively developed by the sediment deposition by the Ganga and Brahmaputra river (Mikhailov and Dotsenko 2007; Sarkar et al. 2009; Jha and Bairagya 2011). Due to the tectonic set up the Bengal basin has been tilted towards east. So the Ganga River has successively changed its course towards east from its historical past. Now the river used to flow eastward direction. Due to the shifting course of the river Ganga Sundarban region in the western part of the Bengal basin has started to suffer from the paucity of fresh water discharge and sedimentation. Auto compaction of loosely attached sediments and gradual land subsidence is also another prominent geomorphic events occurring in this region (Chakrabarti 1995; Islam et al. 1999; Stanley and Hait 2000; Goodbred et al. 2003; Alam et al. 2003; Islam and Gnauck 2008). In the western part of Sundarban region Hugli and Haringhata Rivers carry some amount of fresh water (Bandyopadhyay and Bandyopadhyay 1996; Bandyopadhyay 2007). Sweet water flow along the Hugli River is very much maintained by the Farakka barrage in the northern apex of the Ganga delta. So the tectonic activities and shifting river courses have an impact in the lower segment of the delta in terms of sediment supply as well as fresh water supply.

Nature of the tidal estuary

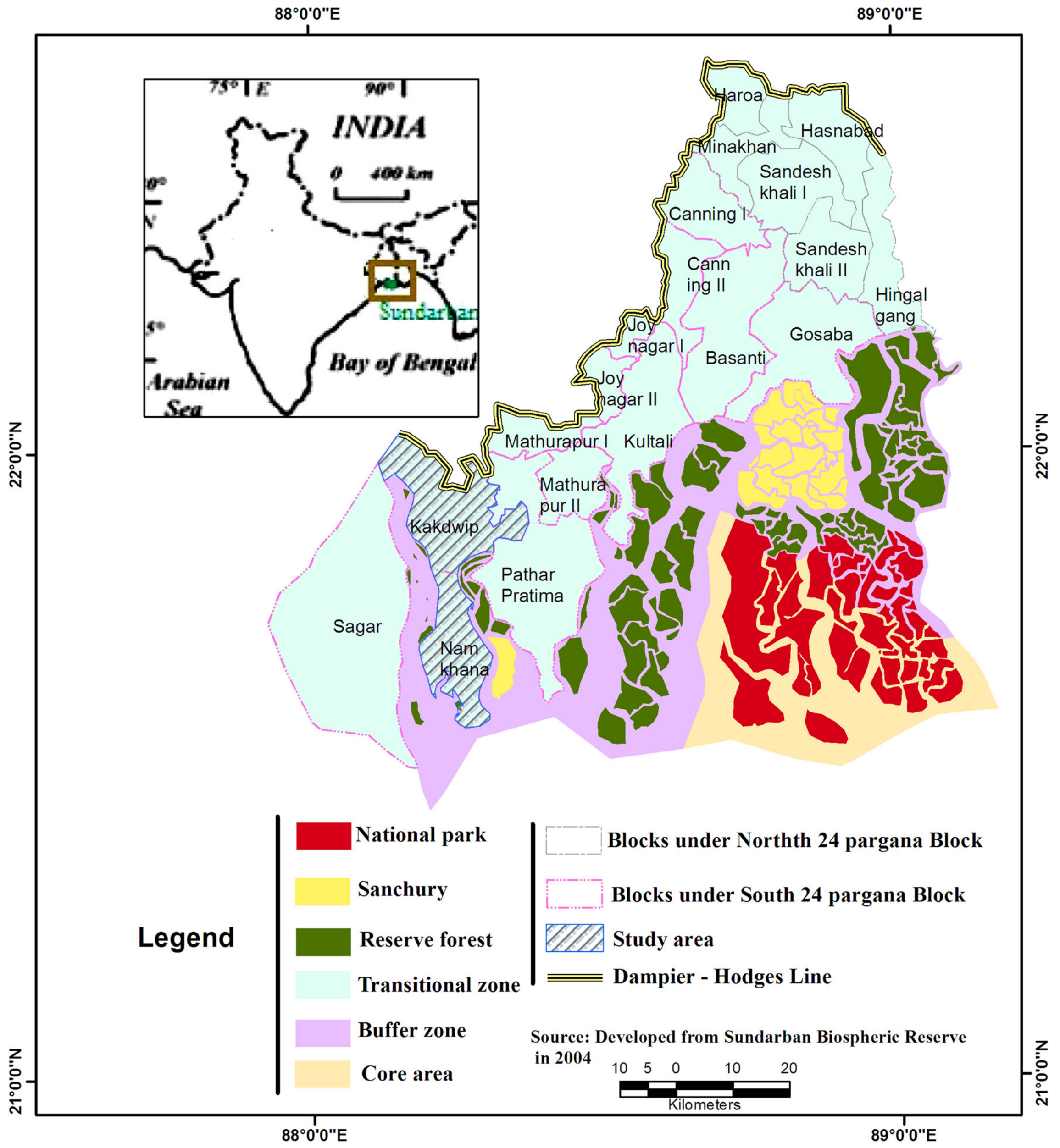
Sundarban is a macro tidal (Tidal range >4 m) active delta of Bengal basin. The rivers of the upper part of the delta have ended in the low marshy wetlands and they have not any connection with the Ganga or any other sweet water sources. Hence the hydrological characters of almost all the rivers are controlled by the tidal rush. The shape of the estuary is also important in shaping the face of the land masses. The funnel shape mouth and land ward narrowing of the channel is mainly responsible for the tidal asymmetry, due to such condition high tidal water enters in the estuary but the low tidal water cannot properly pass out, this flow variation has key role to damage the bank line in the estuarine belt. The velocity and the duration of flood tide remains very high then ebb tide which significantly damaged exposed embankments. So the land word increase in tide level and the tidal velocity have extremely damaged the marginal exposed low lying areas (Bandyopadhyay and Nandy 2011). Similarly the directions of tidal flow, channel forms and river bed configuration have a strong connection with the extent of erosion and deposition patches (Paul 2002; Das 2006).

Climatic extremities in the Sundarban

The region is extremely affected by the strong cyclonic activities. The surface temperature, sea level temperature has progressively changed since last decade which has energized the cyclonic activities over time (Bandyopadhyay 1997; Hazra et al. 2010; Danda et al. 2011; Ghosh, 2012; Mallick and Vogt 2015). The last decades has witnessed some immense cyclones namely Mala (2006), Sidr (2007), Nargis (2008), Aila (2009) and many others extremities collectively massacred the marginal parts of the Sundarban (Ghosh 2012). Generally it has observed during south west monsoon season in India tidal bores have generated in these regions, when they co insides with the cyclonic events the situations become very severe. The maximum concentration of cyclonic activities took place during June to October month. During this time the strong surges developed over this region due to intensive low pressure which significantly damaged the marginal embankment every year. The situation becomes extreme when the cyclonic active coincides with full moon. The enormous tide generated during this period massacred the flat coastal belts and low lying marginal parts of entire Sundarban region.

