

Monitoring shoreline environment of Paradip, east coast of India using remote sensing

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In the present study, we used multi-temporal satellite images of Indian Remote Sensing Satellites (IRS1D and IRS P6 – Resourcesat) from 1998 to 2005 to monitor the coastal environment of Paradip, east coast of India. The resultant coastal vector maps were used to estimate the geomorphological changes and shifting of the shoreline position. This integrated study is found useful for exploring accretion and erosion processes in the region. The shoreline maps were compared with the 1973 Survey of India toposheets to estimate the changes which have occurred in the region. Results indicate an increase of 7.72 km in shoreline length and a net loss of 18.73 km² of beach area between the years 1973 and 1998, and 0.46 km reduction in shoreline length and 3.11 km² increase in beach area between 1998 and 2005. An overall net increase of 7.26 km length shoreline and a net loss of 15.6 km² was observed between 1973 and 2005. The years 2001, 2002 and 2003 exhibited loss in length of shoreline as well as area of the beach. These years coincided with certain coastal activities carried out in the study region.

Keywords: Accretion, erosion, geomorphology, remote sensing, shoreline changes.

THE shoreline is one of the rapidly changing landforms of the coastal zone. Coastal zones are important not only economically, but biologically and ecologically also¹. Geological and physical processes such as erosion, deposition, flooding and sea-level variations alter the shoreline continually. Shoreline changes directly affect the economic development and land-use management². Therefore, shoreline changes have drawn great attention worldwide. Shoreline oscillation along the coast of India due to erosion and deposition has become a major concern for environmental managers. Recent developments of industries and urbanization have increased pressure on the coastal environment of India. Scientific data on shorelines are required periodically to ensure environmentally effective coastal zone management practices. In view of this, it is essential to review decisions made and developments undertaken pertaining to the coast from time to time. The historical and functional approaches to study

shoreline changes along with various landforms help in deciphering the coastal processes operating in an area^{3,4}.

Remote sensing is the best and most popular tool to detect shoreline changes due to synoptic and repetitive data coverage, high resolution, multi-spectral database, near orthogonal projection and its cost effectiveness in comparison to conventional techniques^{1,2,5-7}. El-raey *et al.*⁸ used remote sensing for detecting beach erosion and accretion along Damietta Port, Egypt. Narayana and Priju⁹ studied the shoreline changes along the central Kerala coast using satellite images. Shoreline-change mapping was carried out for the entire Indian coast for the periods 1967–68, 1985–89 and 1990–92 using LANDSAT MSS/TM and IRS LISS II data on 1 : 250,000 and 1 : 50,000 scale¹⁰. This has provided insight into large-area sediment transport studies and detecting long-term change in the entire coastline.

Meijerink¹¹ and Rao¹² studied the dynamic geomorphology of Mahanadi delta and problems of coastal dynamics and shoreline changes which arose after the construction of Paradip port. Rupali¹³ studied the spit stability adjacent to the Jatadharmohan creek based on hydrodynamic conditions of the creek and slope stability. Near-shore erosion, deposition, sediment budget and longshore transports off Paradip were studied by Ananth and Sundar¹⁴ and Sarma and Sundar¹⁵. Nayak *et al.*^{16,17} and Chauhan *et al.*¹⁸ studied erosion that is observed north of Paradip and Ennore ports on the east coast of India, due to construction of artificial breakwaters and jetties.

Accurate demarcation and monitoring of shoreline (long-term, seasonal and short-term changes) are necessary for understanding the coastal processes. The coastal processes along the Indian coast were studied using measured current and wave data¹⁹. During the last 30 years, availability of remote sensing data has ensured synoptic and repetitive coverage of the coastal ocean and we could generate useful spatial information on various scales with reasonable classification and control accuracy. The objective of the present study is to evaluate and monitor shoreline changes along the Paradip coast due to external processes using LISS III data of IRS 1D and IRS P6 satellites.

