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Assessing coastal vulnerability of Kanthi coast, WB

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Abstract

The study location is about 45 km coastal stretch between Ramnagar-I, Ramnagar-II, Contai-I, and Contai-II of the West Bengal state, it is located north east coast stretch of India. The coastline, which includes harbour, hotels, tourist resorts, fishing coastal villages and towns, it has faced threats of various disasters like floods, storms, cyclones, tsunami and erosion. The study area is situated in sub-tropical littoral tract; the coastal tract is prone to tropical cyclones, storm surges and tsunamis. The coastal blocks of Kanthi have experienced in the recent years, flooding taking place by not only because of storm surges originating in the Bay of Bengal, but also due to flooding from the rivers as well as from heavy precipitation associated with tropical cyclones and monsoon depressions. The present study aims to develop a coastal vulnerability assessment using CVI (Coastal Vulnerability Index) between Digha to Junput coast, West Bengal using relative risk variables. The use of CVI index is help to recognize high and low vulnerable zones and areas of water inundation due to flooding CVI is also facilitate to study sea level rise, and land loss due to coastal erosion. The present study used both conventional and remotely sensed data were for analysis. The zones of vulnerability to coastal hazards of different magnitude (very high, high, medium, low and very low) are documented. This study pointed out that Digha to Jaldah estuary has high vulnerability, Jaldah to Pichaboni estuary has medium vulnerability and Pichaboni to Rasulpur estuary has low vulnerability in the study area. The major findings of this research showing the majority of coastline is prone to erosion, the findings suggest that the Ministry of Environment should declare new areas as protection areas and develop special environmental programs for national level planning.

Keywords: sea level, vulnerability

Introduction

The state of Odisha situated on the Bay of Bengal coast of India, periodically experience loss of life and severe damage from tropical cyclones originating in the Bay of Bengal. In addition to that diverse human pressures, many Coastal areas are already experiencing acute environmental problems, such as coastal erosion, pollution, degradation of dunes and saline intrusion of coastal aquifers and rivers. The coastal land and water comprise 8% of the earth's surface. It is the reservoir of 25% of the entire global biological productivity. The said are comprises watersheds, marshes, flora and fauna, coastal and fresh waters, forest etc. [1]. Though being important resource-wise, the coastal zone of West Bengal is under severe and increasing pressure from high density of population, rapid urbanisation, pollution, tourism development, and continued development in hazard prone areas, aquaculture and habitat alterations [2]. The coastal zone is also proving to natural hazards. Such as cyclones, floods, erosion, dune erosion and shifting of sands etc. the increasing pressure of human activities in the coastal areas is felt more when one fined numerous problems affecting the said area viz. land erosion, siltation, sea level rise, salinization of fresh water aquifers, loss of wetlands and coastal biodiversity [3]. The increase of several unplanned development activities has also made way to the pollutants reaching the coastal zone and thereby threatening the coastal ecosystems. The combined effects of natural as well as anthropogenic factors on the coastal areas call for critical understanding of all the factors and issues involved for sustainable utilization on this vast resource base. We observed the sea-levels are ever-increasing along the eastern coast of India too. Studies based on the analysis of long-term tide-gauge data from various stations along the Indian coastal regions, corrections for vertical land movements included, indicated that sea levels are rising at a rate of about 1.0–1.75 mm per year due to global warming [4, 5, 6] used coastal slope, geomorphology, mean tidal change, sea level rise mean shoreline change rate, and mean wave height for assessment of coastal vulnerability of the US Atlantic coast [7]. Have assessed the coastal vulnerability of Golden Gate National Recreation area to sea-level rise by calculating a coastal vulnerability index (CVI) using both geologic (shoreline-change rate, coastal geomorphology, coastal slope) and physical process variables (sea-level change rate, mean significant wave height, mean tidal range). The various physical variables like sea-level rise, coastal erosion, Storm water inundation, potential vulnerability implications of sea-level rise for the coastal zone of Cochin, SW coast of India has been studied [8] to provide climatic change and sea level rise. Odisha, on the eastern coast of India, is not only attains rains from the southwest monsoon branch from the Bay of Bengal like the west coast, but also from the annual cyclones from the Bay of Bengal which influence it and bring copious rain with two seasonal peaks, July-August and October-November. Digha - Junput coastal tract over which this study has concentrated is a part of Kanthi coastal plain of Purba Medinipur, West Bengal (Fig. 1). The extents of the study area is between Latitude 21°36′50″N to 21°43′00″N and Longitude 87°29 ′40″E to 87°49′30″E. The length from Digha to Junput coastal tract is 45 km and it has 4 blocks are Ramnagar-I, Ramnagar-II, Contai-I, Contai-II. The elevation of the coast in the southernmost region is <3 m above the sea level.