Human interruption in the Sundarban

The face of the low lying marshy forested land of Sundarban region has been altered over time by human encroachment. The Britishers initiated rapid reclamation over this region with the help of local Zamindars (Land loads of pre independence India) for revenue collection. The entire phrases of land reclamation took place in five different phrases (1770–1780, 1780–1873, 1873–1939, 1945–1951 and 1951–1971). The post independence periods have experienced galloping population growth in the Sundarban region. In the last two century intense land use alteration, harbour construction, heavy embankment construction etc. have triggered the river bed siltation process which acts as a maneuvering fact for increasing tidal level (Bandyopadhyay and Bandyopadhyay 1996; Mukherjee, 2002; Mandal et al. 2009; Tsoukala et al. 2015; Misra and Balaji 2015; Hossain et al. 2015). The Sundarban region is one of the most dense populated region hence the human induced activities in the form of large scale deforestation, reclamation of immature low land for agriculture and commercial fisheries, development of large scale tourism activities and river jacketing through embankments have collectively influenced the natural geomorphic setup and tidal environment, which further intensified the erosion and depositional extent.

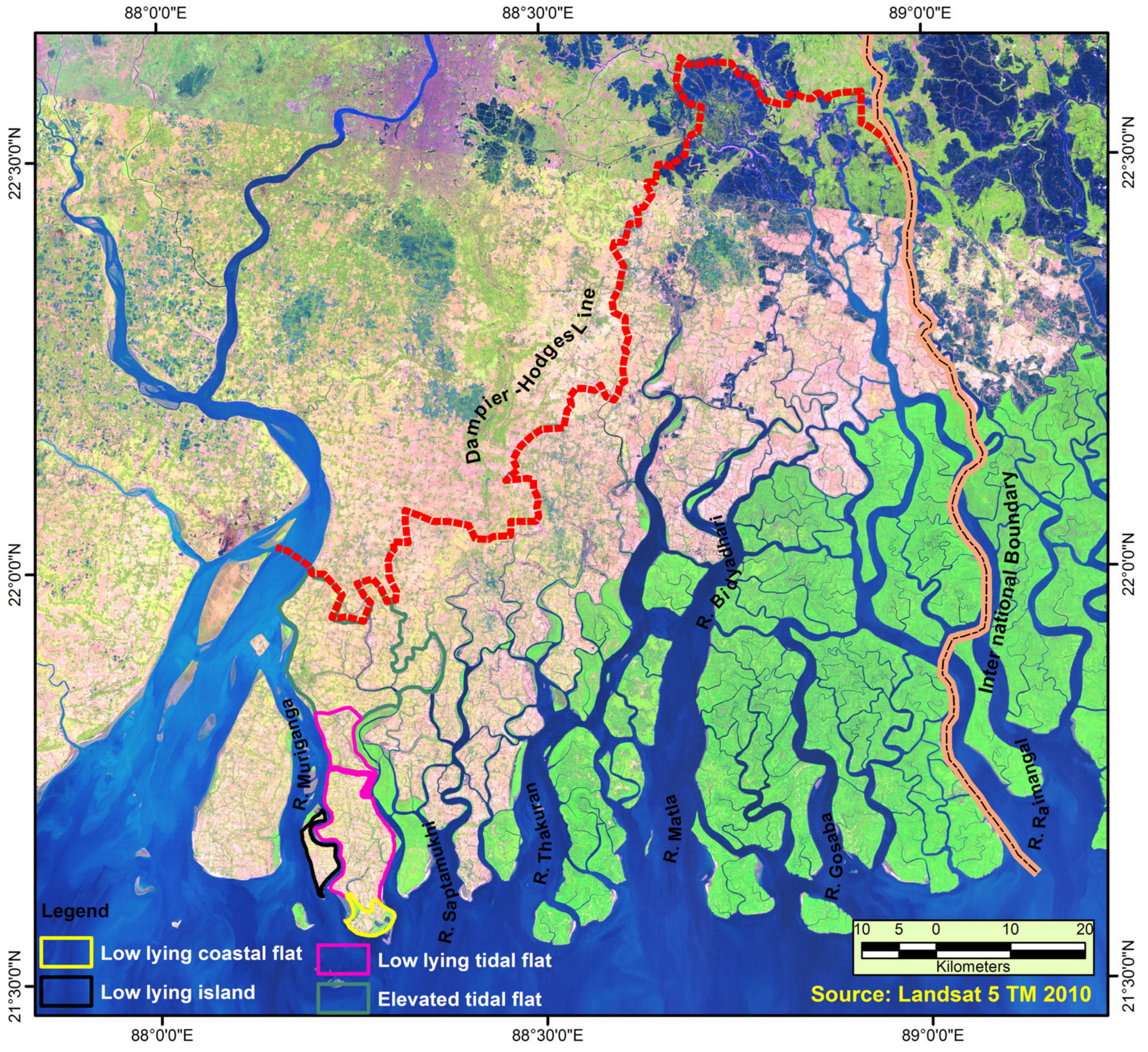


Source: Developed from Sundarban Biospheric Reserve in 2004

Fig. 1 Location of the study area

Table 1 Hydro—geomorphic divisions of the area. Source: Survey of IndiaToposheets1967–1968, 1968–1969, IRS P6 LISS IV Image 2014 and field investigation 2013–2015

Geomorphic units	Relief and slope pattern	Nature of rivers and creeks	Active processes and morphological signatures	Active geomorphic agents
Low lying coastal flat	2–2.6 m Flat and gentle sloping towards south	Small tidal creeks connected with sea	Erosion, deposition, shore line change, Sand dune formation, sands ply, salt marsh formation	Tide, wave, long shore current, seasonal wind action
Low lying tidal flat	2.6–3.8 m Flat and gentle sloping towards marginal parts from inner part	Tidally active rivers and small creeks with dynamic bank line	Erosion, deposition, bank line change, flood and prolonged water stagnation	Tide, surge
Low lying Island	3.9–2 m Flat and gentle sloping towards south	Surrounded by large rivers and creeks	Erosion, deposition of bank line, shifting sand dune, sands ply, salt marsh formation	Tide, wave, surge, seasonal wind action
Elevated tidal flat	3–6 m Slightly elevated and gentle sloping towards south	Moderately stable small tidal creeks	Erosion, deposition, bank line change	Tide, surge