The area is enclosed between latitudes 20°30'N and 20°45'N and longitudes 86°15'E and 86°45'E, covering an area of 3115.4 km² (Figure 1). Paradip port is located at the mouth of the Mahanadi river, and primarily exports iron ore. The eastern portion of the study region is covered with low forest and wild growth of cane and brush wood, and intersected by innumerable creeks which are sluggish and silty. The western portion of the study area is fertile, though affected by frequent floods due to Mahanadi and Devi rivers. The climate is generally tropical with fairly good rainfall during the monsoon season. The daily mean minimum temperature varies from 11.0°C in January to 26.7°C in May. During May and June, the maximum temperature varies from 26.6°C to 36.6°C. The annual evaporation rate is nearly 787.5 cm in the coastal

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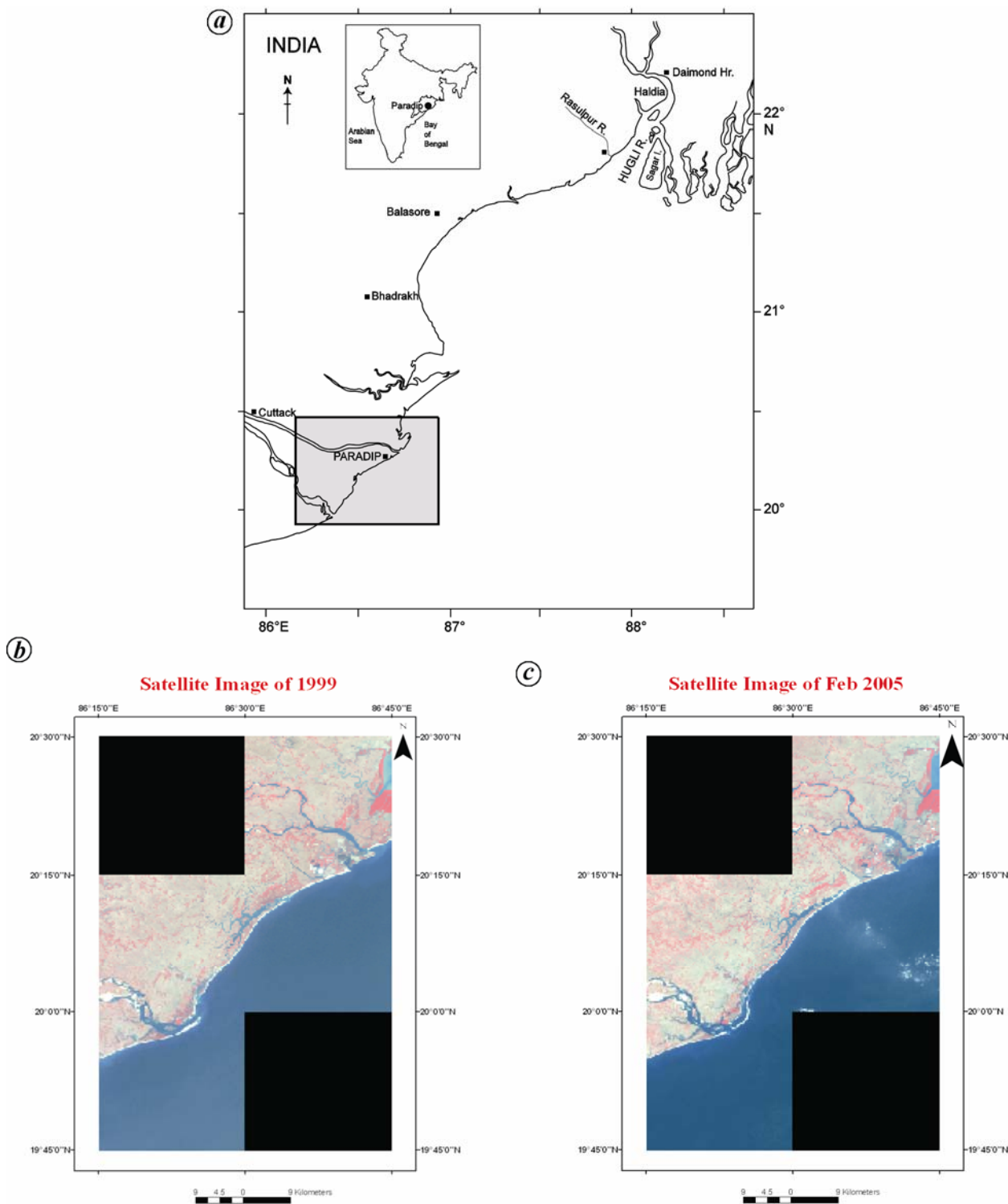