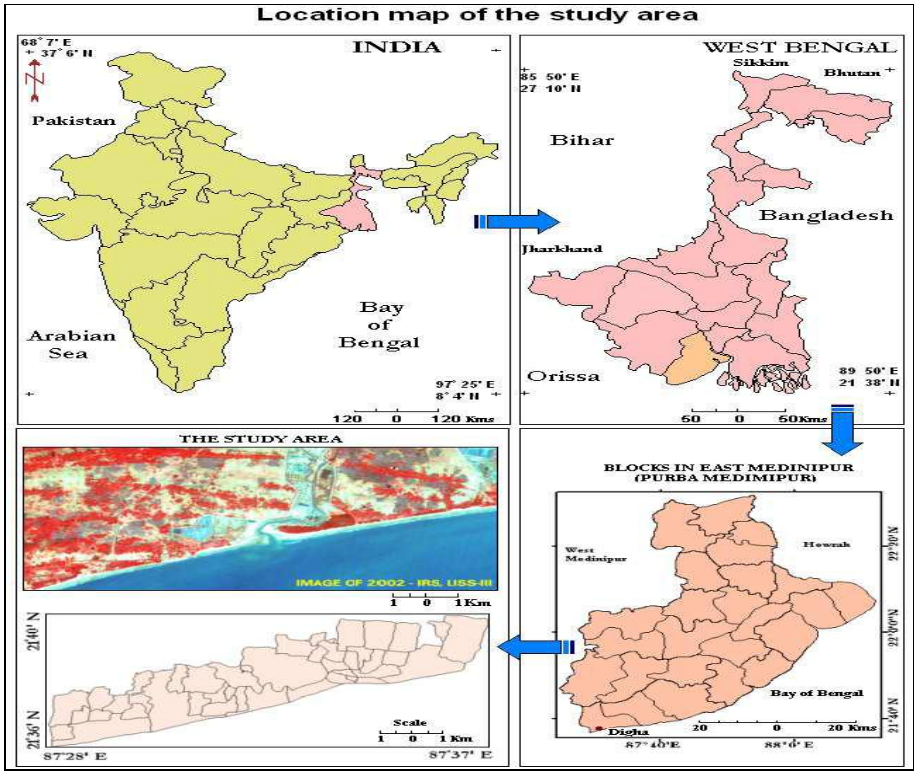

Fig 1: Location map of the study area

Objectives

Geo environmental study of any a coastal area in India appears to be a real challenge because of it's over changing conditions as well as the lack of availability of sufficient data. For the study of geo-environmental viz: coastal erosion, shifting of shoreline, change of geomorphology and land use is influenced by the micro level local change of sea level. Based on the forgoing scenario this investigation has been carried out the following objectives:

1. To study the present sea level rise using Sea level and tidal gauge data.
2. To find out the local and regional level coastal vulnerability

Data use

To understand and study the sea level rise and coastal vulnerability assessment the different data sets are used for Coastal vulnerability indexing (CVI). The present research methodology can be analyzed to have two parts where first part considered the trends of sea level rise through the available sea level data (PSMSL). While another part involves to the analyses of sea level rise effects by using by using shuttle radar topographic mission (SRTM) Global Digital Elevation Model (DEM) and the satellite images(Details about the data used are given in Table 1.

Table 1: Data used in the present study

Types of data and software	Details of the data	Sources
Sea Level Data	Monthly and yearly tidal gauge data	PSMSL
SRTM DEM	3-ARC (90 m), 2000	USGS
Landsat MSS and TM satellite imagery	Path/row: 149/45 and 139/46 dated 18/01/1990 and 22/05/2005	USGS website

