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Analysis of Shoreline Changes along Western Section of East Midnapore Coastal Tract of West Bengal, India: An Application of Digital Shoreline Analysis System (DSAS)

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Abstract : *Coastal erosion is considered as one of the threatening hazards faced by the global community living in coastal region for their life and livelihood. With rapid increasing trend of the coastal population and developmental activities along the coast, adequate information about the rate and trend of coastal erosion in the past and the present is important. A comprehensive analysis of the shoreline change along the coast is necessary for appropriate coastal protection and management measures needed for the future. The coastal erosion results huge loss of coastal lands threatening the loss of habitat, livelihood and the coastal ecosystem. The shore line change and coastal morpho dynamics is best studied using coastal erosion and accretion. The shoreline change of the East Midnapore district of West Bengal has been studied using Landsat imageries of 1975, 1988, 1996, 2003, 2014 and 2022. Arc GIS version 10.4. with version 5.0 of Digital Shoreline Analysis System (DSAS) software is used for study of coastal erosion and accretion rate. The rate of change of the shoreline is calculated using End Point Rate (EPR), Linear regression rate (LRR), and Weighted Linear Regression (WLR). The shoreline erosion has been divided in to high, moderate, low. The accretion has been divided in to high and low accretion. The present coastline is affected by geological, tectonic factors, waves, longshore current, wind speed and direction, effect of storm surges, sea level fluctuations etc. The wave and wave induced currents control the littoral transport, erosion and accretion process in this tract. A strong littoral drift and longshore current exist along the shoreline in the north easterly direction. The coastal erosion of the study area is due to growth of Digha urban center for tourism, fishing port, increasing population pressure on the coastal land for agriculture, high tide, longshore current, storm surge by cyclonic storms and reduced sediment discharge by the river Subernarekha located on the extreme southern part of the tract. In spite of various protection measures include sea walls, dyke, groin and jetties to control erosion, erosion still continues. Extensive plantation and beach nourishment can protect the coast. The present study would help for understanding the status of erosion and further preventive measures to arrest coastal erosion.*

Key words: *Shoreline Change, Erosion, Accretion; DSAS, Linear Regression Rate*

Introduction

The study of the coastal erosion and deposition are important parameters of coastline change and morphodynamics of the coast (Armenio et al.2019).Between the land and the sea the shoreline

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is the interface is changing in response to the geological, climatic and morphological factors (Mujabar and Chandrasekar 2013). The characteristics of the shoreline depend on the interaction between and among physical processes, geotectonic, storm, rivers, waves and tides. (Passeri et al. 2015). Along the coast the human activities are highly vulnerable due to coastal erosion. The coastal districts are highly vulnerable and are changing due to increasing the number coastal disasters (Saxena, Geethalakshmi, and Lakshmanan, 2013). On the Earth, the coast is one of the most dynamic landforms and is subjected to change by tidal action, wave, geomorphology, geology, sediment transport by longshore current, sea level rise, periodic storms and human activities (Carter and Woodroffe 1997; Zhang, Xie, and Liu 2011).

In recent past in India numerous studies have been done on coastal shoreline change using Geographical Information System (GIS) and remote sensing (Kaliraj, Chandrasekar, and Magesh 2013; Kumar et al. 2010; Chandrasekar, Viviek and Saravanan 2013; Alesheikh, Ghorbanali, and Nouri 2007). The geospatial technique and automatic calculations by extended tools of GIS software used for the detection and computation of shoreline change. The accretion and erosion of the coast are due to the shore current and wave action. (Nassar et al. 2019). The accretion or deposition of the coastal zone is considered as addition of land are less vulnerable in comparison of the erosion areas ,which results in decreasing of the land area and increasing the vulnerable risk of coastal hazards to the coastal population (Jana and Hegde 2016). The longshore currents, waves and wind move sand from the shore and deposit at other beaches, ocean dips, trenches and deep ocean floor (Seibold and Berger 2017). Due to coastal erosion and sharing of the sand, the beach structure and shape in many cases may change in course of time. The impact of coastal hazards on coastal erosion and deposition takes longtime to observe (Prasad and Kumar 2014).

Several studies have been done globally, spatio-temporal variations ,quantitative and qualitative analysis of the shoreline (Maiti and Bhattacharya, 2009, Addo, Jayson- Quashigah, and Kufogbe 2012; and Nassar et al. 2019;). Using satellite imageries, most important technique is the End Point Rate (EPR) for the shoreline change computation and analysis (Sebat and Salloum 2018). The Linear Regression Rate (LRR) method has the advantage over other methods for more than two shoreline change. (Sheik and Chandrasekar 2011; Burningham and French 2017; Sheik and Chandrasekar 2011). For a particular transect of the shoreline points, the least square regression line determines the LRR.

The rate of shoreline change has been analysed using Digital Shoreline Analysis System (DSAS) extension tool and the statistical analysis of multiple shoreline positions from time series data. The DSAS has been used by the U.S. Geological Survey's Coastal Change Hazard project has used the DSAS for collection of regression rates in a repeatable method to collect data at different scales. To get change rate information results and also to assist the shoreline change calculation processes, the DSAS software is used (Murali et al. 2013). Any universal purpose that calculates time to time positional transformation like chronological order of glacial limits from aerial photos, land use/land -cover changes, evaluating change of river edge borders can be done using DSAS (Thieler et al. 2009). A baseline is generally defined by three main components, Weighted Linear Regression Rate (WLR), Linear Regression Rate (LRR), End Point Rate (EPR) etc. by several methods and models. (Jonah et al.2015; Sheik and Chandrasekar 2011). Assessment of the shoreline position through different time period the statistical change measures are derivative within DSAS include Linear Regression Rate (LRR) , End Point Rate (EPR), Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE), and Weighted Linear Regression Rate (WLR). Significant review must be considered with care to make accuracy in digitization. For the prediction pattern of the shoreline characteristics the DSAS historical rate of change trend as potential indicators assuming continuity of physical, natural or anthropogenic forces at the site has been used (Oyedotun 2014). The progress shoreline positions alteration and cliff geometry can be effective in systematic analysis using DSAS in spite of few drawbacks of this tool (Nassar et al. 2019; Moore 2000; Oyedotun 2014).

The East Medinipur coast is one of the most important tourist destinations. Development of tourist infrastructure at the coast leads to coastal deforestation, Increasing population pressure at the coast increased demand of land for cultivation and degraded the coastal vegetation. The cyclonic storms developed over the Bay of Bengal hit the West Bengal coast leading to severe coastal erosion. In spite of various measures are taken to prevent coastal erosion, the coastal erosion continued unabated. New methods of anti-erosion need to be implemented in the study area. There is no mechanism to monitor regularly the erosion trend in this region. Community participation needs to be implemented for better coastal zone management. In this research paper an attempt has been made to use remote sensing images, GIS technique and uses of DSAS method which is highly accurate to measure the coastal erosion and accretion and rate of change of coastline. The research work bears much significance as no work has been done using DSAS technique to understand the coastal vulnerability to erosion of this tract and implement appropriate preventive measures by the administration.

The objectives of the study of the coastal erosion of east Medinipur coastal track are (i) Analysis of the shoreline change over the period (1975–2022), (ii) The factors responsible for the shoreline change both natural and anthropogenic and (iii) the measures to be taken to control coastal erosion.

Study area

East Midnapore district is located on the eastern coast of West Bengal bordering the Bay of Bengal between latitudes 21°36' 35"N to 22°02' 23"N and longitudes 87°22' 48"E to 88°01' 12"E (Figure. 1). The study area is about 55.22 sq. km. The length of the coast of the district is 55.22 km extending from the border of Odisha in the south to Rasulpur estuary in the north. It covers four C.D. Blocks of the district are Ramnagar-I, Ramnagar-II, Contai-Iand Deshopran. It is discontinued by Jatra Nullah, Peechaboni estuary, Jaldah estuary and river Rasulpur. River Rasulpur meets the sea near Petuaghat and Rasulpur village of Purba Medinipur district. The coast has geomorphic and biochemical diversity on the basis of landforms, soil characteristics and marine

