



Coastal Erosion in Gabardhanpur and Surrounding Area, Patharpratima, South 24 Parganas, West Bengal, India

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JGEESI/2018/41617

Editor(s):

(1) Anthony R. Lupo, Professor, Department of Soil, Environmental and Atmospheric Science, University of Missouri, Columbia, USA.

Reviewers:

(1) Abidemi O. Ilori, University of Uyo, Nigeria.

(2) Emmanuel Etim Okon, University of Calabar, Nigeria.

Complete Peer review History: <http://www.sciencedomain.org/review-history/24706>

Short Research Article

**Received 23rd April 2018
Accepted 16th May 2018
Published 22nd May 2018**

ABSTRACT

Sundarban mangrove delta represents one of world's delta where the Tidal action is extremely active. This unique tropical ecosystem has been delineated as almost vulnerable and disaster prone area in the world due to several aggressive natural hazards like sea level rise, cyclone, coastal erosion, salinization etc. Coastal erosion is the one of the most important hazards. This paper aimed to evaluate the coastal erosion in this area. It also attempted to find out the causes and consequences of coastal erosion in this area. Another objective of this study is to measure and quantify the rate and pattern of coastal erosion. Gobardhanpur and its surrounded mouzas (Mouza is the least administrative area in India. It is also called as a village) have been chosen for the study area. This village is most affected area due to coastal erosion in this region. Descriptive types of research method, literature survey, and questionnaire survey methods have been applied to this work. Questionnaire has prepared by 4 point Likart scale. Satellite data, mouza map and topographical map have been used for chronological analysis and determination of the rate of erosion. The maps and satellite images have been processed to digital images and superimposed for exploration of a pattern of coastal erosion through image processing software. The result shows that the Gobardhanpur and Plot G 6th portion are the most affected area. Another finding is that the Plot G 6th Portion almost vanished from the map. The cause of the coastal erosion of this area is

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mainly natural because forested areas are still extremely eroded. Man-made or anthropogenic causes are less in number. The result shows the consequences of this hazard. People lost their land which was used for agriculture, prawn culture, fishing. They have lost homestead property. They have diverted their occupation. People also migrated from this area as refugees.

Keywords: Vulnerable; Mouza; anthropogenic; satellite data.

1. INTRODUCTION

Coastal erosion can be defined as the removal of material from the coast by wave action, tidal currents and or the activities of man, typically causing a landward retreat of the coastline [1]. On the other hand land ward displacement of the shoreline caused by the forces of waves and currents is termed as Coastal Erosion. The Coastal areas have become more prone and vulnerable to natural and human-made hazards which lead to Coastal Erosion [2]. The occurrence of coastal erosion is dependent upon the balance between the resistance, or erodibility, of the coastline and the strength, or erosivity, of the waves and tides affecting the area. Consequently, rates of coastal erosion and accretion are very variable at regional, national and international scales.

Coastal erosion typically results in a landward retreat of the coastline. This can increase the risk of coastal flooding and result in loss of land and damage to buildings, infrastructure and agricultural land. Sudden coastal erosion events, particularly those in the vicinity of coastal cliffs, may directly endanger the lives of people. The movement of salt-water into freshwater areas (saline intrusion) can occur during coastal flooding and can impact upon the biodiversity of previously freshwater or terrestrial ecosystems. In Sundarbans coastal erosion is a big problem. Both physical and socio-economic environment has been affected by coastal erosion.

2. LITERATURE REVIEW

Several types of research conducted on coastal erosion in the different coastal region specifically link coastal erosion in West Bengal coast. Some researchers also assessed the coastal erosion in Sundarban region for both India and Bangladesh.