Methodology

Assessing coastal vulnerability to sea-level rise

Coastal plays a significant role in the economy of nation with large shoreline like India and is under stress due to intense use and high population density. Being a high dynamic part of the earth's surface, coastal area are subject to various types of hazards like coastal erosion, storm surges, tsunami, cyclones etc. Thermal expansion is associated with the sea water expansion and it is the effect of high sea surface temperature [9]. The level of the water in the ocean is the result of water volume increase which is caused by increase of sea surface temperature [10]. According to IPCC (The Intergovernmental Panel on Climate Change) report, the Predicted sea level fluctuation of 21st century, gradually increases at the rate of 1-2mm per year [11], where [9] has mentioned that the average sea level has increased in the 20th century is about 1.5 ± 0.5mm per year causing by physical and human-induced climate change. The IPCC reports also have predicted that the sea level may rise in the order of 0.17 m to 0.59 meters in the next 100 years (Fig. 2). But this is significantly different than the 0.06-0.37 meters (4-10 inches) that the sea level has been raised over the last hundred years. Generally, sea level is fluctuated with the Glacial and Interglacial Period. During the ice ages, the sea level is lower, but when the ices get started melting in the Inter-glacial period, sea level is increasing [12]. An improved understanding of sea-level rise and variability will help to reduce the uncertainties associated with sea-level rise projections [10] thus, effective to more effective coastal management and planning. Adaptation measures to minimize the potential losses include restrictions on where, what and how to build, strengthened building codes, and developing local infrastructures which are mostly suitable for flooding [13]. Sea level rise poses greater impacts on the coastal environments [14], as these are the densely populated area that may be submerged fully or partially and easily exposed to face the natural disasters [15]. Eastern Coast i.e. Bay of Bengal is not exception of that. The eastern coast is also affected by the several storm surges of the Bay of Bengal. That also takes few responsibilities for the rising of sea level. This may be due to thermal expansion of seawater, ice melting, etc. [9]. But, in general, for every 1 centimetre (0.39 inches) that the sea level rises, 1 meter (39.3 inches) of coastal land will be lost. The SLR will also contribute to the recession of the world's sandy beaches, 70% of the sandy beaches have been retreating in the past century. East Coast of India had also experienced the rising tendency of the sea level not in an equal tendency, but it varies differently throughout the coastal areas [16]. However, increasing coastal population, recent observed cyclones and storm surges, and climate change induced sea level acceleration stressed the importance of the scientific studies on coastal vulnerability and the collect appropriate information for government decision makers, community residents [17]. We observed the sea-levels are ever-increasing along the eastern coast of India too. Studies based on the analysis of long-term tide-gauge data from various stations along the Indian coastal regions, corrections for vertical land movements included, indicated that sea levels are rising at a rate of about 1.0–1.75 mm per year due to global warming [2].

The study location is about 45km coastal stretch between Digha to Junput of the West Bengal state, it is located north east coast stretch of India. The coastline, which includes harbour, hotels, tourist resorts, fishing coastal villages and towns, it has faced threats of various disasters like floods, storms, cyclones, tsunami and erosion. The study area is situated in sub-tropical littoral area; the state is prone to tropical cyclones, storm surges and tsunamis. The coastal of West Bengal have experienced in the earlier years, severe flooding taking place by not only because of storm surges originating in the Bay of Bengal, but also due to flooding from the rivers as well as from heavy precipitation associated with tropical cyclones and monsoon depressions. The present study aims to develop a coastal vulnerability assessment using CVI (Coastal Vulnerability Index) between Digha to Junput coast, West Bengal using relative risk variables. The use of CVI index is help to recognize high and low vulnerable zones and areas of water inundation due to flooding CVI is also facilitate to study sea level rise, and land loss due to coastal erosion. The present study used both conventional and remotely sensed data were for analysis. The coastal Vulnerability Index (CVI) index allows the 8 physical variables to be related in quantifiable phenomena that assess the relative vulnerability of the coast to physical changes due to sea-level, Tsunami and flood effect. A variety of spatial dates i.e., coastal geology, geomorphology, coastal slope and coastal morphodynamic variables have been considered as additional important variables (Table 2). Once the coastline is assigned a risk value for each variable, the CVI is calculated by the square root of the product of the ranked variable divided by the total number of variables [18]. The CVI is represented by the Equation (1).