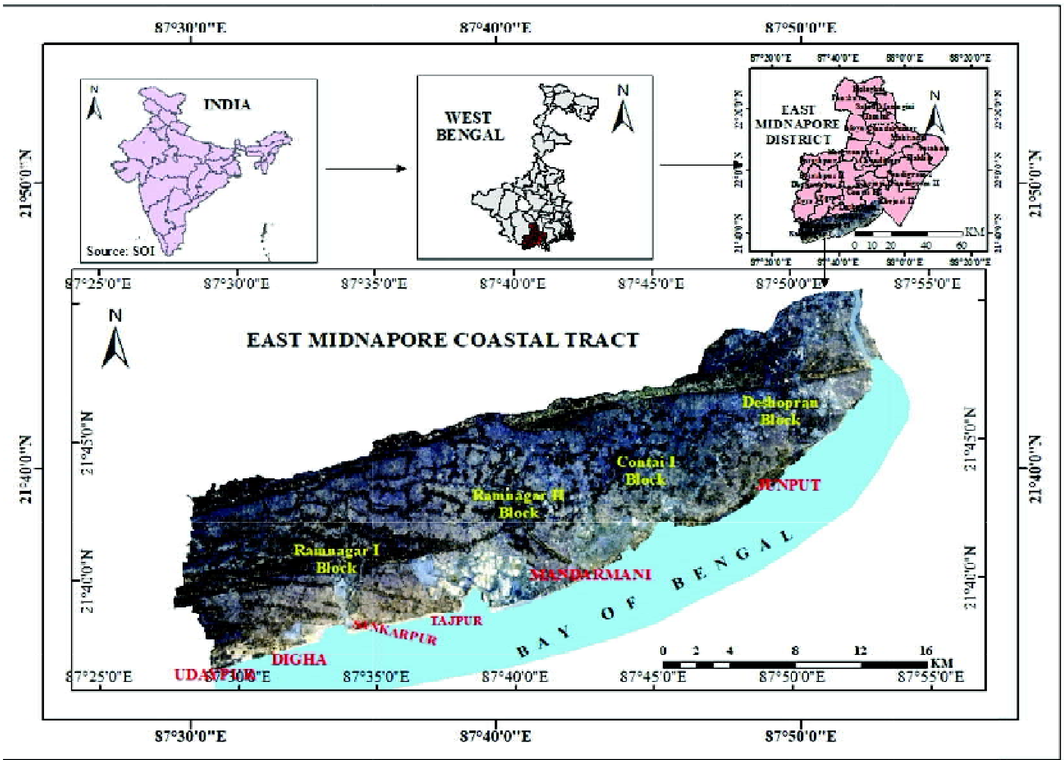

Fig. 1 Location map of East Medinipur coastal tract

species. The East Medinipur coastal tract is very significant as a consequence of Geo-morphological and ecological diversity. In relation to Physiography, the East Medinipur district can be divided into two physiographic divisions (i) almost flat plains in the east, west and north (ii) the Kanthi coastal plain on the south. There are three types of coastal plains, such as Kanthi coastal plain, Ganga delta and Subarnarekha delta. The East Medinipur coastal plains experienced deposition and seaward expansion is influenced by sea level changes and geotectonic processes. The coast is affected by cyclones occasionally. Tidal floods are quite regular in these four blocks. The coastal area is flat with sandy beach, chains of sand dunes and mud flats. The coastal area is a natural museum of several types of coastal dunes, which control physical environmental as well as coastal landforms. The present coast line is affected by the geological, tectonic factors, waves, tidal current and volume of water flow, wind speed and direction, effect of storm surges, sea level fluctuation etc. These factors have modified the coast line. The coast line of the state faces enormous erosion hazard. The surface sediment samples show that major part of the sediments consist of fine to medium sand with some patches of clay, silt and sandy clay is found in the Western Channel of Hugli River. In shallower part, patches of silty sand and sandy clay are also present. The population density is quite high and the land is used for Digha urban tourist center, rural settlement, agriculture and Haldia port. Narrow strips of coastal *casuriana* plants and mangrove vegetation could not prevent coastal erosion. Due to intensive use of the coastal land the wave action intensifies the coastal erosion.

Data base and Methodology

Data base

The study is based on the satellite image analysis, in situ observation and information collected from secondary sources. 48 years data from 1975 to 2022 has been used to study the shoreline change. Landsat open source data (ETM, TM and OLI TIRS) from the USGS website (https://earthexplorer.usgs.gov/) for the year 1975, 1988, 1996, 2003, 2014 and 2022. The Multi-temporal (1975–2022) images of Landsat sensors viz. Multispectral Scanner (MSS) (1975), Thematic Mapper (TM) (1988 & 1996), Enhanced Thematic Mapper (ETM) (2003) and Operational Land Imager (OLI) & Thermal Infrared Sensor (TIRS) (2014 & 2022) used to detect shoreline changes (Table 1). To get cloud free and error free data pre-monsoon (March-April) or post-monsoon (September to October) data are being used (Wentz et al. 2014; Lima et al. 2019). The satellite data used for the months of March for years of 1975, 1996, 2003, 2014 and 2022 and February month for the year 1988. Since 1970s the Landsat data having multispectral resolution, synoptic view and repetitive coverage are used to measure land and sea surface geophysical features of the coast (Mishra et al.2019; Woodcock et al. 2008; Moore 2000).

Table.1 Satellite data used

Sl. No.	Satellites	Sensors	Resolution	Date of acquisition	Path/row	Cloudiness/ Haziness
1	Landsat 2	MSS	60 m	29-03-1975	149/045	Free
2	Landsat 5	TM	30 m	01 -02-1988	139/045	Free
3	Landsat 5	TM	30 m	10-03-1996	139/045	Free
4	Landsat 7	ETM	30 m	22-03-2003	139/045	Free
5	Landsat 8	OLI TIRS	30 m	12-03-2014	139/045	Free
6	Landsat 8	OLI TIRS	30 m	18-03-2022	139/045	Free

Source: Computed by the author

Methods

The shoreline change rate is extracted by digitization of multi-date satellite images (1975-2022) using DSAS tool. After construction of base line (buffering of 50 m. from common shore line towards offshore), coast transects were generated to 2 km. length from base line with

50m.transect spacing and smoothing distance 1 km. using DSAS to study the changes occurred along the coast of the study area. Linear Regression Rate (LRR), End point Rate (EPR) and Weighted Linear Regression are used to calculate the shoreline change. On the basis of the results and final output, the final decision matrix is prepared. The Arc GIS 10.4 is used for the online digitization of the vector data of multi-temporal satellite images for the extraction of the shoreline. Manually digitized multi-temporal used for the extraction of the shoreline. The Digital Shoreline Analysis System (DSAS) extension version 5.0 used different time period shoreline data for computation of shoreline change for 48 years (1975-2022) (Figure. 2). In the attribute table the different time period shoreline extracted were merged as a single feature, that created a single shape file of multiple shorelines. The cross shore transects generated for calculating the shoreline change by closely digitizing the direction and shape of the outer shoreline baseline. The DSAS version 5.0 of the ARC GIS developed by the United States Geological Survey (USGS) is used to generate the shoreline change (Himmelstoss et al. 2018).

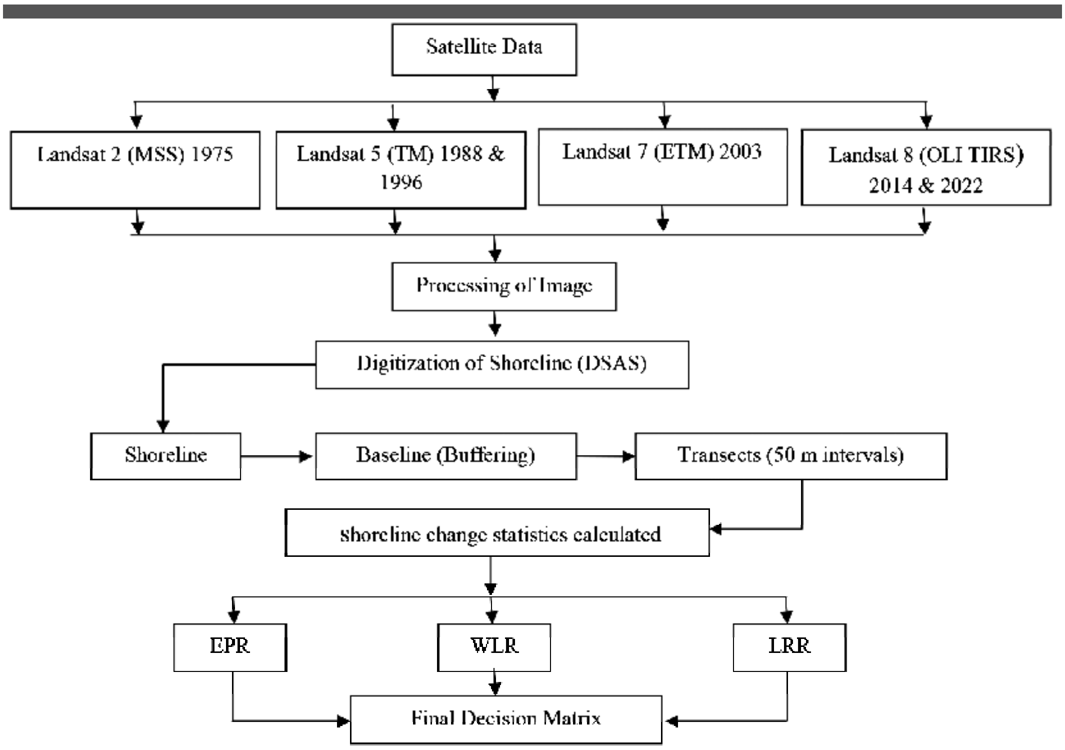

Fig. 2 Flowchart of the methodology

Total 1040 transects are computed for the East Medinipur coastal tract using DSAS. Zone I has 184 transects covers 9.10 km., Zone II has 178 transects covers of 9.58 km., Zone III has