Figure 1. Study area.

areas. This region gets rain during both the SW and NE monsoons and the average rainfall is 1445.5 mm. However, major rainfall is received during the southwest monsoon. Monsoon depressions in the Bay of Bengal also cause heavy precipitation.

In the present study, we used LISS-III data (Table 1) of IRS-1D and IRS-P6 (Resourcesat) satellites having the same spatial resolution (23.5 m) for monitoring shoreline changes along the Paradip coast. The images were acquired for the path 107 and row 058 available for different

years (Table 2). The image taken was FCC on 1 : 50,000 scale, having band combination of 3 : 2 : 1 (IR : Red : Green). The IR band was found suitable for demarcation of shoreline as the contrast between land and water is sharp. The Survey of India (SOI) topographic sheets (map nos 73L/8, 73L/11, 73L/12 and 74I/5) in 1 : 50,000 scale were used as base maps of the study area for demarcation of the shoreline.

The digital satellite data and SOI scanned top sheets were geometrically rectified and georeferenced to world space coordinate system using a digital image processing software. The root mean square error achieved was less than 0.3 pixels. The shoreline and beach pattern of 1973 from the topographic sheets and LISS-III data during 1998–2005 have been digitized as a polyline and as polygons respectively, using GIS software. Prior knowledge of the study area and image interpretation techniques was used to map the shoreline and beaches. The shoreline and beach layers of 1973, 1998, 1999, 2000, 2001, 2002, 2003, 2004, February 2005 and December 2005 were combined to give a new output image. The values of length of shoreline and areas of beaches were used for detailed intra-annual analysis.

Diurnal and annual cycles of the sea level also need to be considered as a potential source of error for location of the shoreline from remotely sensed image. The satellite images were selected after examining for similar tidal conditions. The annual variation of shorelines has been accomplished with the help of GIS map-manipulation functions as they provide greater freedom for map-handling. Finally, the maps were compared to estimate the changes in shoreline length and beach area along the Paradip coast from 1973 to 2005 (Tables 3 and 4).

Wave data have been used to exhibit wave domination from directional wave rider buoy. It was deployed in 1996 for 8 months off Paradip Coast. Significant wave height varied from 0.50 to 3.41 m and maximum wave height was up to 6.32 m. Long-period waves were from 18.0 to 21.0 s and peak periods were 8.0 and 15.0 s. The long-period waves could be due to the effect of cyclones and monsoon winds²⁰.

Urbanization and industrialization are the two significant environmental and societal issues existing in the study region. Changes in the pattern of sediment movement, wave action, dredging, etc. increase the pressure in the coastal zone and lead to coastal geomorphologic