2.1 Empirical Study

Bandhyopadhyay (2000) studied the changing coastline of the Gangetic delta of West Bengal. He prepared a map to show the changing

coastline of Bengal delta with the data from 1770 to 1908-10 AD. His analysis shows that the coast line of Sundarban shifted. Gobardhanpur coast of Patharpratima block was included in this coastal area. He also studied on another coastal area like Sagar, Bakkhali, Mousuni etc. The causes of the shoreline shifting and coastal erosion are physical factors like a sea wave, the intensity of tide instead of river effect. Other causes are morphological structure, geology, sea level change, the morphology of sea floor. But deforestation is not involved in the coastal erosion [3]. Paul [4], suggested the factors of coastal erosion like offshore and onshore drift, wave energy variations, wave refraction pattern, longshore current, water table alteration, development intervention, human-induced land use changes, sediment character, high water level situations, high-level situation etc. Hazra [5] stated that Sundarbans, the only mangrove tiger-land of the globe is presently under threat of severe coastal erosion due to relative sea level relief. Mukherjee,(2016) has reported that the GP is very much threatened by impacts of climate change induced climatic shock which caused disappearing of one village Gobardhanpur inside the sea 10-12 years ago. "The southern part of Sitarampur has disappeared, while the northern part is slowly getting swallowed up as the land gets eroded by the onslaught of the sea." – The Hindu, Feb 24, 2008 [6]. Bangladesh Centre for Advanced Studies (2012) found out that one of the worst affected mouzas is Gobardhanpur. The Bay of Bengal has eaten away almost three – fourth parts of Gobardhanpur Mouza and the inhabitants of this mouza have lost their lands, assets & livelihoods and become the victims of coastal erosion. They are compelled to migrate permanently without any rehabilitation package [7]. Saha, Bhandari and Ghosh (2015) surveyed Gobardhanpur village. It was the most affected mouza during 'aila' in 2009 in Patharpratima CD block. This cyclone accelerated the coastal land erosion process. Saini [8] pointed out that the village Gobardhanpur has an overall high vulnerability to climate change. Das and Bandyopadhyay (2012) stated that the main causes of coastal erosion of southern facing areas of Sundarban are abandonment of

sediment-replenishing western distributaries of Ganga, due to western tilting of the Delta and off-shore interception of westward transportation of sediment by the swatch of No Ground submarine canyon (Bandyopadhyay and Bandyopadhyay, 1996; Bandyopadhyay et al., 2003) [9]. Bera [10] examined that Gobardhanpur village is the most destructive village due to chronic floods and rapid land erosion. A large number of people had been displaced due to rapid land erosion during the 1980s. Saini [11] studied on the immediate threats and vulnerabilities faced by the poor people in Sundarban coastal region due to climate change. The village Gobardhanpur in Patharpratima block of Sundarban has covered by a study which has an overall high vulnerability to climate change.

2.2 Satellite Study

Chatterjee (2015) have shown that landforms of Sundarbans are changing shape rapidly following the impact of several forcing parameters, both natural (atmospheric, physical, chemical and geological) and anthropogenic (pollution, tourism, deforestation). She has assessed the changes in shoreline pattern of 14 islands in Indian Sundarbans (ISD) since 1979. Using multi temporal satellite images of LANDSAT, she found that as many as four islands within Indian Sundarban have lost area in excess of 30%. While the area loss for another three islands has been between 10 and 30%, five islands show minor loss of area (<10%). The shoreline variations in two other islands, however, are of extreme nature. An interesting difference in nature of land loss is seen between a western and eastern group of islands. She compared that over the last 32 years, the total loss of area in six western islands (Ghoramara, Sagar, Jambudwip, Mousuni, Namkhana, Lothian) has been 23.64 km², while another six islands from eastern Sundarbans (Surendranagar, Dhanchi, Bulchery, Chulkati, Dalhousie and Bhangaduani) have lost about 53.85 km² of land area. Gobardhanpur is located in Surendranagar. She also determined the role of various forcing parameters, such as longshore current, abnormal tidal heights, subsidence, tilting of crust and sub-surface geomorphology, in effecting changes in shoreline pattern in 14 Islands of the Indian Sundarbans. She discussed the shoreline pattern of eastern Sundarbans over the last little more than three decades. The Surendranagar Island under Patharprotima Block is located southeast of Namkhana. This almost lenticular shaped island faced rapid erosion along its southern boundary