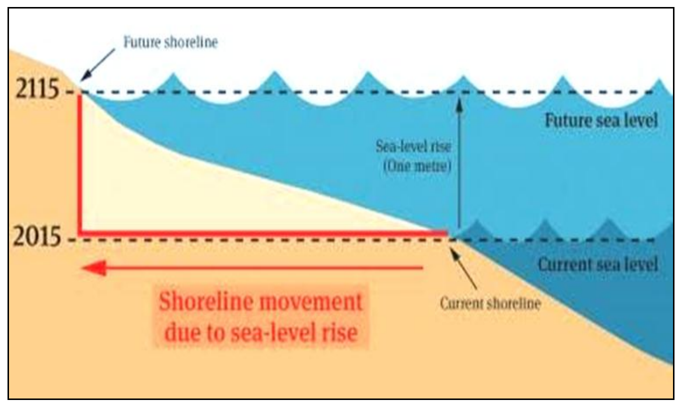

Fig 2: Assessment of future sea level rise (IPCC)

The study is focused on Remote Sensing and GIS analysis of different vulnerable zones is identified and coastal vulnerability assessed. The zones of vulnerability to coastal hazards of different magnitude (very high, high, medium, low and very low) are documented. This study pointed out that old Digha, Shankarpur, Chandpur zone has very high vulnerability, New Digha, Mandarmani coastal has high vulnerability, Dadanpatrabar has medium vulnerability and estuarine and Junput has vulnerability low and very low vulnerable in the study area (Fig. 2). The major findings of this research showing the majority of coastline is prone to erosion, the findings suggest that the Ministry of Environment should declare new areas as protection areas and develop special environmental programs for national level planning.

Table 2: CVI index thematic layers

Variables	Risk rating		
	Low(1)	Medium(2)	High(3)
Shoreline change rate (m/y)	>0 (accretion)	≥-10 and 0 (erosion)	>-10(severe erosion)
Coastal slope (degrees)	>1.0	>0.2 and ≤1.0	≥0 and ≤0.2
Coastal regional elevation(m)	>6.0	>3.0 and ≤6.0	>0 and≤ 3.0
Sea level change rate(mm/y)	<=0	>0 and ≤1.0	>1.0 and ≤2.0

Significant wave height(m)	-	1.4-2.1	-
Tidal range(m)	≤2.5	2>.5 and≤ 3.5	>3.5
Geomorphology	Highly Dissected Hills	Moderately Dissected Hills	Sandy beaches, spits
Tsunami arrival height(m)	≥0 and ≤2.38	>2.38 and ≤3.0	>3.0

$$CVI = \sqrt{a+b+c+d+e+f+g+h+i} \qquad (1)$$

Where,
a = Shoreline change rate (m/y)
b = Sea level change rate (mm/y)
c = Coastal slope (degrees)
d = Significant wave height (m)
e = Tidal range (m)
f = Coastal regional elevation (m)
g = Coastal geomorphology
h = Tsunami run-up (m)

Results and Discussion

We calculate the CVI scores are categorized into very high, high, moderate, low and very low, categories based on the quartile ranges. All the studied shorelines were found to have an erosion/accretion rate between -2.0 and +2.0 m/yr and are ranked as being of high vulnerability in terms of that particular variable. The rate of relative sea-level change is ranked using West Bengal rate of sea-level change eustatic rise (1.0 to 2.0 mm/yr) as moderate vulnerability. Mean wave height contributions to vulnerability rank very low (0- 0.5 m) and mean tidal range rank low (>2.1m).Those parts of the coastline having CVI values ranging. The very high CVI values 7.14 to 12.65 are categorized as very high vulnerability observed in old Digha, Shankarpur and Chandpur. The medium vulnerability area ranges is 5.12 to 7.90 it is cover the areas of New Digha, Mandarmani, Gangadharpur. The CVI values of low vulnerability coastline are about Dadanpatrabar to Junput (Table 3).

Table 3: Ranking of coastal sensitivity index in the Kanthi coastal tract

CVI index	Stations	Category
High	Digha, Shankarpur, Chandpur	12.65-7.14
Medium	New Digha, Mandarmani, Gangadharpur	5.12-7.90
Low	Dadanpatrabar to Junput	3.5-4.40