Table 1. LISS-III sensor details

Sensor	Spectral band (µm)	Ground resolution (m)	Swath (km)
LISS-III	0.52–0.59 (Green)	21.2–23.5	142.0
	0.62–0.68 (Red)		
	0.77–0.86 (Near IR)		
	1.55–1.70 (SWIR)	63.6–70.5	

changes. Table 3 shows the summary of rapid changes in the study area. A difference of 7 km in the length of the shoreline and a net loss of 15.62 km² area (Table 4) were found between the SOI topographic sheet prepared in 1972 and the satellite image of December 2005. Topographic sheets show the existence of many small islands in the mouth of Devi River and to its north. However, the recent satellite images do not show their presence. Sandy bodies extended towards the northeast direction. The Jatadharmohan creek flowed at the northern extent of the Devi river, then with a small mouth exposed to the Bay of Bengal. The results show that natural and anthropogenic factors are responsible for the modification of geo-

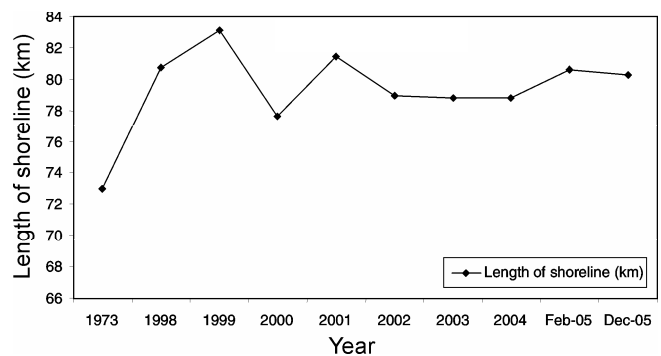


Figure 2. Annual length (km) of shoreline along the study area (1973–2005).

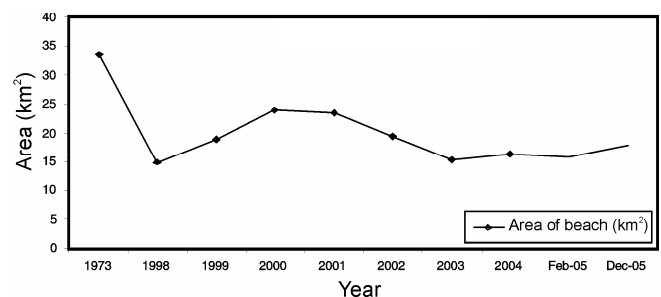


Figure 3. Area of beaches (km²) in the study area (1973–2005).

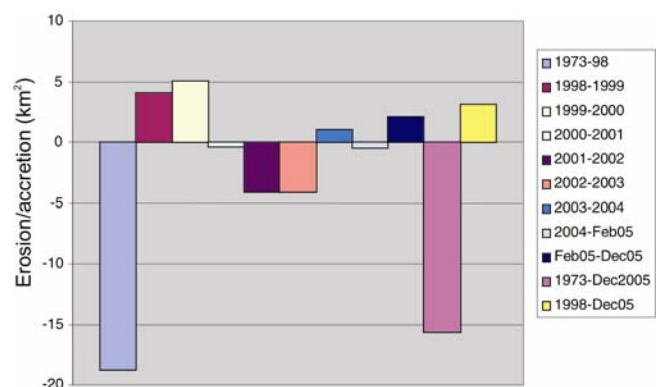


Figure 4. Erosion and accretion (km²) along the coast in the study area.

Table 2. Data used in the study

Year	Path/row	Satellite ID	Date and time of acquisition (GMT)
1998	107-58	1D	24 January 1998 and 05 : 00 : 45
1999	107-58	1D	28 February 1999 and 05 : 10 : 30
2000	107-58	1D	19 January 2000 and 05 : 13 : 44
2001	107-59	1D	22 February 2001 and 05 : 11 : 43
2002	107-60	1D	13 January 2002 and 05 : 05 : 26
2003	107-61	1D	17 February 2003 and 04 : 53 : 16
2004	107-62	P6	13 January 2004 and 04 : 59 : 09
February 2005	107-63	P6	24 February 2005 and 04 : 57 : 30
December 2005	107-64	P6	09 December 2005 and 04 : 51 : 53