Source: Landsat 5 TM 2010

Fig. 2 Geomorphic divisions of the study area within entire Sundarban delta

Table 2 Multi temporal data base for the study

Maps	Scale	Survey year	Remarks
Survey of India Toposheets (79 c/1, 79c/2, 79c/5, 79c/6)	1:50,000	1920–1921, 1922–1923	Detection of shoreline
US Army Toposheet (NF 45–11)	1:250,000	1955	Detection of shoreline
Survey of India Toposheets (79c/1, 79c/2, 79c/5, 79c/6)	1:50,000	1967–1968, 1968–1969	Detection of shoreline

Image	Date of acquisition	Path	Row	No. of bands	Spatial resolution (m)	Remarks
Satellite image						
Landsat-5 TM	06/02/2010	138	45	7	30	Detection of general geomorphic set up of the whole Sundarban region
Landsat-5 TM	06/02/2010	138	44	7	30	Detection of general geomorphic set up of the whole Sundarban region
IRS P6 LISS IV	18/02/2014	108	57	3	5.8	Detection of shoreline

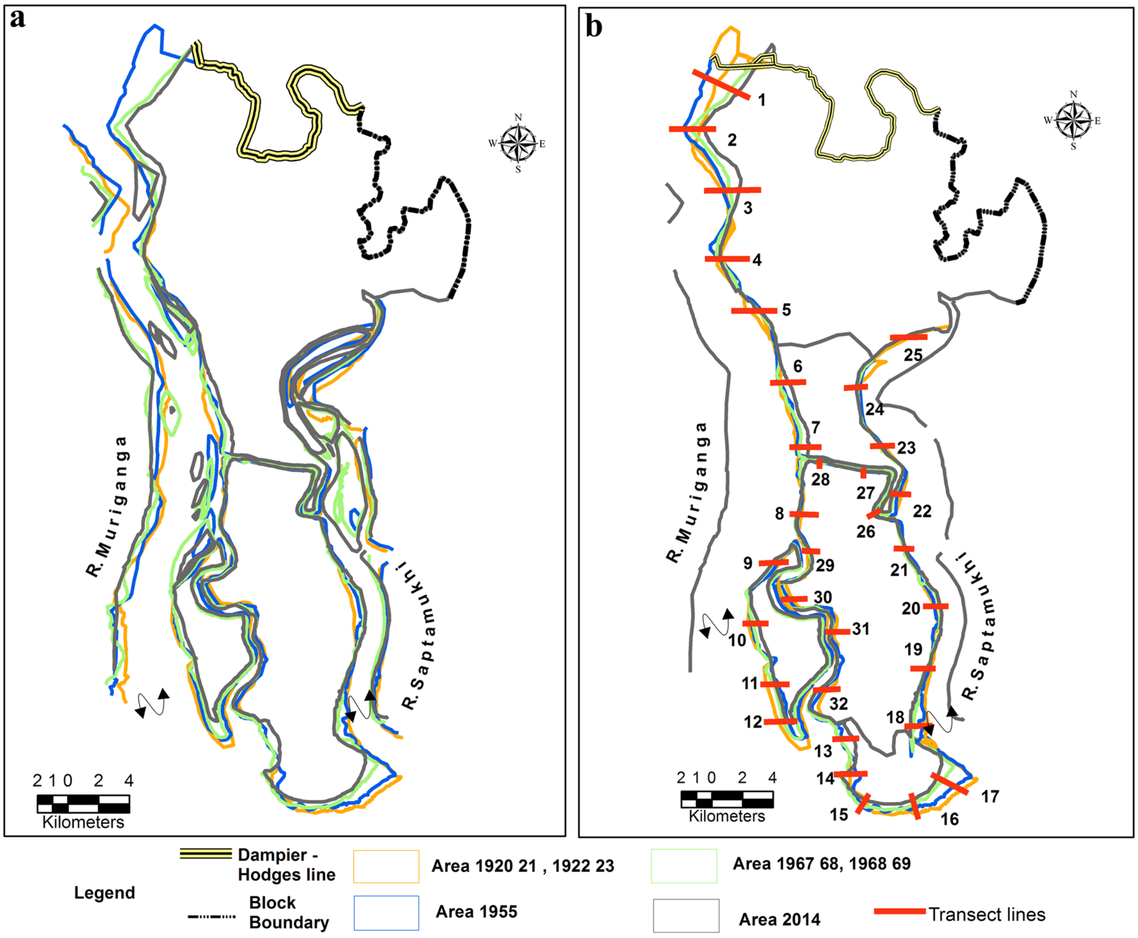


Fig. 3 **a**, **b** Superimposition of shorelines and distribution of transect lines

Selection of the study area

In the present paper for determining of erosion hazard zone using net shoreline changes, spatio—temporal analysis of erosional and depositional processes on the quantitative analysis has taken on the selected area on Muriganga–Saptamukhi interfluve of western estuarine Sundarban using multi temporal data base. The region has distinct

Table 3 Net changes and Average changes of shoreline over time. Source: Survey of IndiaToposheets 1920–1921, 1922–1923, 1967–1968, 1968–1969, IRS P6 LISS IV Image 2014 and field

No. of transects	Net shoreline change (in meters)						Average end point rate of shoreline change (1920–1921, 1922, 1923–2014)
	1922–1955		1955–1968		1968–2014		
	Positive changes	Negative changes	Positive changes	Negative changes	Positive changes	Negative changes	
1. North west				−1940		−628	−209.333
2. North west				−544		−986	−328.667
3. North west		−643		−419		−747	−249
4. North west		−443			247		0
5. Mid west		−1040	500		278		0
6. Mid west	237		223			−617	−205.667
7. Mid west		−309		−391		−871	−290.333
8. Mid west	286		305			−217	−72.3333
9. Mid west	368		393			−181	−60.3333
10. South west		−473		−289		−653	−217.667
11. South west		−987		−375		−254	−84.6667
12. South west		−693		−319		−762	−254
13. South			260			−1084	−361.333
14. South		−699	1145		278		0
15. South	510					−584	−194.667
16. South		−771		−413		−504	−168
17. South		−741		−884		−473	−157.667
18. South east		−295		−567		−371	−123.667
19. South east		−204		−370			0
20. Mid east		−77	430		373		0
21. Mid east	117			−375	234		0
22. Mid east		−306		−332	220		0
23. Mid east		−19		−288	50		0
24. North east				−256			0
25. North east		−581					0
26. Inner creeks		−283		−217		−198	−66
27. Inner creeks		−160		−152		−180	−60
28. Inner creeks		−181		−152	260		0
29. Inner creeks		−301		−201		−240	−80
30. Inner creeks	474		322		240		0
31. Inner creeks	375		222				0
32. Inner creeks	575		624			−50	−16.6667

coastal zone affected by long shore current as well as estuarine zone of strong tidal current. So this zone can be treated as the representative of the Sundarban deltaic region and the present discussed statistical methods and modes can be applied in the other parts of this region.