Source: Field data & satellite data

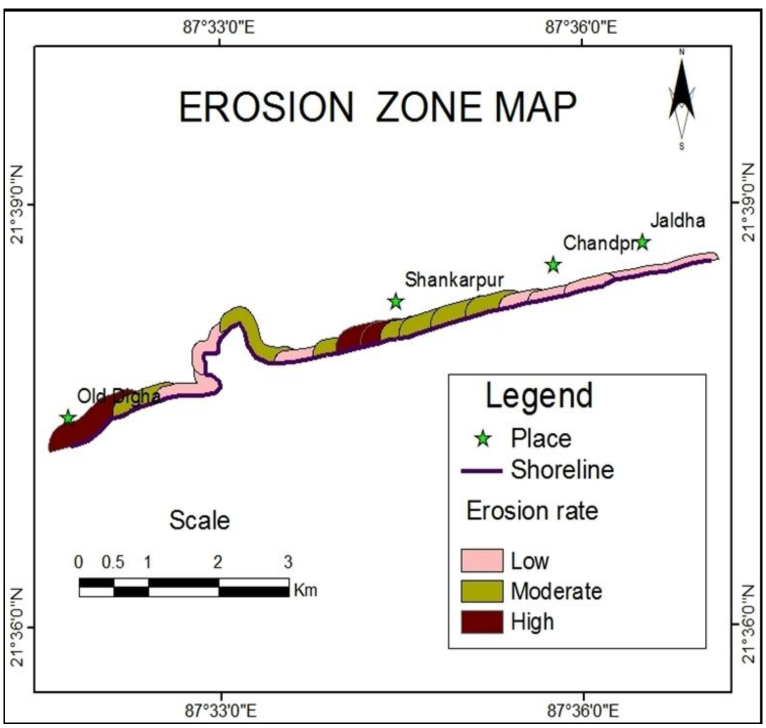

Fig 2: Coastal vulnerability map to sea level rise

A. Risk Assessment

Risk provides the basis for decision-making and institutional acceptance of protective measures. Risk is calculated by correlating information derived from the hazard assessment and the vulnerability assessment, i.e. (Hazard + Vulnerability) = Risk. The characteristics of risk are then analysed in terms of estimated probability of occurrence, magnitude and incidence of losses, which can be calculated both in quantitative or qualitative terms. With the help of a risk zone map prepared for the study area, it has been estimated that around 1500 people are under the immediate risk of coastal flooding and loss of habitat and displacement from Digha-Shankarpur & Jalda coast, unless shore protection measures are taken immediately. The number can significantly increase in the near future along the entire open coastal stretch, if we consider accelerated rise in sea level and an increased frequency of severe cyclones and surges. So, the coastal tract of Digha to Jaldah is high risk and the Jaldah to Pichaboni estuary and Pichaboni to Rasulpur estuary is medium and low risk zone (Table 4).

Table 4: Ranking of coastal risk zones of Kanthi coastal plain

Coastal tract	Risk zones
Digha to Jaldah estuary	High
Jaldah to Pichaboni estuary	Medium
Pichaboni to Rasulpur estuary	Low

***Source*:** Field & satellite data

B. Assessment the Shoreline Changes

In New Digha, the slope of maximum portion of shore zone is gentle type, about 1° 13′ 7″; the angle of wave impact is 5° 48′. Old Digha shows some steeper beach slope, about 2° 34′ 3″, the angle of wave impact is 3° 3′ 35″. In Shankarpur - Chandpur, the beach slope is also gentle, about 1° 52′ 35″; the angle of wave impact is 7° 42′. At present there is a narrow beach in old Digha and become wider towards the new Digha. The breaker condition is spilling. The coast of Chandpur is for more prone to erosion by mainly long shore current due to greater angle of wave impact. One unit of incoming long shore drift is concentrated to a smaller portion of the cost here due to steeper angle and so intensity of erosion is high. Angle of wave impact is not related directly with wave but with shoreline configuration and prevailing wind direction. In Shankarpur - Chandpur region angle of wave impact is more than old and new Digha and it is responsible for erosion. The breaking wave energy is also responsible for the erosion of coastline in this region. The result shows that the shoreline in the eastern part (New Digha) has seaward shifting with average rate of 14 m/y and hence the area is depositional. In eastern part, covering seawall protected Old Digha, Chandpur up to Jaldah show shoreline shift in the opposite direction with an overall rate of 13 m/y and the area is under severe erosion. In 1994 in New Digha HTL and LTL showed 44 m seaward and 122 m landward shift as compared to the 1986 position. The beach of new Digha is rising and in old Digha lowering from 1986 to 1994 till date. The position of HTL and LTL has shifted seaward by 127 m and 90 m respectively in the western part and about 32 m and 150 m land ward in the eastern part with compared with 1986 position of of HTL and LTL. The erosion is occurring in back shore in the eastern part of Chandpur. From the study, it has been observed that the entire terrain extending between Shankarpur - Mandarmani and Dadanpatrabar is under the threat of rapid erosion except the extreme Western parts where riverine accretion is taking place (Fig.3).