183 transects covers 9.79 km., Zone IV has 209 transects covers 12.19 km , whereas Zone V has 286 transects covers 14.56 km (Table 2). The DSAS has used the End Point Rate (EPR) and Linear Regression Rate (LRR) statistical techniques (Figure. 2). For a particular transect of all coastal shoreline points the least square regression line ia applied in LRR method. The slope of the line indicates the rate of change of the shoreline. The linear rate of shore line change between the latest shoreline and the earliest shoreline is determined using the linear regression method. The linear regression rate computation of the two fields is explained by long and short term intersect metadata.

Table. 2 Zones and correlation with Digital Shoreline Analysis System (DSAS) transects

Zones	Include the areas	Transects	Coastal Length (Km)
I	Udaypur, Old Digha, New Digha	1-184	9.10
II	Sankarpur Beach, Tajpur Beach	185-362	9.58
III	Mandarmani Beach	363-545	9.79
IV	Junput Beach	546-754	12.19
V	Bankipur Beach, Baghaput Beach, Petuaghat Fishing Port	755-1040	14.56

The rate of change of the shore line is calculated for the period (1975, 1988, 1996, 2003, 2014 and 2022), by plotting the points where shoreline is intersected by transects. The rate of change of the shoreline is calculated by linear regression equation.

$$y = mx + b \qquad \text{Equation- 1}$$

(y) represents the distance (meter) from the base line (i.e. buffered of 50 m from common shore line towards offshore, here the common shore line has been created by digitization), (x) shoreline dates (years), (m) the slope of the fitted line (m/year) (i.e. represents the shoreline change rate, LRR), and (b) is the y-intercept. EPR is dividing the distance of the shoreline by the time taken between initial and most recent. A small differences for computed results found in both methods. The LRR technique is based on acceptable statistical ideas is easier to use with satisfactory accuracy of final output.

The baseline, transect, shoreline and intersect explain to describe the relationship between space and time. The distance between the baseline against the shoreline is shown in the map and diagram. Plotting the shoreline intersect positions with time (year) is determined by the linear regression rate (LRR). There are two statistical methods (LRR and EPR) were preferred to present the computational results. End Point Rate (EPR) has been accomplished by this formula (Equation 2).The linear regression advantages are: (i) all the data with change in trend and accuracy are used (ii) the computational method; (iii) conventional statistical method and (iv) it can be easily acquired (Figures .3 and 4). The multi-temporal digitized data of the shoreline transacts give dependent and independent variables using DSAS. The erosion and deposition rates automatically calculate (LRR). This method is used to get EPR, NSM, WLR, LRR of the shorelines for better accuracy with limited time. For higher accuracy multi-date satellite date is used in DSAS digitization process. (Sekovski et al.2014).

$$EPR = \frac{\text{Distance (metre) between oldest and most current shoreline}}{\text{Time between oldest and most current shoreline}} \quad \text{Equation -2}$$

Long-term Changes

The multi-temporal Landsat images are used for the long-term shoreline change study. The least square regression line fitted to all shoreline points of a particular transect to determine the linear regression rate of change. A weighted value is the uncertainties associated with each shoreline using Weighted Linear Regression (WLR) method (Equation 3). The function of the variance in the uncertainty of the measurement is the weight (w) (Genz et al.2007):

$$W = 1 / e^2 \quad \text{Equation -3}$$

Where, e is shoreline uncertainty value.

Results

Rate of shoreline change

The rate of change of the shore line is calculated where shoreline intersected by transects for the period (1975, 1988, 1996, 2003, 2014 and 2022). The linear regression equation is calculated for the rate of change of the shoreline.

$$y = mx + b \quad \text{Equation- 1}$$

The regression equation value of this study area is y = 1.756 × -3366 and regression coefficient (R^2) is 0.157 (Figure 3). The accounted rate uncertainty is considered with a confidence interval (ECI) of more than 95%.

The LRR is calculated by the equation of y = 1.756 × “ 3366. The line describing the slope of the equation is the rate (1.756 meters per year). LRR technique is used to study the rate of change of the shoreline of five zones of the East Medinipur coastal tract. The zone I (Udaypur, Old Digha, New Digha beach), has 9.10 km shoreline with both accretion and erosion, but erosion is found in most part of the transect. Average rate of trend of erosion over 184 transects is “2.82 m/year and average accretion rate is 2.71 m/year. Erosion is observed along Villages Purba Mukundapur, Haripur, Maitrapur, Godadharpur , Ratanpur, Daskhin Shimulia and Gobindabasan. In zone II (Sankarpur Beach, Tajpur Beach) with 9.8 km. shoreline, except few transects trend of the rate of change of the shoreline is negative (Figure 5 and 6). Average rate is -2.65m/year over

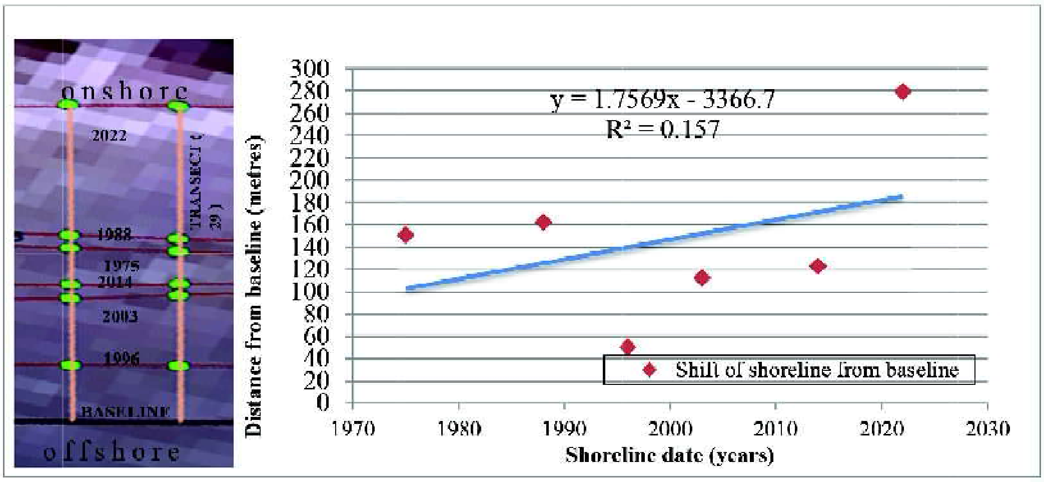

Fig. 3 Representation of baseline, transect (Transect number 29 has been showed), shorelines and intersects.

178 transects with accretion trend. The average rate of erosion is “3.60 m/year and rate of accretion is 4.47 m/year. Erosion is observed along Villages, Shilampur (Western), Chandapur, Tengramari, Jaldha, Bodhora, BeraKhana, Bishwanathpur and Dublabari. Zone III (Mandarmani Beach), of 9.79km. Shoreline having accretion and erosion trend is dominated by erosion. Average erosion rate in this zone is -1.92m/year and accretion rate 1.18 m/year. Erosion is found along Villages, Shilampur (Eastern), SonaMuhi, Rania, Dadanpatrabar whereas accretion trend observed along Daskhin Purusattampur, Samudrapur, Machhalandapur, Daudput. In the zone IV (Dakshin Purusattampur, Junput Beach), with 12.19km coast line, the average rate of change of the shoreline is 5.12 m/year. More than 26 transects, the beach experience erosion and 183 transects accretion. Mean erosion rate -1.09m/year and accretion rate 6.05 m/year. Baguran, Jalpai, Maharampur, Sharadpur villages are Vulnerable to erosion whereas Daskhin Purusattampur (Easter), Serpurjalpai, Mankaraiput, Karanji, Narayanpur, Bagurah villages show accretion trend. The zone V (Bankipur Beach, Baghaput Beach, Petuaghat Fishing Port), has 14.56 km shoreline shows both accretion and erosion, but accretion is found in most of the transect. The mean shoreline change rate over 286 transects is 7.61 m/year with overall erosion trend. Mean erosion is -2.86 m/year and accretion is 10.87 m/year. Erosion observed along Jaganathpur 3rd Part, Gopalpur 5th Part, Tiakala, Kalaroypur villages whereas Daskhin Kadua, Uttar Kadua, KaduaMukundapur, Pratappur, Haripur, Kanai Chatta show accretion.