Hydro geomorphic address of the study area

The concerned study area is situated in the western part of Sundarban in between Saptamukhi River in east and Muriganga River in west extending from 21°32′52″ north to 22°0′40″ north and 88°7′7″ east to 88°22′28″ east (Fig. 1). Northern boundary has been demarcated by Dampier–Hodges line which distinguished tidally active Sundarban delta from mature delta in north. The flat sandy coastal land is the main geomorphological characteristics of its southern tract. The central part of the study area is low lying flat having large number of interconnected tidal creeks with low elevation between 2.6 and 3.8 m. The northern part is slightly elevated then the rest part of the study area with 3–6 m from mean sea level. From geographical set up it is clearly visualized that in the southern part long shore current and strong tidal wave from Bay of Bengal dominates especially during monsoon season but inner part and northern part has been influenced by strong macro tidal current by active rivers. This unique hydro-geomorphic set up makes its marginal embankment very damage sensitive thus the entire area gets inundated by the tidal rush. The Table 1 depicts detail scenario of the morphological set up of the entire region along with major processes and active operating agents (Fig. 2).

Data base and methodology

The paper attempts to understand the spatio-temporal changes of shoreline configuration in relation to the erosion and deposition processes along with their underlying mechanisms, in the estuarine Sundarban region between Muriganga and Saptamukhi interfluve using some old toposheets of 1920–1921, 1922–1923 of survey of India, US Army Toposheets of 1955, Survey of India toposheets of 1967–1968, 1968–69 and IRS P6 LISS IV images of 2014 using Arc GIS (Arc map 10, esri) software (Table 2). Some quantitative analysis on the bank line shift and shoreline configuration have been done by the scientist from the very beginning of the last century (Bandyopadhyay et al. 2004; Raju et al. 2010; Jana et al. 2012; Rudra 2012; Chakraborty 2013; Das et al. 2013). The different erosional and depositional patches as well as the changing bank line conditions have been detected with the imposing of successive digitized layers after image to image rectification from all the toposheets and images of successive periods. Patches of erosion and deposition have been used to calculate the net areal changes in different geomorphic units (Hazra et al. 2010; Jana et al. 2012; Das et al. 2013; Hossain et al. 2015). The net areal change is the absolute difference between eroded area and deposited area. The net areal changes of different geomorphic units have been assigned in descending order to find out maximum and minimum erosion hazard intensity zones.

Results and discussion

Spatio-temporal changes of shore line configuration

The shorelines, river banks are one of the most dynamic geomorphic features over earth surface (Bandyopadhyay et al. 2004; Raju et al. 2010; Jana et al. 2012; Chakraborty 2013; Das et al. 2013; Laha and Bandyopadhyay 2013). Spatio-temporal changes of shoreline configuration of Muriganga–Saptamukhi interfluve of deltaic estuarine Sundarban region has been analyzed between 1920–1921, 1922–1923 and 2014 using transects lines and successive superimposition of shorelines and river bank (Fig. 3a). In order to understand the spatio-temporal changing pattern of shoreline configuration net shoreline movement, end point rate have been employed over transects map (Fig. 3b).

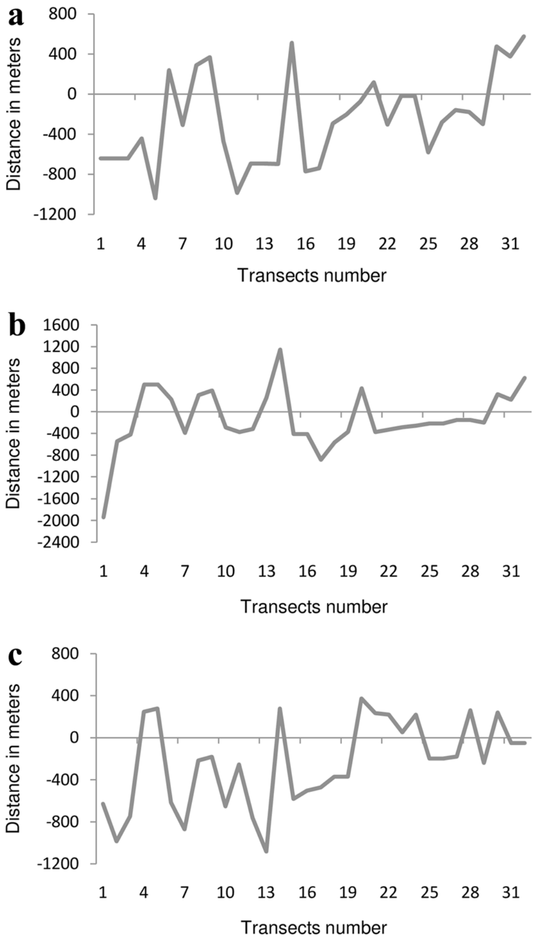


Fig. 4 **a**, **b**, **c** Net shoreline movement in different periods

Net shoreline movement

Net shoreline movement is a statistical measure of the distance between two successive shorelines (Jana et al., 2012; Das et al. 2013) (Table 3). The whole movement has been analyzed in three phases from 1920–1921 to 2014.

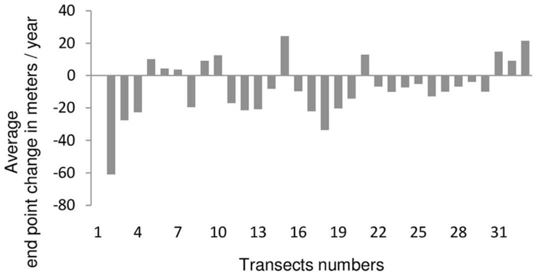


Fig. 5 Average end point change rate of shorelines

Table 4 Areal extent of erosion and deposition over time. Source: Survey of IndiaToposheets 1920–1921, 1922–1923, 1967–1968, 1968–1969, IRS P6 LISS IV Image 2014 and Field survey

Geomorphic units	1920–1921, 1922–1923–1955		1955–1967, 1968, 1968–1969		1967–1968, 1968–1969–2014	
	Erosion	Deposition	Erosion	Deposition	Erosion	Deposition
Low lying coastal flat	Entire southern parts	Patches in eastern and western parts	Southern and eastern parts	Mainly along western parts	Almost entire shoreline	Some isolated patches in western parts and eastern parts
Low lying Island	Entire southern parts	Some patches in north western parts	Entire southern parts	Some patches in north western parts	Entire southern parts	Some patches in north western and north eastern parts
Low lying tidal flat	North east, north west and south east	South western part and central part	North east, north west and south east	South western part, eastern part and central part	North east, north west and south east	South western part, eastern part and central part
Elevated tidal flat	South western part	North western part	Almost entire western part	Some patches in south western part	Almost entire western part	Some patches in south western part