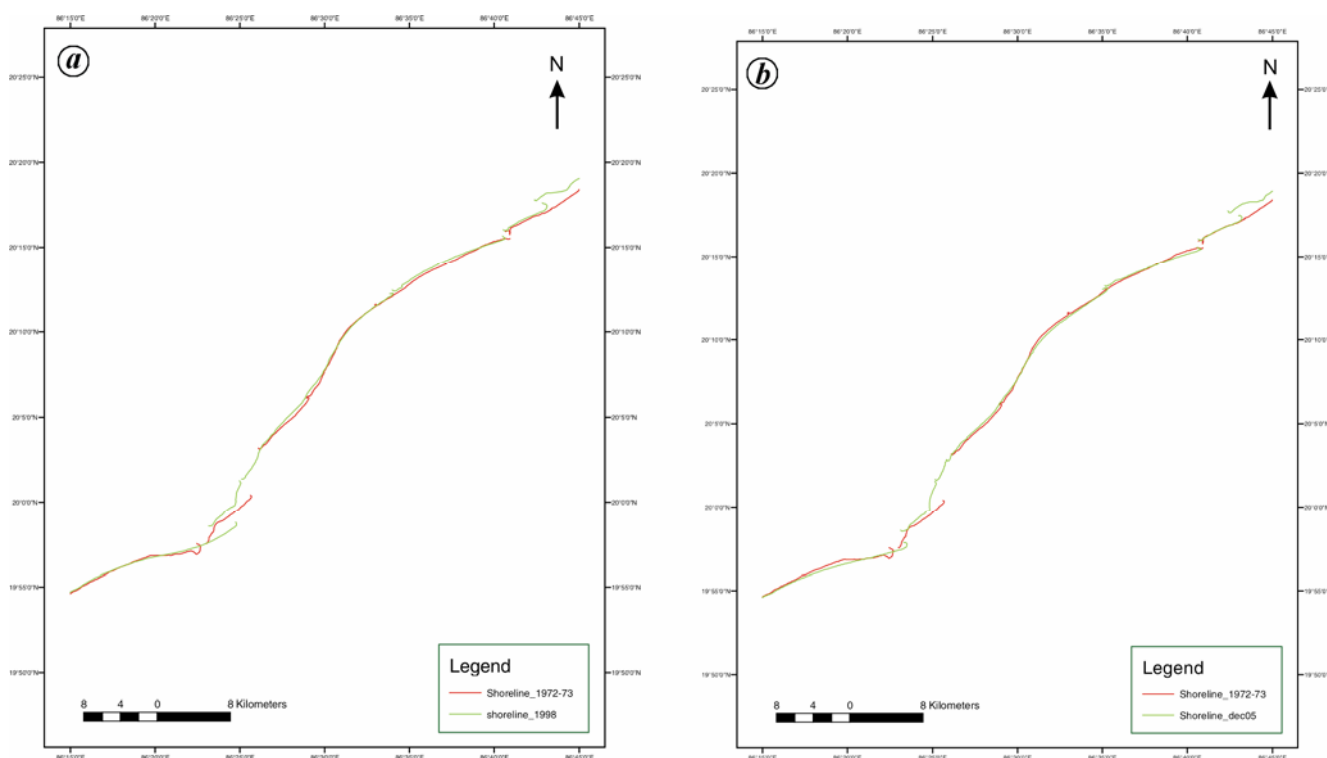


Figure 5. Shoreline map of Jadadharmohan creek area for the period 1973–1998 (a) and 1973–December 2005 (b).

morphic features and length of shoreline changes. Wave data of the region also support the wave domination due to cyclones and monsoon winds.