with the sea. The total land area of the island has been reduced from 47.3 km² in 1979 to a little more than 40 km² in 2011, ensuring a loss of almost 7 km² of land due to erosion. It is observed that the south and southeastern banks of the island faced maximum burnt of erosion. As the Gobardhanpur is located in southern part of this island, so it is affected by coastal erosion [12]. Indian Space Research Organisation (2014) has prepared the shoreline change atlas map on the basis of satellite image SPOT-1 with sensor HRV1-MLA, dated 27th January, 1989 and IRS-P6 with sensor LISS-IV, dated 26th January 2006. This map proved that the coastal area of Gobardhanpur is retreating. Chacraverti (2014) said that archaeological findings by two villagers at Gobardhanpur, at G-Plot, in the Pathar Pratima Block and subsequent investigations by archaeologists have indicated a thriving settlement as old as the third century BC.25 However; all these findings are from sites close to the sea of Gobardhanpur. Therefore, these are indicating that human activity was there in the past. That can be a factor of coastal erosion here [13]. Rahman (2012) has studied on Sundarban which is located in Bangladesh to show the time-series change analysis by remote sensing method using satellite data of 1970 and 2011. He has also calculated the rate of erosion rates in the Sundarbans. He also divided the area into the eastern and western part. The average rates of erosion for the eastern and western parts are 14 m/year and 15 m/year respectively. He did not clear that how much coastal erosion is linked to the global warming and sea-level rise or whether any other associated factors such as geological and anthropogenic induced land subsidence, changes in sediment supply or other local factors are driving these changes [14]. Hazra (2010) studied on the temporal changes of Sundarban islands. He has shown the shore line recession in Indian Sundarban by the analysis of IRS-P6 LISS-III satellite images of 2001 and 2009 [18].

2.3 Archaeological Study

Chakravarti (2014) assessed the history of human settlement in Sundarban region. He pointed out that the archaeological findings at Gobardhanpur in the Patharpratima Block and subsequent investigations by archaeologists have indicated a thriving settlement as old as the third century BC.25. However, all these finds are from sites close to the sea as in the case of Gobardhanpur. Therefore, these are necessarily indicators of habitation in the study area in general. The human habitation and structural

construction and activity can be one of the major causes of coastal erosion [15]. Guriya [16] assessed on the basis of archaeological findings like fossilized bone, brick kilns, domestic materials from 20 feet depth of eroded part in the sea that there were a port or ancient town in Gobardhanpur which is situated in the southern tip of Surendarnagar Island of Patharpratima CD block. He mentioned that 5000-7000 bigha (802-1124 hectare) land was reclaimed after 1930 but all amount of land has been gone to the Bay of Bengal.

3. STUDY AREA

Administratively the study area (Gobardhanpur and its surrounding areas like Buraburir Tat, Sitarampur and Plot G 6th portion) is located in Patharpratima CD in South 24 Parganas district of west Bengal, India. The study area extended in latitude from 21°35'30" N to 21°39'04" N and in longitude from 88°22'56" E to 88°25'51" E. These are four villages or Mouzas. All the four villages were affected by coastal erosion. Gobardhanpur and Plot G 6th portion village was the worst affected mouzas, but the second one has no settlement. The Jagaddal River and Saptamukhi River boarded the east and west respectively of this area. North, side of this area is bounded by Indrapur

village. South side of this area is facing towards Bay of Bengal.

4. OBJECTIVES

- To identify the causes of coastal erosion in the study area.
- To measure and quantify the coastal erosion.
- To find out the effect of coastal erosion on the study area.