Trend of mean shoreline change in selected zones

The Linear Regression Rate(LRR) is used to know the variations of mean erosion and accretion rate in the coastal zones. In zone V the mean accretion rate is 10.82 m/year is the highest and the lowest 1.18m/year in the zone III. The accretion rate of 2.71 m/year, 4.47 m/year and 6.05

m/year are in the zones I, II and IV respectively. The mean accretion rate of the entire coastal tract is 7.52 m/year (for total number of accretional transects 488). For zone I, II, III, IV and V, the mean erosion rate are -2.82 m/year, -3.60 m/year, -1.92 m/year, -1.09 m/year and "2.86 m/year respectively. The zone II has maximum erosion and zone IV has minimum erosion. For the entire coastal tract, the mean erosional rate is 2.75 m/year (for total number of erosional transects 552) (Figures. 6 and 7). The maximum rate of change of mean shoreline 7.61m/year is in zone V and zone II has -2.65m/year with minimum shoreline change. The rate of mean shoreline change of East Medinipur coast is 2.07 m/year.

End Point Rate (EPR) has been accomplished by this formula (Equation 2).

$$\mathrm{EPR} = \frac{\text{Distance (m) between oldest and youngest shoreline}}{\text{Time between oldest and most current shoreline}} \qquad \text{Equation -2}$$

The rate of erosion and accretion by using the End Point Rate (EPR) of the five selected coastal zones is different from the Linear Regression Rate (LRR). Zone –V the mean accretion rate is 8.16 m/year is the maximum, zone I, II, III and IV have accretion rate 4.65 m/year, 1.31 m/year, 1.15 m/year and 6.06 m/year respectively. The mean accretion rate of the coastal tract is is 6.51 m/year (for total number of accretions transects 464). Mean erosion for zone I, II, III, IV and V are -3.73 m/year, -3.84, -2.80 m/year, -1.26 m/year and -1.95 m/year respectively. zone II has maximum erosion and zone IV has minimum erosion. The average rate of erosion for the coastal tract is 3.26 m/year (for total number of erosional transects 576). The maximum mean rate of shoreline change in zone IV is 5.58 m/year and minimum is "3.61 m/year in zone II. The mean rate of shoreline change is 1.1 m/year. Erosion trend is found in Zone I, IV and V whereas accretion trend is observed in Zone II and Zone III (Table 3). The coastal tract shows higher mean accretion rate than mean erosion rate. The Weighted Linear regression (WLR) method shows maximum accretion rate10.82 m/year in zone V and minimum accretion rate 1.18m/year in zone III. zone I, II and IV have accretion rate 2.71 m/year, 4.47 m/year and 6.06 m/year respectively .The mean accretion rate of the of the coastal tract is 6.51 m/year (for total number of accretion transects 464).Mean erosion for zone I, II, III, IV and V are -3.73 m/year, -3.84, -2.80 m/year, -1.26 m/year and -1.95 m/year respectively. zone II has maximum erosion and zone IV has minimum erosion. The average rate of erosion for the coastal tract is 3.26 m/year (for total number of erosional transects 576). The maximum mean rate of shoreline change in zone IV is 5.58 m/year and minimum are "3.61 m/year in zone II. The mean rate of shoreline change is 1.1 m/year. Erosion trend is found in Zone I, IV and V whereas accretion trend is observed in Zone II and Zone III (Table 3). The coastal tract shows higher mean accretion rate than mean erosion rate.

A weighted value is the uncertainties associated with each shoreline using weighted Linear Regression (WLR) method. The function of the variance in the uncertainty of the measurement is the weight (w) (Genz et al. 2007):

$$W = 1 / e^2 \qquad \text{Equation -3}$$

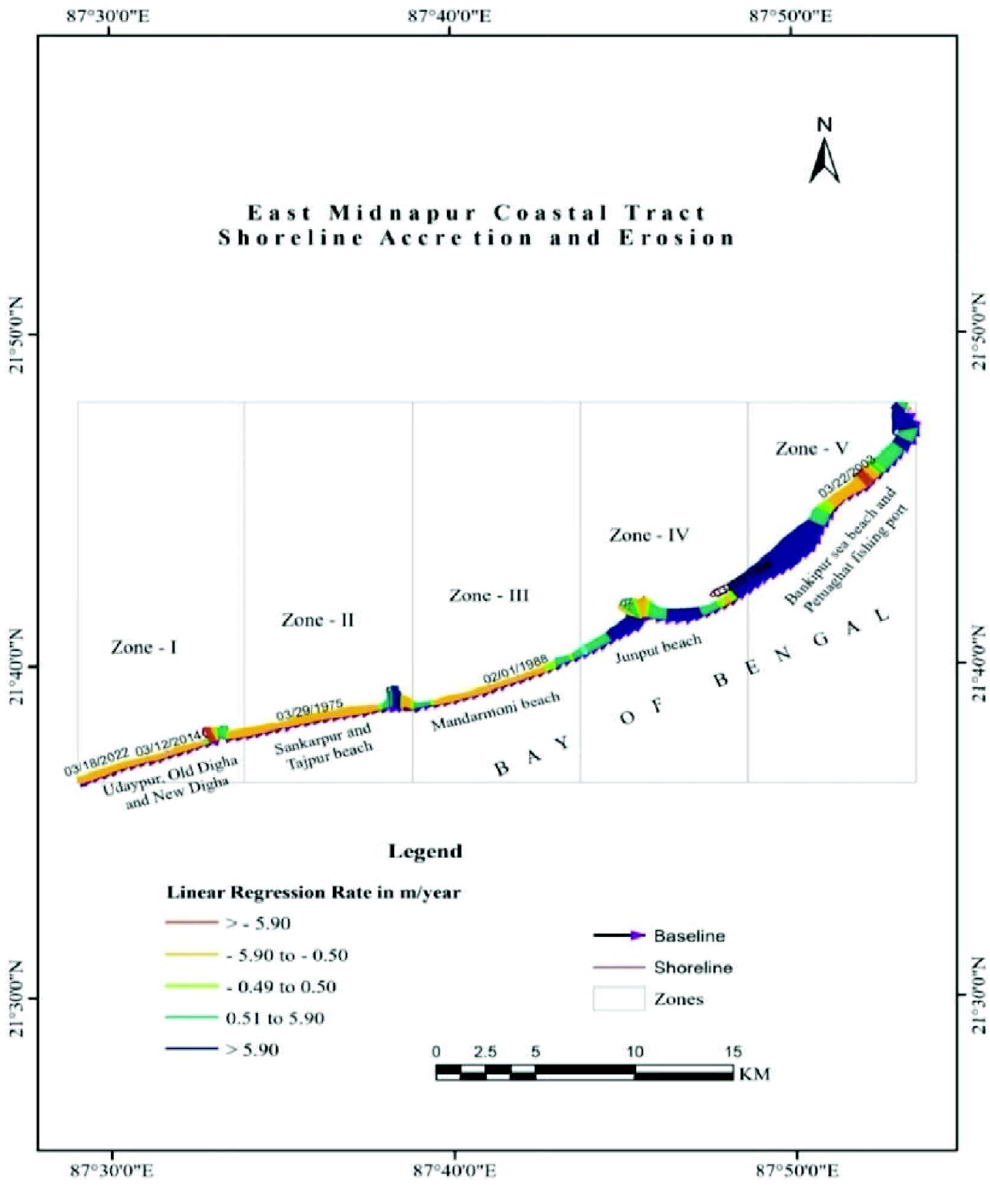

Fig. 4 Shoreline accretion and erosion in East Medinipur Coastal Tract.

Table. 3 Rate of change of shoreline using Linear Regression Rate (LRR)

Zones	I	II	III	IV	V
Number of Transects	184	178	183	209	286
Shoreline length (km)	9.10	9.58	9.79	12.19	14.56
Shoreline change rate (m/year)	-2.40	-2.65	-1.04	5.12	7.61
Erosion rate (m/year)	-2.82	-3.60	-1.92	-1.09	-2.86
Accretion rate (m/year)	2.71	4.47	1.18	6.05	10.87
Total transects that record erosion	170	157	131	26	68
Total transects that record accretion	14	21	52	183	218
Trend	Erosion	Accretion	Accretion	Erosion	Erosion

Source: Computed by the author

Where, e is shoreline uncertainty value.