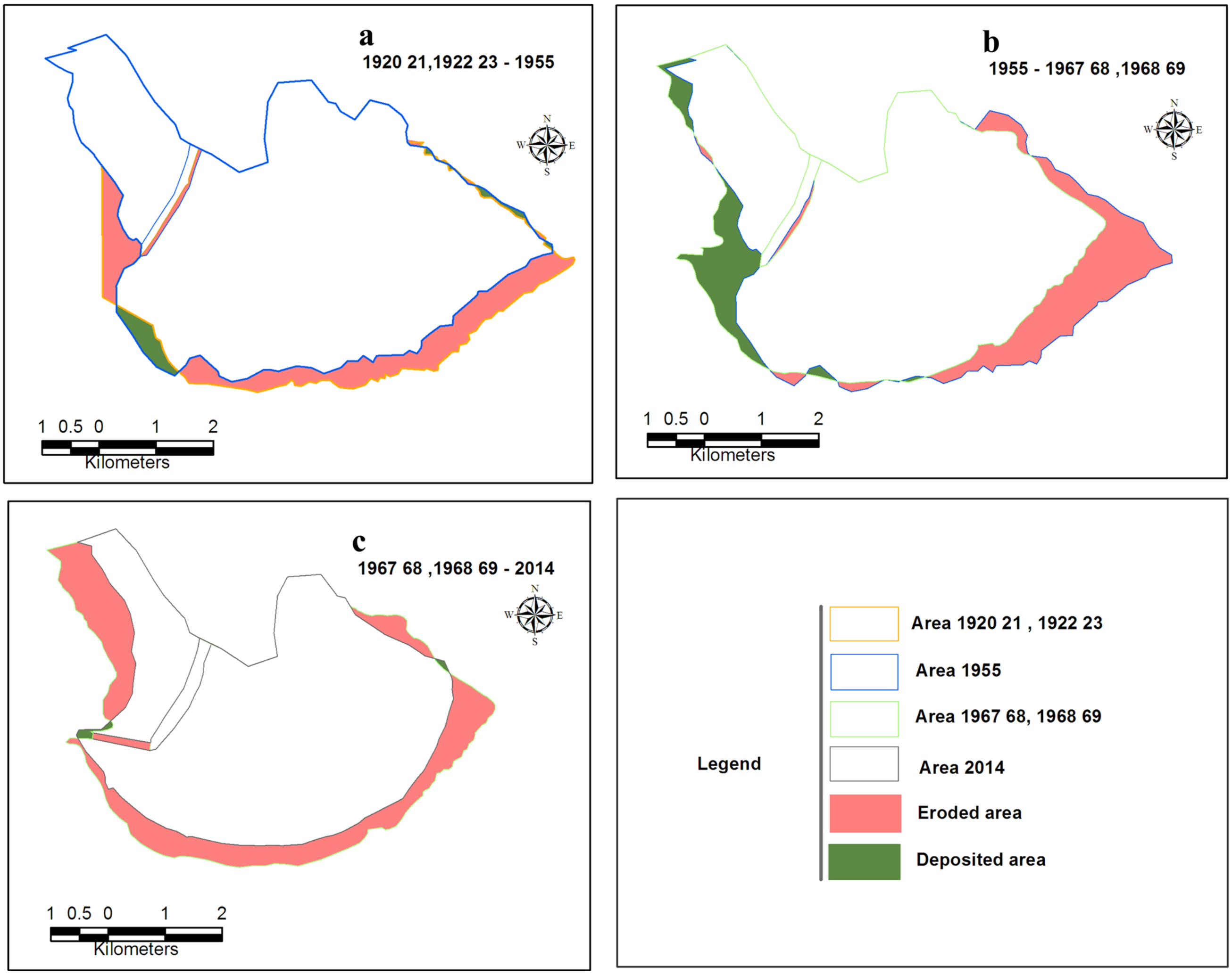


Fig. 6 Extent of erosion and deposition in low lying coastal flat region

Between 1920–1921, 1922–1923 and 1955: During this periods 25 % of the transect lines around different areas have shown positive changes (6, 8, 9, 15, 21, 30, 31, 32) whereas 75 % have shown negative changes (1, 2, 3, 4, 5, 7, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29) (Fig. 4a).

Between 1955 and 1967–1968, 1968–1969: during this periods 32 % of the transect lines have shown positive changes (4, 5, 6, 8, 9, 13, 14, 20, 30, 31, 32) whereas rest of the 62 % transect lines have shown negative changes (1, 2, 3, 7, 10, 11, 12, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26, 27, 28, 29) (Fig. 4b).

Between 1967–1968, 1968–1969 and 2014: this period have also shown similar patterns like previous two. Out of total transects 72 % transects have shown negative changes (1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 25, 26, 27, 29, 31, 32) whereas only 28 % transects have positive change (4, 5, 14, 20, 21, 22, 23, 24, 28, 30) (Fig. 4c).

Average end point rate of shoreline changes

This is another quantitative form of shoreline change measurement (Jana et al. 2012; Das et al. 2013). Here rate of changes are considered instead of absolute distance, in between two successive years (Table 3). The present work highlights an average end point change rate of shoreline between 1920–1921, 1922–1923 and 2014 to make an appraisal on average rate of changes (Fig. 5). Out of total sample transects around the study area almost 69 % of the transects have experienced regressive change and only 31 % of transects have shown positive changes.

Erosion and depositional dilemma in different geomorphic units over time

The present work composes a detail assessment on spatio—temporal changes of each geomorphic unit over time. Using GIS software individual vector layers of shore lines are superimposed successively to extract patches of erosion