5. METHODOLOGY AND DATA BASE

In this study, previous literatures have been used to find out the causes of the coastal erosion of the study area. Satellite images of the study area from LANDSAT (1989, 2000 and 2017) satellites and cadastral maps (1947-51) and Survey of India topographical map 1968-69 were used and analyzed on a GIS platform to determine shift in shoreline and quantify the coastal erosion area of the Gobardhanpur and its surrounding area over a period of 63 years. All LANDSAT images were ortho-rectified and geo-referenced through UTM projection and WGS-84 datum in the USGS web platform. These images have been downloaded. Then for easy visual interpretation, the image processing techniques have been applied through same image processing software QGIS-

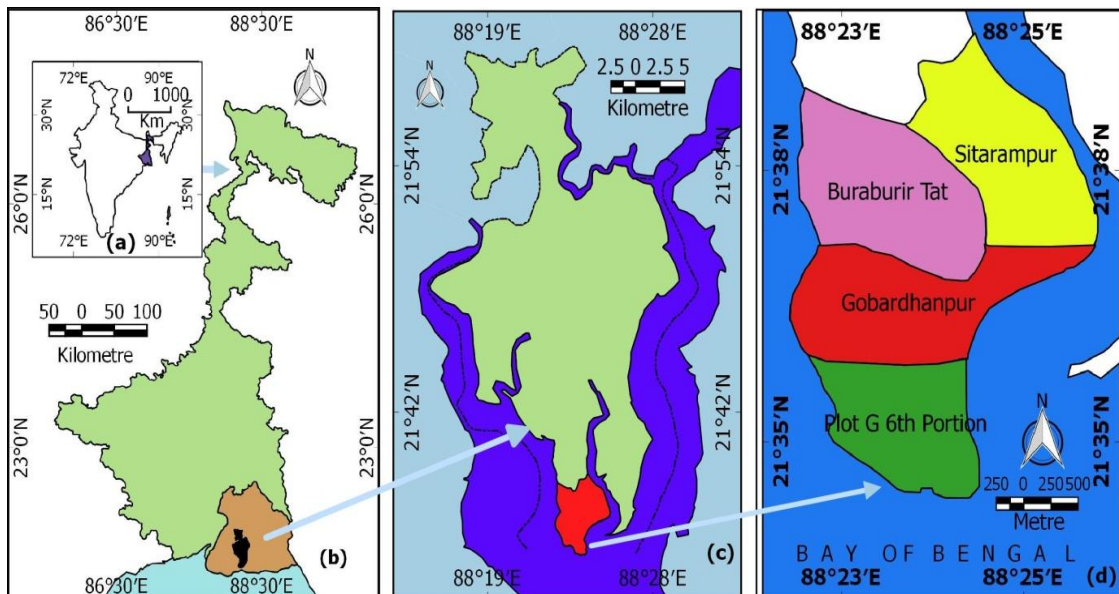


Fig. 1. Location of the Study area - (a) West Bengal in India, (b) Patharpratima CD Block and South 24 Parganas District in West Bengal, (c) Study area in Patharpratima CD Block, (d) Study area

2.14.10. Band combination like the near-infrared (NIR), red and green bands were stacked to produce a standard False Colour Composite image (FCC). Vegetation appears red due to high reflection in NIR by green leaves. A standard FCC was created from Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) data by stacking the bands 4, 3 and 2. A standard FCC was obtained from Multispectral Scanner (MSS) data by stacking the bands 5, 4 and 4 to help identify various different land features. The Survey of India topographical map and cadastral map have been geo-referenced through same projection and datum using image processing software QGIS-2.14.10 and used as base data. Shapefiles were created for this area from cadastral map by digitizing along the village land boundary. Shapefiles for topographical map and images have been created by digitizing along high tide line. The high tide lines were mapped using Survey of India topographic sheets as reference. These shape files contain polygon layers which indicate coastline situation for a given year. Then superimposition of digitized polygon layers as coast lines has been done. The prepared superimposed map shows the coastal erosion quantity and chronological shoreline shifting situation in the study area. They are eroded per year in different villages or mouza within the study area were extracted and plot of area eroded versus time is made. At last, self-prepared questionnaires were surveyed on 40 residents of the study area. Survey questionnaire has been made with 4-point Likert scale which expressed as Strongly Agree, Agree, Disagree and Strongly Disagree where strongly agree rated as 4 and strongly disagree rated as 1. Percentage analysis statistics has been used to find out the effects of coastal erosion. The details of used maps and images are in the following table.