The Weighted Linear Regression (WLR) method shows maximum accretion rate10.82 m/year in zone V and minimum accretion rate 1.18m/year in zone III. zone I, II and IV have accretion rate 2.71 m/year, 4.47 m/year and 6.06 m/year respectively. The mean accretion rate of the coastal tract is 7.51 m/year (for total number of accretion transects 489). The mean rate erosion for zone I, II, III, IV and V are -2.82 m/year, -3.60 m/year, -1.92 m/year, -1.09 m/year and -2.91m/year respectively. The zone II has maximum erosion rate -3.60 m/year and zone IV has minimum erosion -1.09m/year. The Average erosion rate for the entire coastal tract is -2.76 m/year (for total number of erosional

Table 4 Rate of change of shoreline using End Point Rate (EPR)

Zones	I	II	III	IV	V
Number of Transects	184	178	183	209	286
Shoreline length (km)	9.10	9.58	9.79	12.19	14.56
Shoreline change rate (m/year)	-3.41	-3.61	-2.01	5.58	5.44
Erosion rate (m/year)	-3.73	-3.84	-2.8	-1.26	-1.95
Accretion rate (m/year)	4.65	1.31	1.15	6.06	8.16
Total transects that record erosion	177	17O	146	6	77
Total transects that record accretion	7	8	37	203	209
Trend	Erosion	Accretion	Accretion	Erosion	Erosion

Source: Computed by the author

transects 551). The maximum rate of mean shoreline change is 7.61 m/year in zone V and minimum -0.59 m/year in zone II (Table 6). The mean rate of change of shoreline change is 2.07 m/year and Zone I, IV and V shows erosion trends whereas Zone II and Zone III shows accretion trends (Table 4 & 5).

Table 5 Shoreline change rate using Weighted Linear Regression (WLR)

Zones	I	II	III	IV	V
Total Number of Transects	184	178	183	209	286
Shoreline length (km)	9.10	9.58	9.79	12.19	14.56
Shoreline change rate (m/year)	-2.4	-2.65	-1.04	5.17	7.61
Erosion rate (m/year)	-2.82	-3.60	-1.92	-1.09	-2.91
Accretion rate (m/year)	2.71	4.47	1.18	6.06	10.82
Total transects that record erosion	170	157	131	26	67
Total transects that record accretion	14	21	52	183	219
Trend	Erosion	Accretion	Accretion	Erosion	Erosion

Source: Computed by the author

Trend of shoreline change

The shoreline change rate (LRR) of the coastal tract of the district has been divided in to five categories on the basis of maximum and minimum value as high erosion, low erosion, stable or little change, low accretion and high accretion. About 1.50km. coast shows high erosion greater than -5.90 m/year,25.69km. moderate erosion -5.90 m/year to -0.50 m/year and 4.40km. little or no change -0.49 m/year to 0.50 m/year. High accretion along 12.70 km. greater than 5.90 m/year and moderate accretion along 10.93 km. 0.51 to 5.90 m/year of the coast. Erosion is dominant in the zones of I, IV and V such as Udaypur, Old Digha ,New Digha, Junput, Bankipur Beach, Baghaput Beach, Petuaghat Fishing Port and accretion trends is mostly found in the Sankarpur Beach, Tajpur Beach, Mandarmani beach in the zones II and III (Table 6 and Figure .8).

Discussion

The coastal region of East Medinipur is highly vulnerable to various threats, including coastal erosion, due to natural processes enhanced by anthropogenic influences. Shoreline change inventories are the pre-requisite for identifying the coastal stretches subjected to erosion. It is observed that the erosion hotspots with maximum erosion are in Udaypur, Old Digha, New Digha, Junput, Bankipur Beach, Baghaput Beach, Petuaghat Fishing Port and accretion is maximum in Sankarpur Beach, Tajpur Beach, Mandarmani. The historical records of the period 1877 and

Table 6. Different classes of shoreline analysis in East Medinipur coastal tract

Sl. No.	Erosion and accretion	Classes (m/year)	Length in km
1.	High erosion	> -5.90	1.50
2.	Moderate erosion	-5.90 to -0.50	25.69
3.	Little or almost no change	-0.49 to 0.50	4.40
4.	Moderate accretion	0.51 to 5.90	10.93
5.	High accretion	>5.90	12.70
	Total		**55.22**

Source; Computed by the author

1965 shows Digha shoreline moved inland by 970m. with an average of 11 m/ year. It has increased by 525m. between 1965 and 1995 with an average rate of 17.5 m/year. The coastal tract is divided in to five zones from south to north shows different trend of shoreline change. Using LRR the rate of shoreline change in five zones show erosion in zone I, IV and V and accretion in zone II and IV. Maximum erosion -3.60m/year in zone II and minimum erosion -1.09m/year in zone IV. Maximum accretion rate 10.87m/year in zone V and minimum 1.18m/year in zone III .The rate of change of the shoreline is accretion in zone IV&V and erosion in zone I, II&III. (Table 3 & Fig.3&5). Using EPR for shoreline change rate zone I,IV and V show erosion trend and zone II & III show accretion. Erosion rate is maximum -3.84m/year in zone II and minimum -1.26m/year in zone IV. Zone I,II & III show maximum erosion and zone IV & V show minimum erosion. Accretion rate 8.16 m/year is maximum in zone V and minimum 1.18m/year in zone III. Maximum accretion in zone I, IV&V. Minimum accretion in zone II&III. Rate of change of the shoreline is accretion in zone IV &V and erosion in zone I, II&III (Table 4 & Fig.4&6). Shoreline change rate using WLR shows erosion in zone I, IV &V and accretion in zone II&III. Maximum erosion rate -3.60m/year in zone II and minimum erosion rate -1.09 m/year in zone IV. Maximum accretion 10.82m/year in zone V and minimum 1.18 in zone III. Shoreline change rate is accreting in zone IV&V and erosion in zone I, II&III (Table.5).

The trend of the coastline change is erosion in zone I, IV & V and accretion in zone II &III (Fig.7). Out of 55.22 km. coastal tract of the district 27.19km. is under erosion, 23.40km accretion and only 4.40km stable (Table.6 & Fig.8).The coastline change has been compared with the National Centre for Coastal Research (NCCR) data of coastline change. Length of coast eroded varies only 0.66km, stable coast by 3.69km and accretion coast by 4.22km. The variation is due to different scales of estimation and duration. This part of the state has least percentage of stable shoreline due to wave exposure, high tidal current, sediment deprivation and low-lying area made the entire coastal stretch highly vulnerable to erosion (Paul,2021). The natural processes of coastal erosion