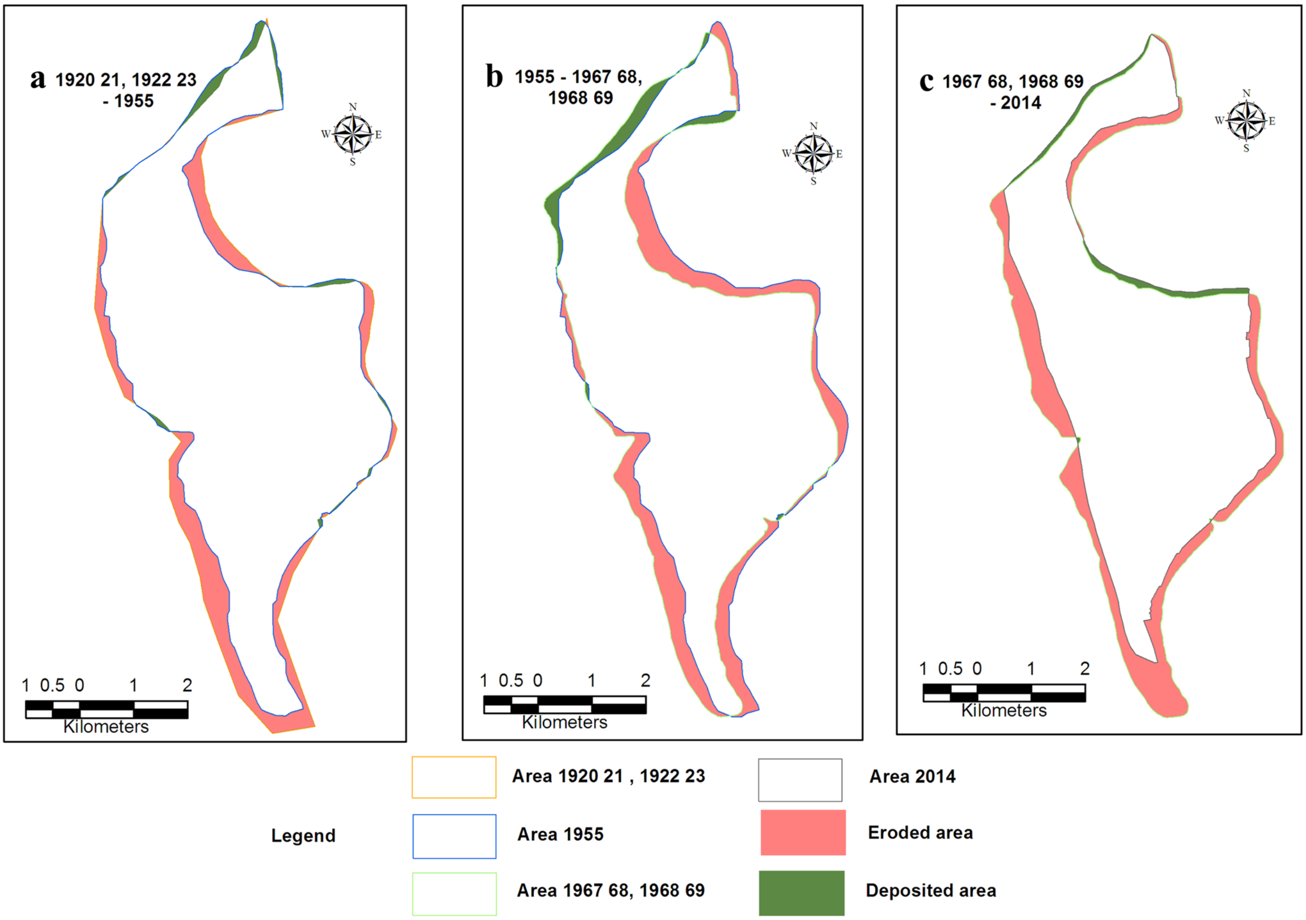


Fig. 7 Extent of erosion and deposition in low lying island region

and deposition over the time (Bandyopadhyay et al. 2004). After the detail mapping of erosion and depositional extent over different geomorphic unit's net change has been formulated out to understand the direction and magnitude of temporal changes after superimposing the multi temporal maps. The resultant fact is that the total amount of land erosion exceeds the total amount of deposition, hence the entire study area is now experiencing a negative change, though the amount of the net areal changes is dynamic from region to region (Table 4; Figs. 6, 7, 8, 9).

Assessment on erosion hazard intensity

The spatio—temporal changing form of erosional depositional extent along the bank line has been detected over each geomorphic unit to find out net areal changes over time. On the basis of the net areal changes erosion hazard zones has been identified (Fig. 10; Table 5). The net areal changes of different geomorphic units have postulated an important fact that the low lying coastal flat and low lying island areas have experienced massive erosion due to estuarine exposure, concentration of loose sandy materials, havoc tidal rush, extremely flat low lying topography, frequent cyclonic disturbances etc. The elevated tidal flat in the upper reaches of the estuary has shown moderate amount of net areal changes depending on channel forms, land word increase in tidal range and tidal flow directions, whereas in case of low lying tidal flat in the middle reaches of the estuary total amount of net areal change is comparatively low than the other geomorphic units due to the inner location, direction of tidal flow and nature of channel forms. The outer convex bank along the left site of the area