GIS analysis of shoreline vector maps shows an increase in the length of the shoreline in the period 1998–99, 2000–01 and 2004–05 as 2.37, 3.78 and 1.81 km respectively (Figure 2). However, the length has been reduced to 5.45, 2.46, 0.13 and 0.05 km during 1999–2000, 2001–02, 2002–03 and 2003–04, respectively. This swinging of shoreline length reflects the natural and human activities in the region. Erosion and accretion confirm the redistribution of sediments. The beach area also varied significantly in the region. During the years 1998–99, 1999–2000 and 2003–04, it had increased to 4.06,

5.04 and 1.04 km² respectively (Figure 3). An increase of 7.26 km length and net loss of 15.6 km² area was observed between 1973 and 2005 (Figure 4). Increase of 7.72 km in the shoreline length and 18.73 km² in the beach area was observed between 1973 and 1998 (Figure 5). The resulting shoreline vector maps reveal the positional changes of the shorelines. Net loss of area 0.42, 4.11, 4.10 and 0.47 km² (Figure 6) was found during the years of 2000–01, 2001–02, 2002–03 and 2004–05 respectively. During 2001–02 and 2002–03, there was a loss of beach area as well as reduction in the shoreline. This would probably be due to various activities going on along the Paradip coast, resulting in a reduction of 0.46 km in length of the shoreline and an increase of

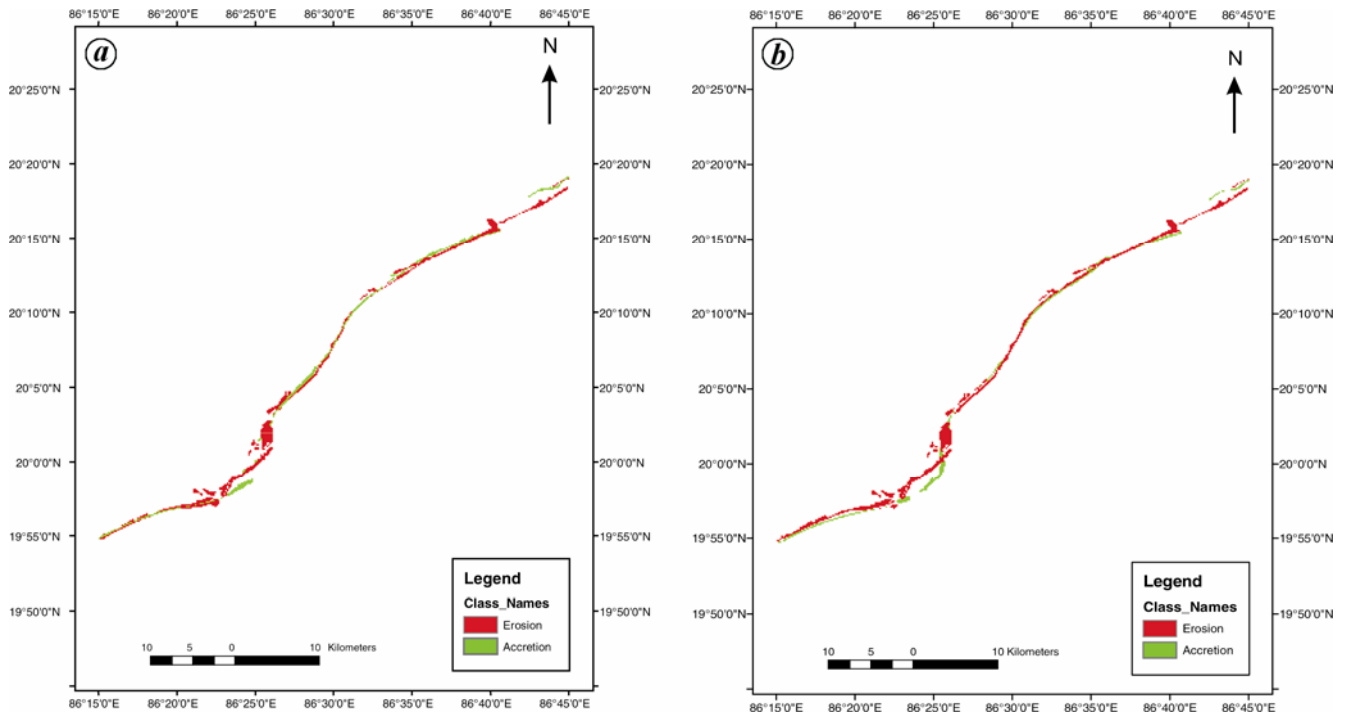


Figure 6. Coastal area changes map of Jadadharmohan creek area for the period 1973–1998 (a) and 1973–December 2005 (b).