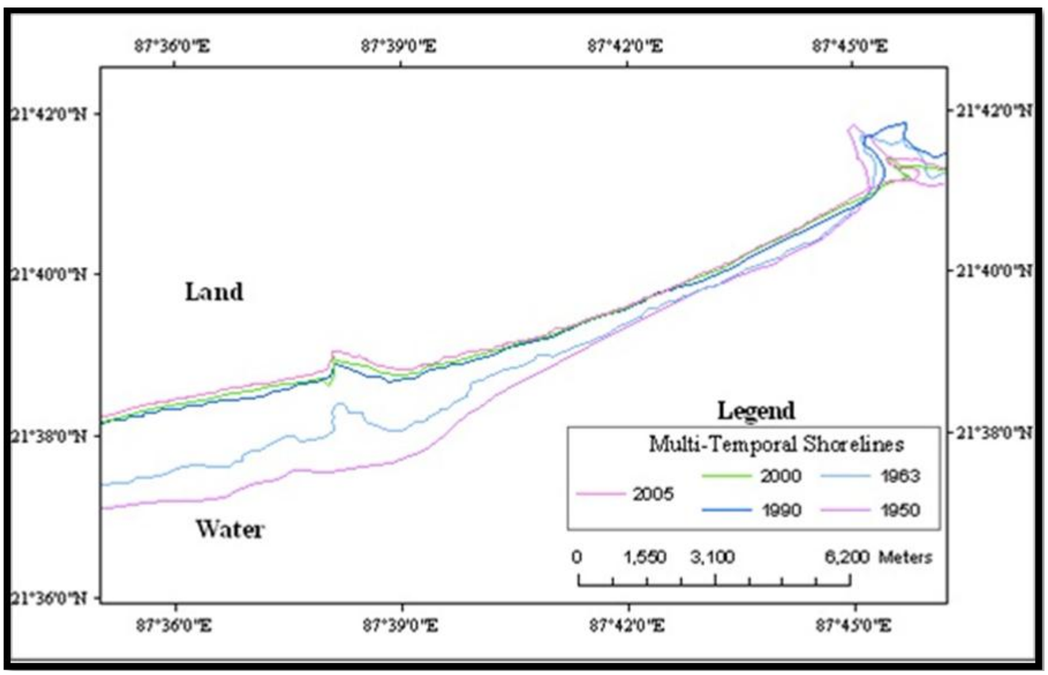

Fig 3: Changes of shoreline over time from 1950 to 2005

About 2519.31 hector land has been eroded due to the coastal erosion in this part in 55 years. However, this serious problem has not been able to raise adequate human awareness. It has been observed that tourism activities have continuously been vandalizing coastal tract for the sake of earning economic profit [19]. According to the Coastal Regulation Zone Notification (referred to as CRZ) dated 19 February 1991, under the Environment Protection Act 1986, no construction should be done in the area falling between the Low Tide Line (LTL) and the Highest High Tide Line (HTL) and even in the area falling within 500 meters of the landward side of the Highest High Tide Line (Ministry of Environment & Forests, 1991). Ignoring this Act, within the reach of high tidal water (High Tidal Line = HTL) hotels have been set up violating the rules and regulations of CRZ, especially in Mandarmani and surrounding tracts. However in Shankarpur, a better scenario persists. The past record of the enormous loss and damage caused by the coastal breech, all the establishments are now shifted from 1 km (approximately) from the beach in Shankarpur.

Conclusion

The conclusion from this study has some implications with short term and long term. From the statistical analysis and obtaining data from different years, we may conclude about some major historical storms, sea level and the coastal elevation effects to the different segments of the coasts. The different physical coastal variables representing different characteristics and coastal processes that can influence the sensitivity of a coastal zone to the impacts of coastal hazards and sea-level rise were ranked for cells along the coast between Old Digha to Shankarpur, West Bengal. The government is undertaking several coastline protection measures to reduce coastal erosion. Evidently, this effort is confined to a small coastal stretch. Nevertheless, this sort of scattered effort is not conducive enough to protect the vast coastal tract of Mandarmani - Shankarpur area of West Bengal. In order to maintain the overall balance of the coastal morphology as well as the environment, care and awareness are required from every section, starting from the grass-root to government level. Otherwise, the coastal erosion may cause the loss of valuable treasures like Mandarmani and its immediate surroundings in the future, and they would only remain in history. Finally suitable policy decisions and adaptive responses can be established in order to mitigate sea level rise.

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