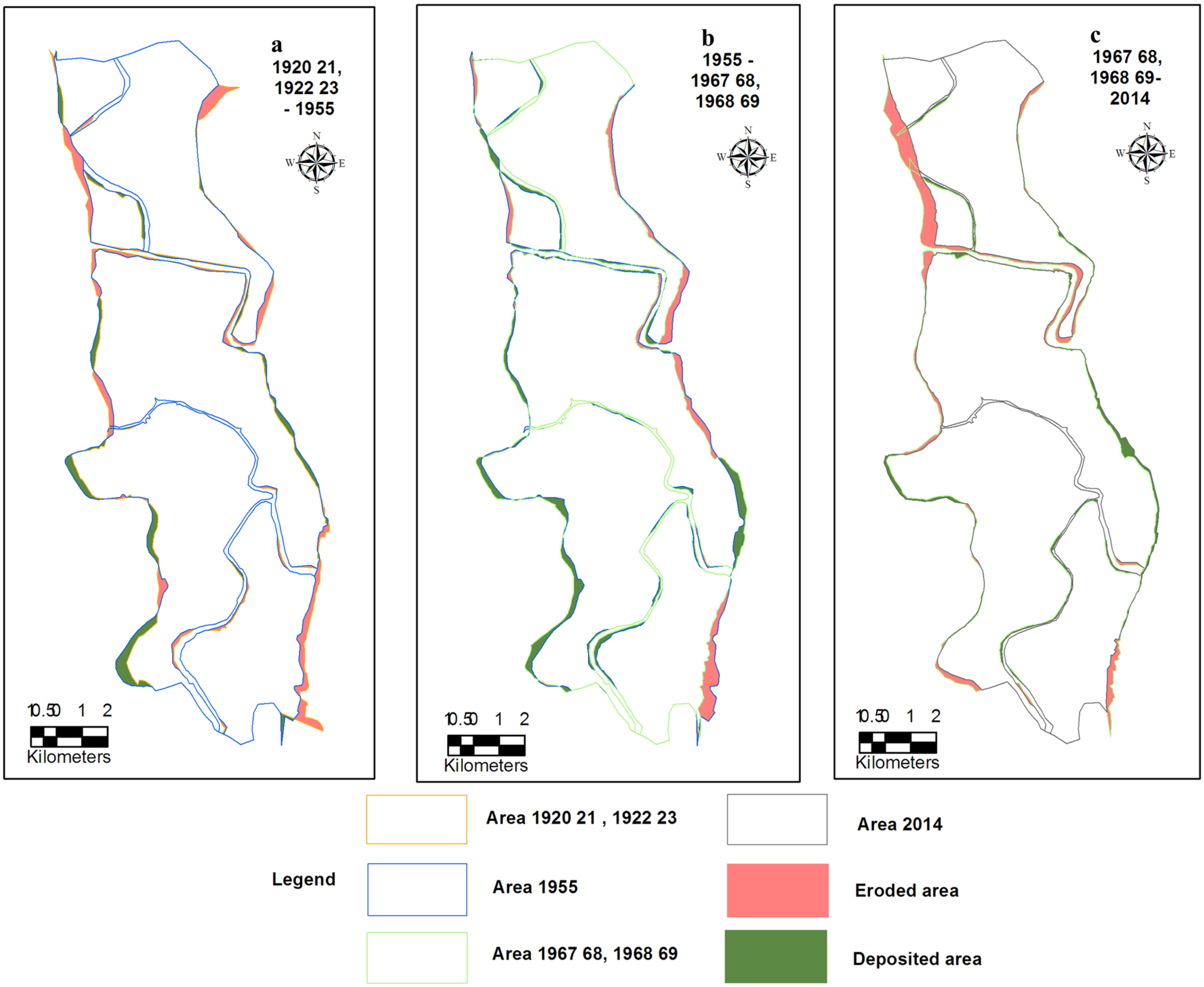


Fig. 8 Extent of erosion and deposition in low lying tidal flat region

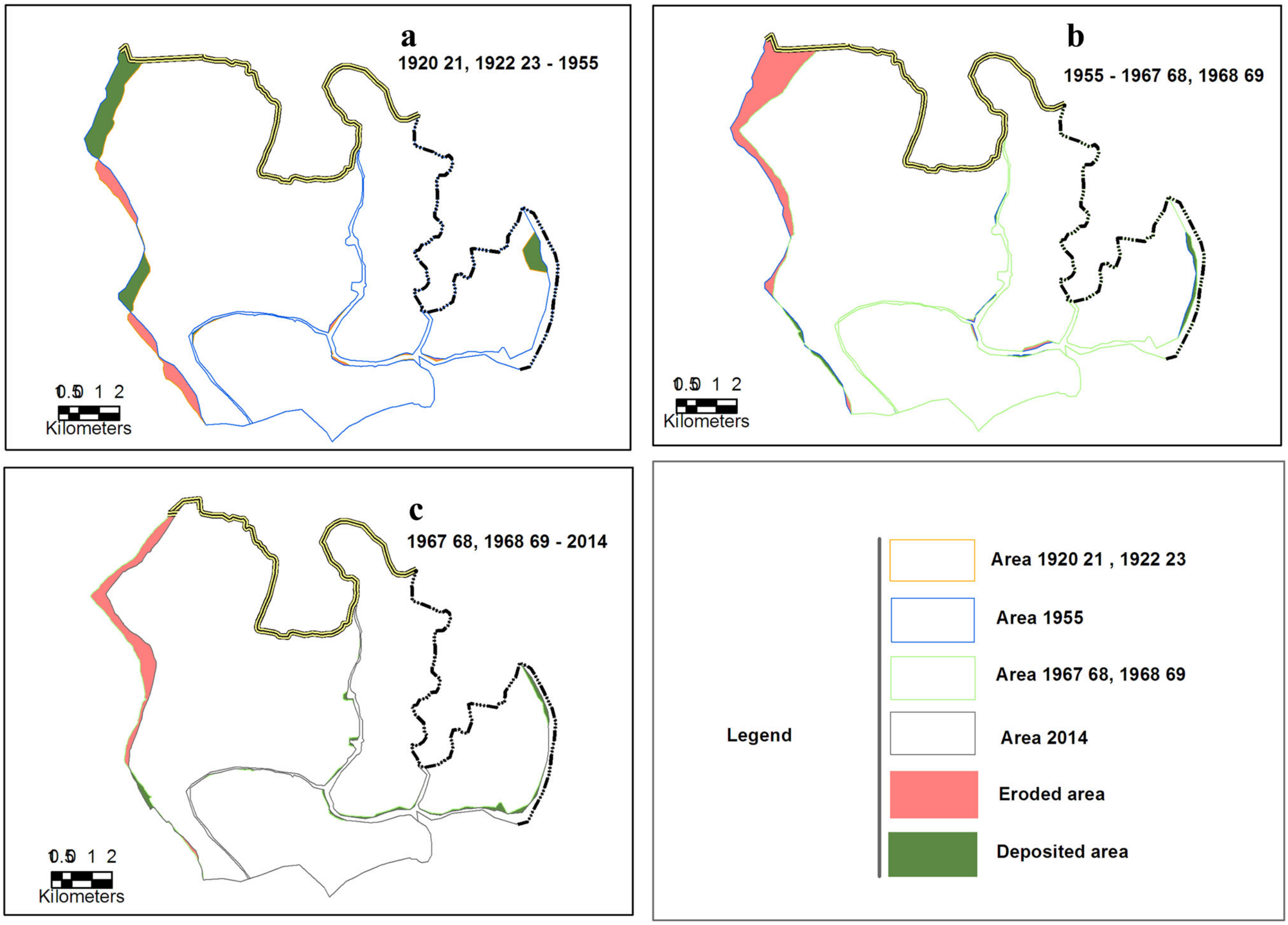


Fig. 9 Extent of erosion and deposition in elevated tidal flat region

has experienced steady erosion side by side depositional process has been active along the right site of inner concave bank.

Strategic framework

At present management of the coastal belts, deltas and estuarine environment is utmost necessary as those regions are highly susceptible to damages by frequent natural calamities and it is the homeland of million peoples (Doukakis 2005; Basu 2013; Weichselgartner and Pigeon 2015). Natural dynamics like coastal erosion, estuarine bank line alteration, rising surface temperature, changing frequencies of severe cyclonic activity, sea level change etc. have a collective manipulation on the geomorphic environment as well as on human communities in the Sundarban region. The western estuarine part of the Sundarban is one of the most vulnerable zones in this regards. Massive erosion, regressive shoreline change and progressiveness of tidal rush collectively enthrones a large confront for the Samaritans of the region. Hence structural and non structural management is needed, whereas true commitment from government and non government organization is also compulsory (Table 6).