6. CAUSES OF EROSION

6.1 Natural Causes

Bottom topography and geology of closed sea of Gobardhanpur is the most important factor of coastal erosion in this area [9], [19]. Tidal action and ocean current play a dominant role in shoreline retreatment in the study area [3]. It has to be pointed out that the causes of rapid erosion of islands are high difference between high tide and low tide, magnitude and intensity of sea wave [3]. Sundarban, the only mangrove tigerland of the globe is presently under threat of

severe coastal erosion due to relative sea level rise [5]. The main causes of the coastal erosion of the sea (Bay of Bengal) facing islands of Sundarban are an abandonment of sediment-replenishing western distributaries of Ganga due to western tilting of the Delta and off-shore interception of westward transportation of sediment by the Swatch of No Ground Submarine Canyon [12]. The other causes of coastal erosion are a frequent cyclonic storm, manmade engineering construction in the coastal area [5].

6.2 Anthropogenic Causes

The role of human being on coastal retreatment is very least, because, these activities have happened within last few decades. Deforestation is not related to coastal erosion in this area. Sea level rise due to greenhouse effect is not important factor till now but it can be an important cause of coastal erosion in this area. Embankment construction can be a major man-made factor for coastal erosion [3]. Here also it has to point out that the archaeological findings at Gobardhanpur, and subsequent investigations by archaeologists have indicated a thriving settlement as old as the third century BC. However, all these finds are from sites close to the sea. So it can be say that human settlement with engineering construction built up in Gobardhanpur. This is also an important factor for coastal erosion. So the causes of the coastal erosion of Gobardhanpur are both natural and anthropogenic [15], [18]. Shoreline water table alteration, development intervention, other human-induced land use changes may be human-induced factor for coastal erosion [19].

7. MEASUREMENT OF EROSION

Superposition and subsequent analysis of maps and satellite images of the study area bring out a significantly faster rate of erosion in all the four mouzas of the study area (Fig. 2). Tables 1 and 2 provide the summary of the findings.

From the study, it is astonishingly revealed that the forested *mouza* (Plot G 6th portion) was eroded more than the reclaimed one. The forested *mouza* also showed progressive erosion. The coastline of all mouza retrograded during this time period between 1954 and 2017. The Maximum coastal retreat of the area is noted in Plot G and Gobardhanpur. Gobardhanpur village situated along Bay of Bengal has already

lost almost three fourth of its land area due to soil erosion.

The above map shows the pattern of coastal erosion in the study area. The trend of erosion has progressed from south to north. Erosion is the main process no doubt, but slight deposition also taken place in the western side of this area side by side. South and south eastern side has the most eroded shoreline in this area. North western and eastern sides are almost stable from the erosion point of view. One can assume that the present trend of erosion would certainly wash

out a major portion of the southern half of the study area.

The following line graphs show the change of area of the respective mouzas. If the changing area is arranged by decreasing order, so the mouzas would be arranged like Plot G 6th Portion, Gobardhanpur, Buraburir Tat and Sitarampur. The Fig. 4 shows the comparison of erosion in between Gobardhanpur and Plot G 6th portion. This comparison shows the coastal erosion status for a period of 1954 and 2017.