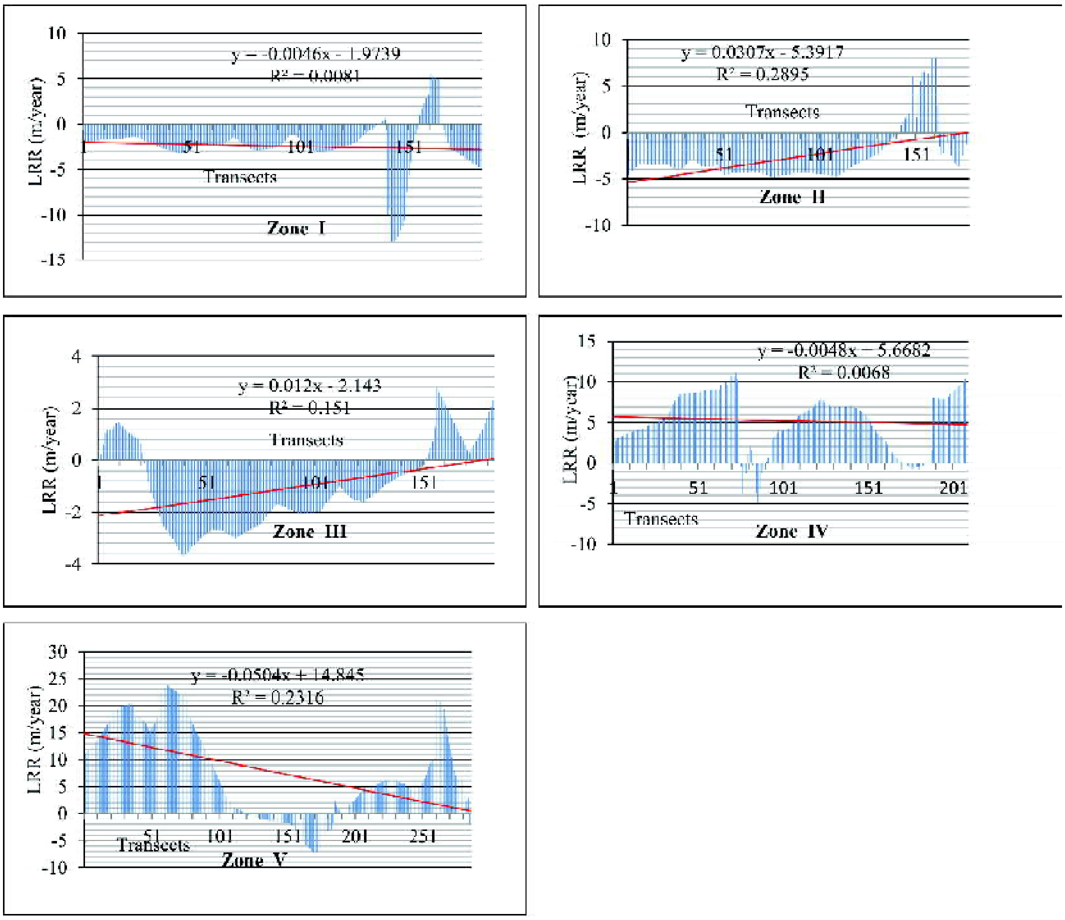

Fig.5 Rate of change of shoreline in zones using Linear Regression Rate (LRR) for each transect.

and accretion modify the shoreline, while coastal sediment transportation is hindered by constructions enhancing the shoreline changes. It has been anticipated that sea-level rise, increased wave activities and frequency and intensity of tropical cyclones under the climate change scenario are likely to cause enhanced shoreline changes in the near future.

A recent study shows that we may lose half of the world's sandy beaches by the end of this century because of coastal erosion driven by the rise in sea level. Coastal geomorphic environments naturally maintain the balance in sediment supply along the coast. However, high wave activities during monsoons, cyclones and anthropogenic influences like coastal construction, dam construction and the subsequent reduction in sediment input tend to disturb the sediment equilibrium, resulting in shoreline changes. Long-term shoreline changes are mainly induced by

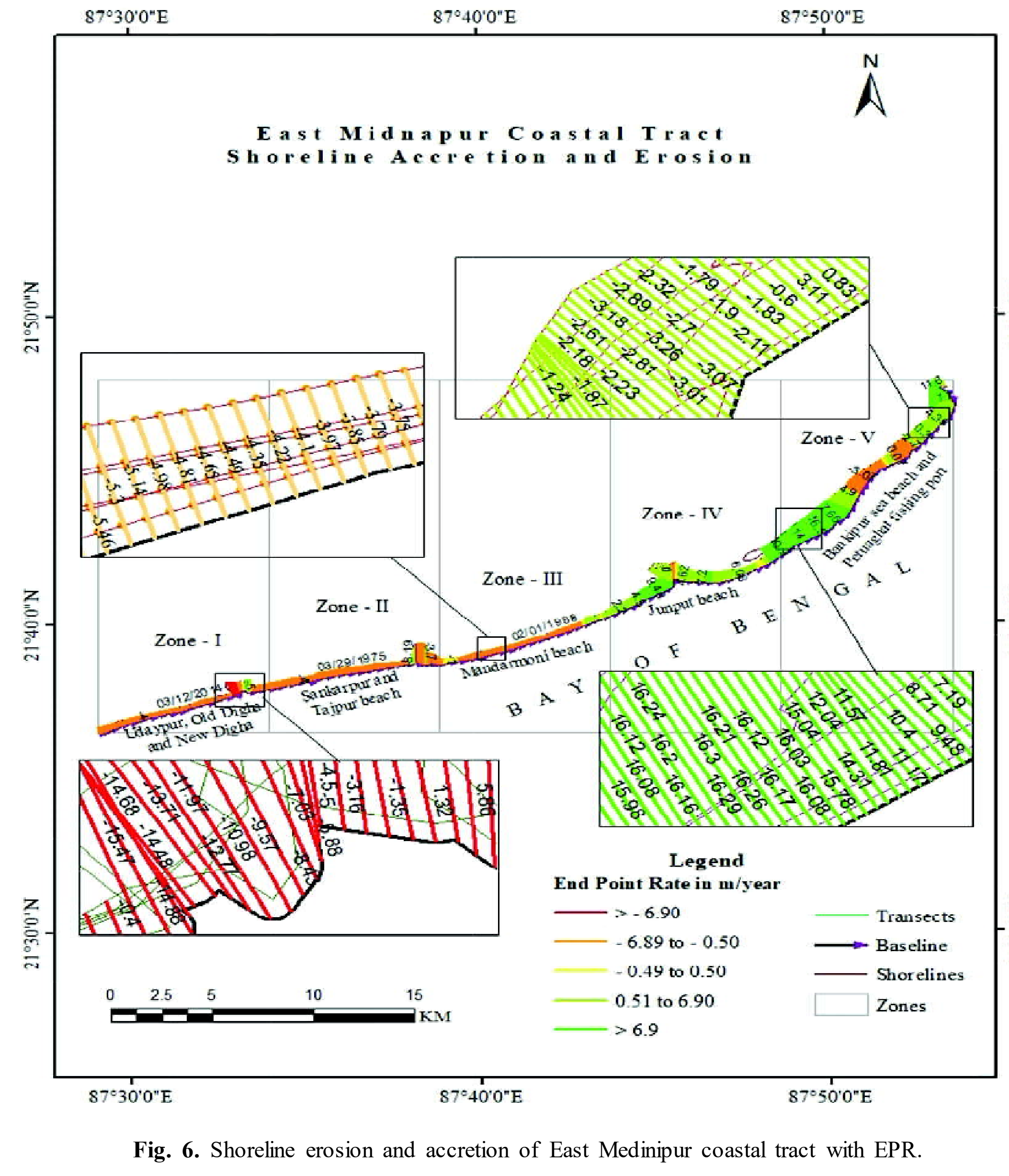

Fig. 6. Shoreline erosion and accretion of East Medinipur coastal tract with EPR.

longshore sediment transport. Eroding shorelines are mostly accompanied by an adjacent accreting coast. It shows that the coastal tract of the study area is highly vulnerable to erosion. Change of local sea level and storm surge effected the coast line. It is observed that the annual Mean

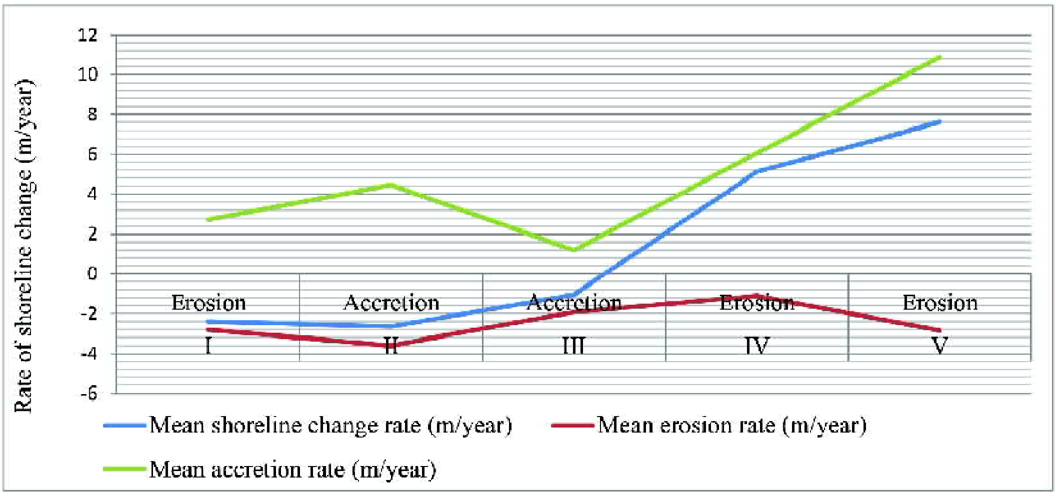

Fig. 7 Trend of the rate of accretion, erosion and shoreline change rate in the Medinipur coastal tract.