Conclusion

The face of the Sundarban has changed successively over time due to natural and human induced reasons. The flat sandy coastal belts, deltaic estuarine low lands in the Sundarban region on the one hand have been severely affected by natural processes like long shore current, macro tidal rush, seasonal cyclonic activities, land subsidence, relative sea level rise etc. and on the other hand by anthropogenic processes like embankment construction, deforestation, immature land reclamation and bank dwellings etc. which have collectively influenced the natural

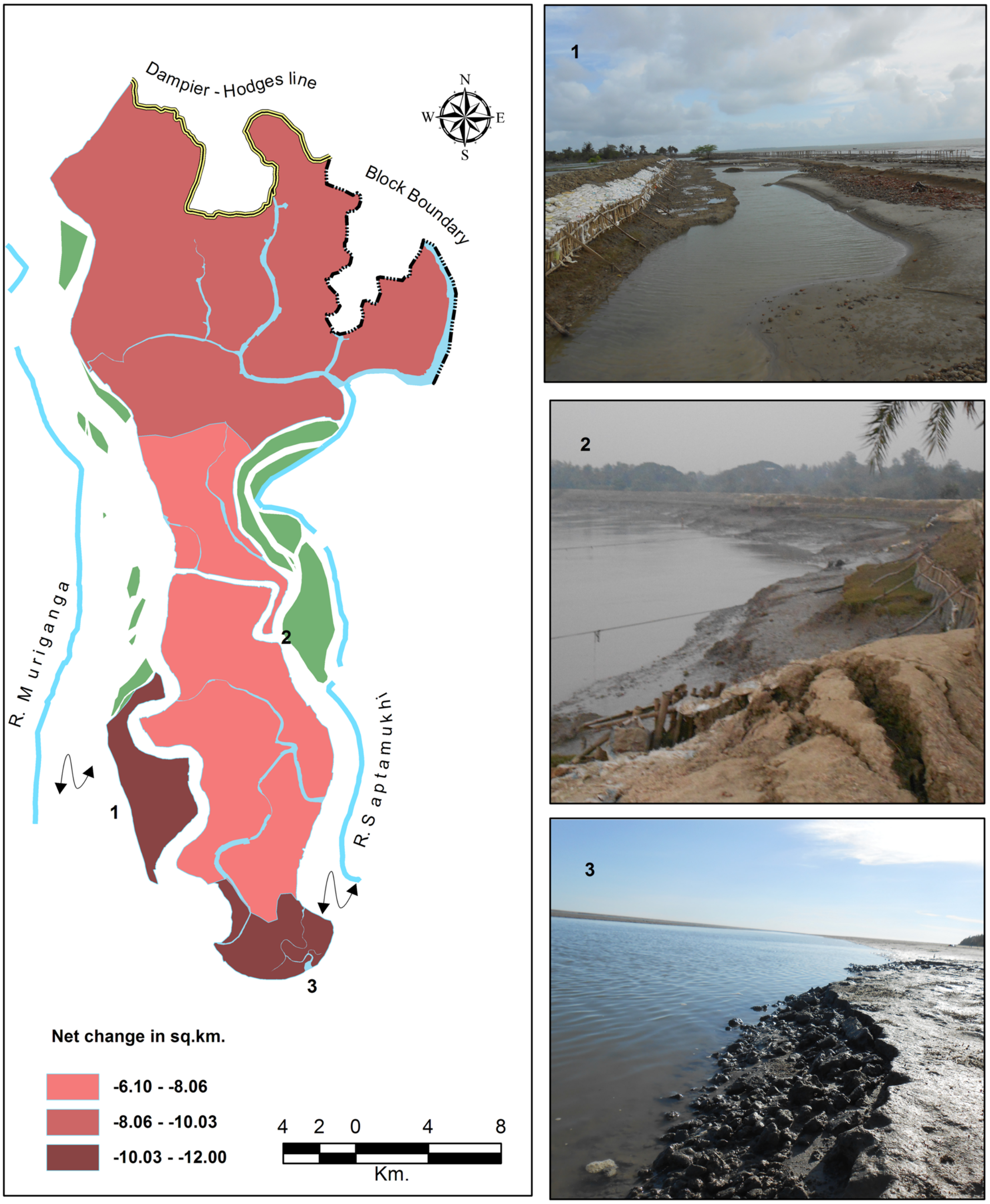


Fig. 10 Erosion hazard zones based on net areal changes over time

landscape of Sundarban region. The region especially its marginal parts have been severely affected by the erosional processes and salt water ingression. Coastal belts in the extreme southern parts, most of the low lying islands in the mouth reaches of the estuaries and exposed river banks of the Sundarban region have been severely eroded by the immense tidal bores resulting regressive changes in the morphological shape and extent of the shoreline configuration. Over time land loss becomes an important environmental crisis of this deltaic part of Sundarban region. So the currently used quantitative techniques for determining the net shoreline change, average rate of end point change

Table 5 Net areal changes in each geomorphic unit over time

Time/area	Low lying coastal flat		Low lying tidal flat		Low lying Island		Elevated tidal flat	
	Erosion (square kilometers)	Deposition (square kilometers)	Erosion (square kilometers)	Deposition (square kilometers)	Erosion (square kilometers)	Deposition (square kilometers)	Erosion (square kilometers)	Deposition (square kilometers)
1920 21, 1922, 1923–1955	3.5	0.5	6.4	4.3	4	0.6	4.4	7.9
1955–1967, 1968, 1968–1969	4	2	5.8	5.9	5.1	1	9.9	1.6
1967–1968, 1968, 1969–2014	5.5	0.1	7	2.9	5	0.5	6.3	2.4
Total	13	2.6	19.2	13.1	14.1	2.1	20.6	11.9
Net areal change (square kilometer)	10.4		6.1		12		8.7	

Table 6 Strategies and agencies involved for the management of natural hazards

Areas of management	Agencies involved	Scale of impact
Embankment and sluice gate construction	Department of irrigation and waterways, Government of West Bengal	Regional
Embankment management, infrastructural development	Department of irrigation and waterways Government of West Bengal, Sundarban affairs department Government of West Bengal, Integrated coastal zone management plan Government of West Bengal, Block Development office, village panchayets, District disaster management Committee	Regional
Conservation of forest resource	Sundarban affairs department, Integrated coastal zone management plan Government of West Bengal, Block Development office, village panchayets	Regional
Monitoring the bathymetric condition of the estuary	Kolkata Port Trust. Marine Department	Regional
Conciseness, education and campaigning	Sundarban affairs department Government of West Bengal, Integrated coastal zone management plan Government of West Bengal, Block Development office, village panchayets, District disaster management Committee	Local to regional
Monitoring climatic conditions and tide	Regional meteorological centre, Alipore Kolkata. Kolkata Port Trust. Marine Department	Regional

and net areal change can well be applied in other parts of Sundarban region. Consequently proper coastal zone management strategies can be fruitfully implemented.

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