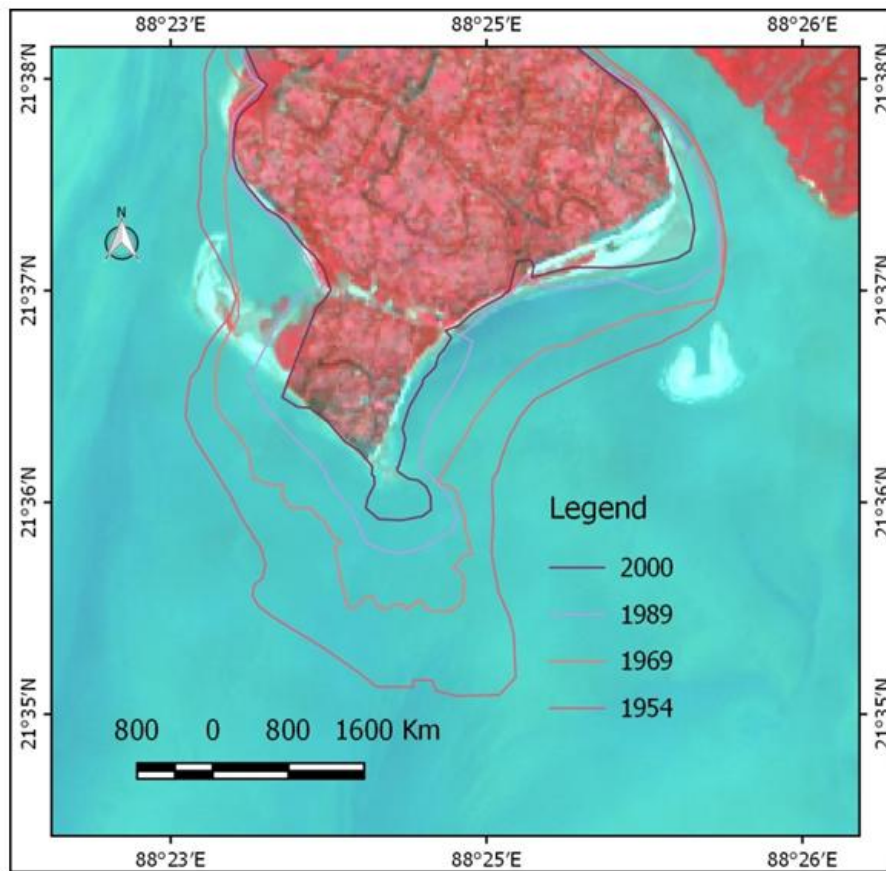


Fig. 2. Recession of shoreline from 1954 to 2017 (The image of 2017 belongs to FCC)

Table 1. Maps and satellite images used for this study

Maps / Satellite Images	Year of survey / acquisition	Path / Row	Scale / Spatial Resolution	Sources
Cadastral map	1947-51	-----	1:3960	Land Record office
Topographical map	1968-69	-----	1:50, 000	Survey of India
Landsat - 4 TM	1989	138 / 45	30 m	United States
Landsat - 7 ETM+	2000	138 / 45	30m	Geological Survey
Landsat – 8 OLI TRISS	2017	138 / 45	30 m	