Sea Level (MSL) has increased due to the sediments of the Ganga-Brahmaputra delta at the rate of 3.14mm/year (Hazra, et. al., 2002). The factors contribute to the shoreline change are sediment budget, human activities, climate, relative sea level and coastal processes (Fig.9).The factors control the coastal erosion of East Midnapore coastal tract are - (a) strong littoral drift and flat beach bordered by dunes, (b) sand removed inland from the beach by wind, (c) in the recent past possibility of faulting features in the Digha shore-face (d) the strong tides occur during cyclonic storm (Mukherjee and Chatterjee,1997). The longshore current during south west monsoon is from south to north and during winter retreating monsoon it is from north to south. The longshore current erode southern part of the coast and deposits in the northern part. During the south west monsoon season normal wave produces net loss of sediments by erosion in the lower part

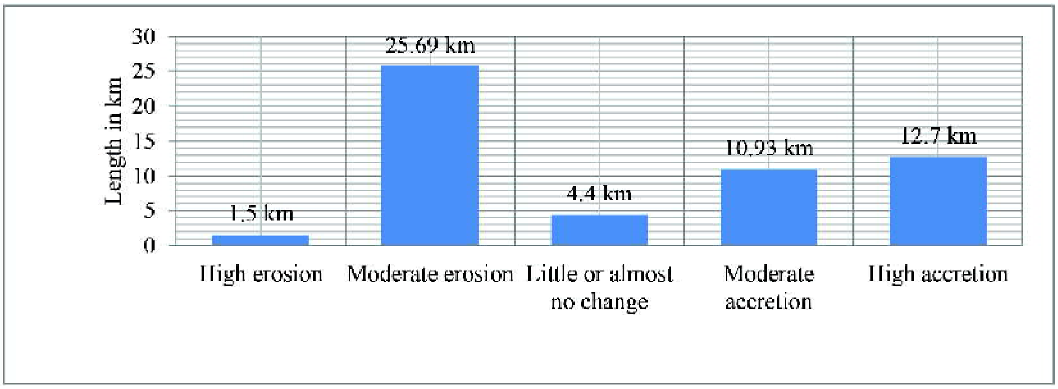

Fig. 8. Categorization of shoreline change in East Medinipur coastal tract

of the sandy beach. The rate of sedimentation along the coast is 20-25cm per year. In winter several sectors of the beach face deposition and in summer severe erosion. Total erosion in summer greatly exceeds the winter deposition (Subba Rao,2020).

Waves and wave induced currents control the littoral transport, erosion and accretion pattern in the tract. A strong littoral drift along the shoreline exists in the northerly direction (Fig.10). Sediment movement in the beach is caused by longshore current and onshore offshore movement. The coastal stretches of Digha in West Bengal mainly experience action of sea waves. Coastal erosion and increasing tidal activity, wave interaction and excess rise of water level during depression are responsible for increasing erosion (Sen et al.005). The wave dynamics and related parameters like wave height, wave period, wave approach angle have a direct bearing on the erosion/accretion regime. Intense and vigorous wave energy domains are erosional segments and zones of less intense energy comprise the accretion segment. Tidal range is very high in post-monsoon season and comparatively low in winter season (December). At Sankarpur tidal activity in post-monsoon season is more vigorous than at Digha. Wave height during south west monsoon

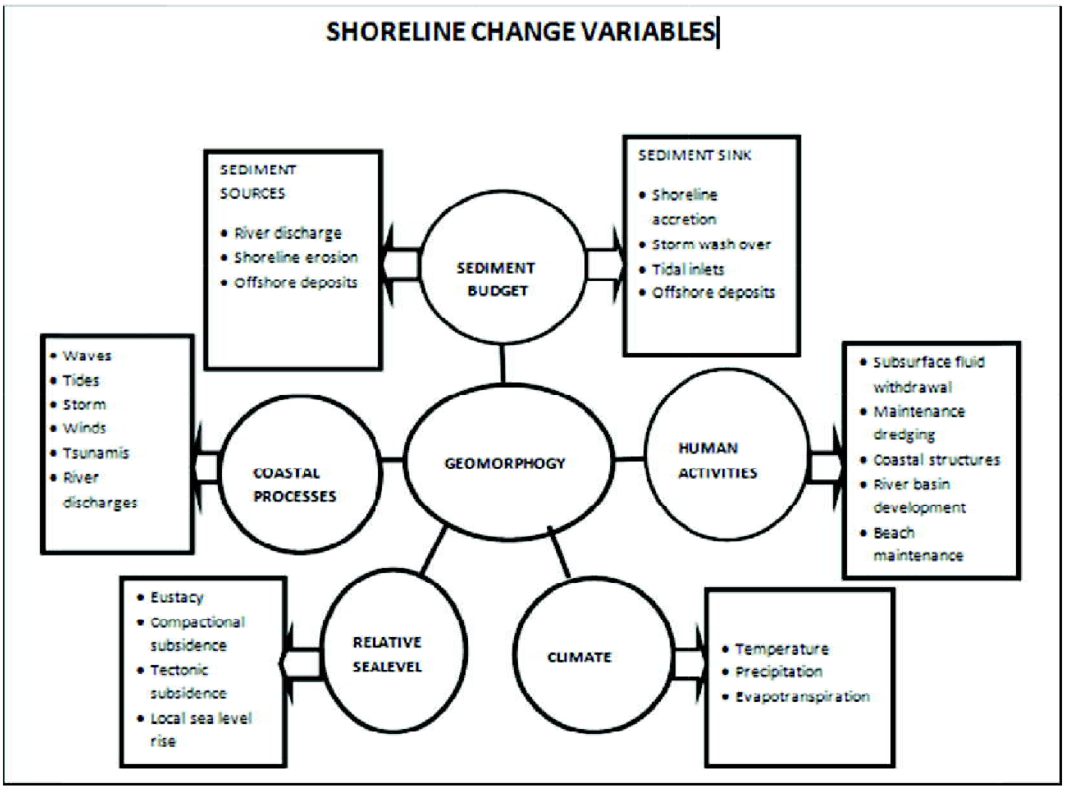

Fig.9 Shoreline change variables

season reaches up to 2.5 m. and wave period 10.5. The sediment load of the river Subarnarekha located extreme southern end of the Medinipur coast shows fluctuating trend. Maximum annual sediment was 112,219,11MT to minimum 1,09,180MT.The beach is not getting enough sediment for beach accretion.

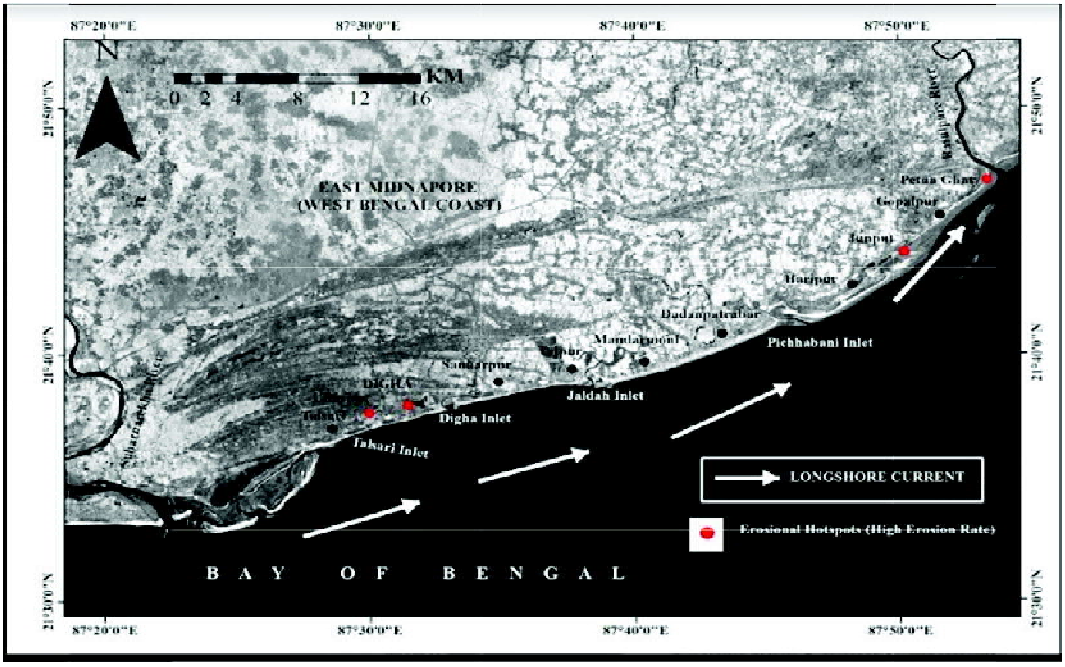

Fig. 10 East Medinipur coast with erosion hot spots and direction of longshore current

The whole coastal stretch from Digha-Dadanptrabar to west Dadanptrabar is under severe coastal erosion and the eastern segment observed a small tidal estuary is under steady conditions of accreting. From the year 1994 an accelerated rate of erosion is also noticed (Fig.11,12,13&14). The coastal erosion has adversely affected life, livelihood, property and ecosystem. The number of displaced people is increasing as a result of more land is eroded following cyclonic storm (Paul, A. K, 2001). Communication and transport facilities are completely paralyzed due to coastal erosion.