Table 3. Details of annual length of shoreline (km) and beach area (km²; 1973–2005)

Year	Length of shoreline (km)	Area of beach (km ²)
1972–73 (topographic sheet)	73.00	33.59
1998	80.72	14.85
1999	83.10	18.92
2000	77.64	23.96
2001	81.42	23.54
2002	78.96	19.42
2003	78.83	15.31
2004	78.77	16.36
February 2005	80.59	15.88
December 2005	80.26	17.97

Table 4. Details of changes in shoreline length (km) and beach area (km²)

Year	Shoreline length (km)	Changes in beach area (km ²)
1973–98	7.72	-18.73
1998–99	2.37	4.06
1999–2000	-5.4	5.04
2000–01	3.78	-0.42
2001–02	-2.46	-4.11
2002–03	-0.13	-4.10
2003–04	-0.05	1.04
2004–February 2005	1.81	-0.47
February–December 2005	-0.32	2.08
1973–December 2005	7.26	-15.62

3.11 km² in beach area between 1998 and 2005. Wave data are in good agreement with the geomorphologic changes of the study area.

The results of this study reveal the shoreline positions and its swinging over a period of 32 years. This would help decision-makers prepare a master plan for CZM due to anthropogenic activities as well as natural processes. The coastline vector maps can be used to determine the rate of change over different periods of time. Detailed wave modelling for this area will reveal more information on the evolution of this coast by natural processes. The enhancement in spatial and temporal resolution of the images will improve the quality and frequency of monitoring in future.

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Influence of crop establishment methods on methane emission from rice fields

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A field experiment was conducted to know the effect of rice sowing and transplanting methods as well as nutrient management through 12 treatments were assessed during kharif 2004 at Crop Research Centre, Pantnagar. The maximum methane flux was recorded in 100% NPK + straw + manual transplanting practice (7.70 mg m⁻² h⁻¹), whereas the lowest 0.70 mg m⁻² h⁻¹ in vermicompost + direct sowing. The treatment 100% NPK + sulphur + manual transplanting gave higher grain yield of rice (6.85 t ha⁻¹) and CH₄ emission (2.25 mg m⁻² h⁻¹). However, the treatment 100% NPK + sulphur + direct sowing was effective in reducing methane flux (1.57 mg m⁻² h⁻¹) with higher rice grain yield of 6.62 t ha⁻¹.

Keywords: Aerobic rice, direct seeded rice, mat-type rice transplanter, methane flux.

METHANE, a major component of natural gas is the second most important greenhouse gas (GHG) after CO₂. It plays a major role in global warming and climate change, and its reduced emission is essential without adversely affecting crop production. Methane emitted from rice fields under various cultural practices has been an area of research, as little information is presently available on this aspect. It is important because the warming effect of methane is 21 times greater than that of CO₂. Methane emitted from flooded rice fields is a major source of atmospheric methane¹. Methane emission is prominent in irrigated rice due to long periods of flooding and anaerobic decomposition of incorporated organic matter². Methane emission from rice fields is affected by climate, water regime, soil properties, irrigation, drainage, organic amendments, fertilizers and rice straw management. Much attention has been devoted in recent years to the 'greenhouse effect' of the atmosphere and its enhancement by increased anthropogenic activities of radioactive gases, which tend to alter the heat budget of the earth's atmosphere, while most often burning of fossil fuels (petroleum, coal and natural gas) has been cited as the major culprit. However, the role of agriculture in climate

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