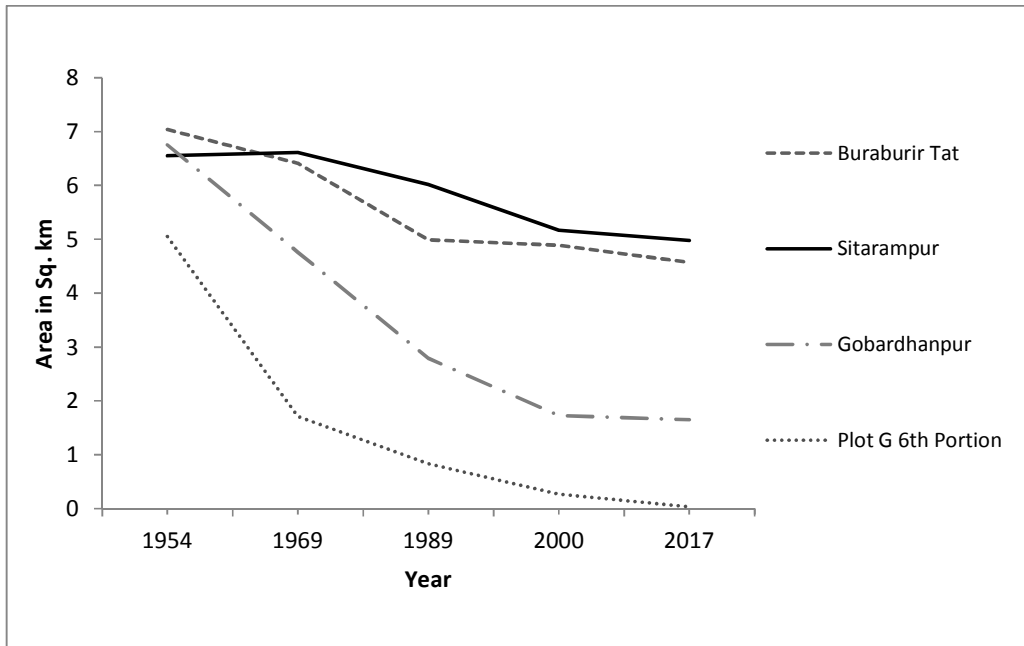


Fig. 3. Change of area of the respective mouzas

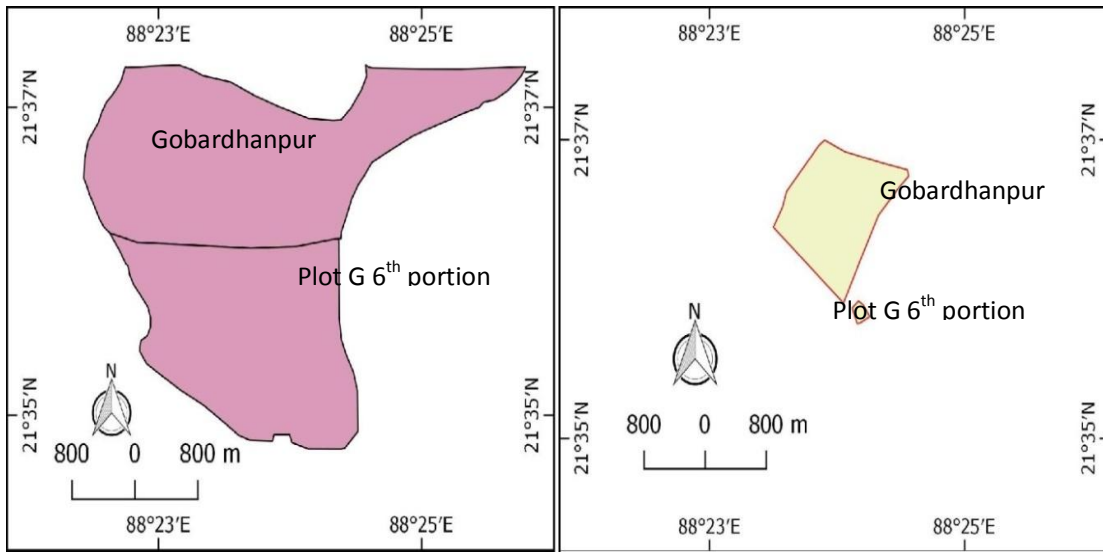


Fig. 4. Status of Gobardhanpur 1954 and present status of that area (2017)

Table 2. Area of mouzas in chronological order

Mouza	Area in Km ²				
	1954	1969	1989	2000	2017
Buraburir tat	7.04	6.41	4.99	4.89	4.57
Sitarampur	6.55	6.61	6.02	5.17	4.98
Gobardhanpur	6.75	4.76	2.79	1.73	1.65
Plot g 6th portion	5.05	1.71	0.83	0.27	0.03

Table 3. Rate of erosion

Mouza	Rate of erosion $\text{Km}^2 \text{yr}^{-1}$			
	1954-1969	1969-1989	1989-2000	2000-2017
Buraburir Tat	0.042	0.071	0.009	0.018
Sitarampur	-0.004	0.029	0.077	0.011
Gobardhanpur	0.133	0.098	0.096	0.004
Plot G 6th portion	0.022	0.044	0.051	0.014