To prevent beach erosion, engineers have normally relied on interposing static structures between the sea and the shore. Protection against direct storm wave attack requires the construction of a massive barrier, so seawalls have been built to protect the land, but not the beach. In their simplest form, boulders are placed as armouring along the backshore. A range of environmental problems arises from seawalls in all kind of beaches (Jayappa, et al., 2003). Being essentially static features, they conflict with dynamic beach changes and impede land-sea sediment

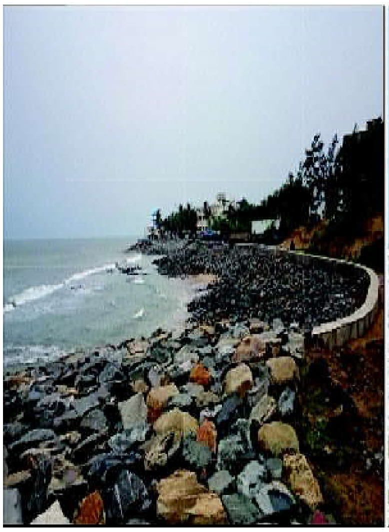

Fig.11 Digha Beah stone packing to prevent erosion

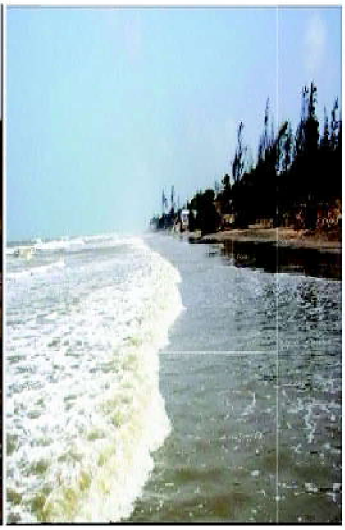

Fig.12 Coastal erosion due to cyclonic storm at Digha

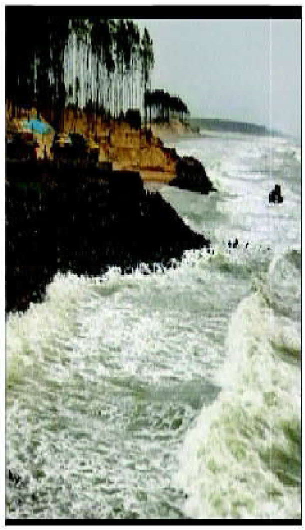

Fig.13. Mandaramani beach coastal erosion and protection measures

exchanges (Carter, 1988). In addition, during strong storms waves increase the undercutting processes and after some years the seawall partially collapses. That happened several times to the seawall along Digha-Sankarpur Beach. The beach profile is steeper than before and beach nourishment works have been much more complicated after the seawall removal. To prevent coastal

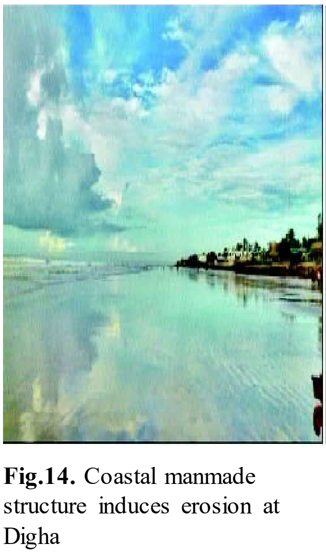

Fig.14. Coastal manmade structure induces erosion at Digha

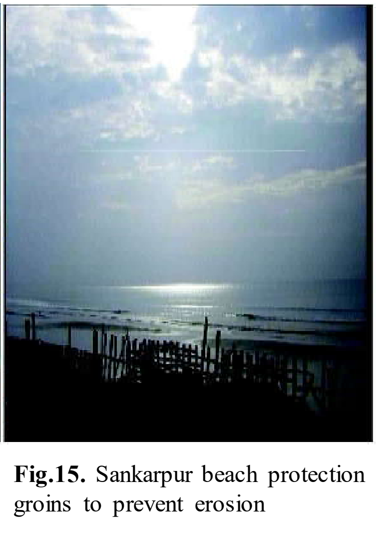

Fig.15. Sankarpur beach protection groins to prevent erosion

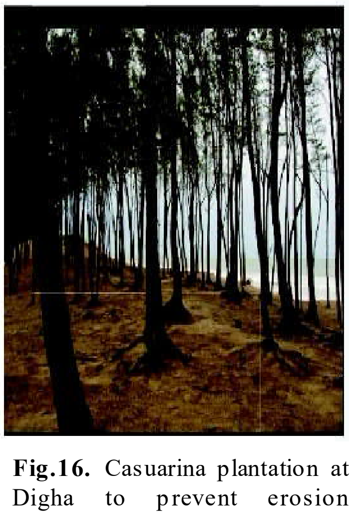

Fig.16. Casuarina plantation at Digha to prevent erosion

erosion 4.7 km. long sea wall with laterite stone is constructed between 1972-1988 at Digha coast (Paul,2002). These structures do not seem to provide much protection against long-term coastal change (Bruun, 1985). It is considered that after the construction of seawall the beach became steep than the pre-construction period in the coastal zone (Mukherjee and Chatterjee, 1997). Other coastal protection measures like coastal casuarina plantation, groins and synthetic geo-tubes are taken up (Fig.15&16). Beach nourishment by emplacement of terrestrial sediment at the coast may lead to significant accretion. The waste components contain a high proportion of cement causing solidification of the sand and pebble both in the submerged and emerged portion of the beach. The cementation of beach materials blocked the alongshore littoral transport, but the entire area remained stabilized. These methods are attractive to coastal managers because they do not involve the construction of expensive structures and the results appear more "natural". In many cases such restoration is economically preferred (Carter, 1988). These "soft solutions" are better than rigid structures because, at least, they do not disturb littoral dynamics. Human activities affecting coastal dunes include sand mining, agriculture, development (housing), recreation (effects of pedestrians and vehicles) and also over-management. In some areas dunes have been fixed and vegetated, preventing sediment movement (Viles and Spencer, 1995). The coastal dunes have had a spectacular reduction due to human activities. Some dunes have been stabilized by planting casuarinas trees to prevent dune migration, (i.e. Guardamar del Segura). Uncontrolled dune modifications are related to agricultural uses.

Conclusions

The East Medinapur coastline is highly vulnerable both by natural and anthropogenic processes. The West Bengal coast is one of the highest erosion prone coasts of India. Of the 55.22 km. coastal tract of the district 27.19km. is under erosion ,23.40km accretion and only 4.40km stable. It is observed that average accretion rate is 7.52 m/year and erosion rate is -2.76 m/year. Udaypur, Old Digha, New Digha, Sankarpur, Tajpur and Mandarmoni beach show erosion hotspots. The Junput, Bankipur and Petuaghat fishing port beach are accreting. The coastal tract divided in to five zones. The change rate observed using LRR, EPR and WLR found that zone I, IV and V are erosion prone and zone II & III accretion. The sediment load of the river Subernarekha has been reduced leading to coastal starvation of sediments leading to more erosion. The coastal erosion is basically observed due to human interference in the coast by constructing artificial structures, deforestation and removal of beach materials for various construction purposes. Digha coast the most tourist attractions every year alters the coastal morphology resulting heavy coastal erosion. To prevent further the coastal erosion, the government took various anti erosion measures like construction of seawall, groins, and synthetic tubes. In spite of various anti erosion measures taken by the government erosion continues unabated. New artificial methods of using imported or borrowed materials from different places and removing encroachment on sand dunes for beach nourishment. There is no mechanism to monitor regularly the erosion trend in this region. Community participation needs to be implemented for better coastal zone management to protect the coast from erosion, need of the hour is the beach nourishment by emplacement of terrestrial sediment, discourage manmade structures at the coast and avoid human activities affecting coastal dunes include sand mining, agriculture, development of buildings and stabilization of coastal dunes by plantation. Sand from the sand dunes nourishes the eroded beach to prevent further erosion by natural process. As coastal erosion is a serious threat to both the ecology and economy of the state, the shoreline change inventory will serve as the primary information required for planning coastal development activities. The use of remote sensing data and DSAS technique is highly beneficial for shoreline change study in the age of climate change.

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