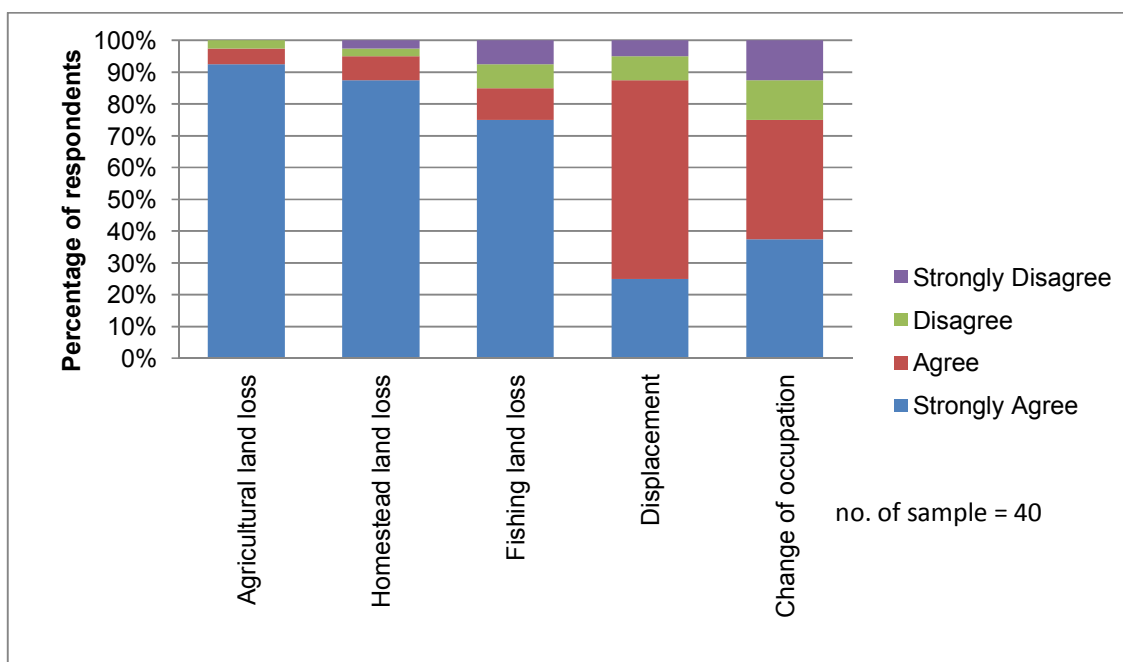


Fig. 1. Effects of coastal erosion

8. EFFECTS OF EROSION

Gobardhanpur mouza like other mouzas of Sundarban has lost their huge land into the sea [3]. The major effects of coastal erosion on Bengal coastal area are property loss, displacement of population, loss of livelihoods, tourism loss, and environmental degradation [7]. The inhabitants of this mouza have lost their lands, assets & livelihoods Gobardhanpur was surveyed as it was the most affected mouza during 'ailla' in 2009. Gobardhanpur of Pathpratima is the mouza where agriculture dominates and in all these mouzas the economic condition of the inhabitants is below average [10]. It can also increase the risk of coastal flooding which may cause damage to infrastructure, agricultural land, buildings etc. Salt water intrusion can make the soil infertile and drinking water unfits [17]. Questionnaire survey outcome undermines us the effect of coastal erosion from a socio-economic point of view. The

following figure (Fig. 5) shows that more than 95 % people were agreed to loss of their agricultural land. Gobardhanpur village has already lost almost three fourth of its land area due to soil erosion. It also strongly affects their economy, as maximum people were depended on agriculture.

They also lost their homestead land and fishing areas. Almost 90-95% people were agreed and strongly agreed with these effects of coastal erosion. Next important effect of coastal erosion is displacement of people. They have been shifted or migrated from this place to neighbouring village or far away of this region. Above 85 % people were agreed with this problem. Residents of this coastal area did change their occupation. People of this area basically depended on agriculture and fishing. They have changed their occupation to other secondary economic activity. Some people also migrated from this area for the sake of better job opportunity.

9. CONCLUSION

The findings show that all the three mouzas have been facing the threat of coastal erosion. Satellite images and other maps help to indicate the future disastrous fate of the villages of Gobardhanpur and Plot G 6th portion. The trend shows that Plot G will vanish in very near future. Gobardhanpur is the second most affected village which has already lost about 80% of land area into the sea. People are trying to manage alternative forms of livelihood. Proper solution measures have curtailed the rate of erosion compared to the past. Local government and other NGOs have been initiating to take the responsibility to find out a solution in this respect.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sciencedomain.org/review-history/24706>