

# Chapter 6

## Long-Term Shoreline Change Analysis and Impact of Hard Coastal Structures on Shorelines—A Case Study of the Nagapattinam-Ramanathapuram Shoreline



C. Prakasam, R. Aravinth, and S. Sanjeevi Prasad

**Abstract** Shorelines are dynamic and complex in nature and shoreline changes are induced by numerous factors such as littoral currents, waves, riverine activities and sometimes tides as well. Construction of hard coastal structures disrupts natural deposition tendencies and erosion occurring along the coast. The way they are affected depends upon the type of structure and longshore transport. This Chapter examines a shoreline stretch of approximately 376 kms from Kodikkarai in (Nagapattinam) to Mandabam (Ramanathapuram) covering the districts of Thanjavur, Thiruvarur and Pudhukottai in Tamil Nadu, India. The shoreline change analysis entailed the use of satellite imageries used are derived from LANDSAT (MSS, TM, ETM, ETM+ and OLI) during the years 1988–2015. To derive the shoreline data from the satellite images, band 5 in Landsat (MSS) and band 6 (ETM–OLI) were used as they allow us to distinguish between land and water boundaries clearly. The shorelines were demarcated and digitized using various sources including LANDSAT, LISS and Google Earth Imageries. The datasets were saved based on the standard format of (DD/MM/YYYY) for analysis. The erosion and accretion rates have been calculated using the DSAS plugin. The resultant maps were used to demarcate depositional features that were predominantly observed over the period 1988 to 2015. The highest amount of deposition and erosion were along Tirutturappundi and Mandabam respectively. For, the assessment of the impact of hard structures along the coast requires high resolution satellite imageries, hence Google Earth imageries were used to interpret the data. Most of the sites show both depositional and erosional features. Site

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C. Prakasam (✉)

Department of Geography School of Earth Sciences, Assam University, Diphu Campus (A Central University), Diphu, Karbi Anglong, Assam 782462, India  
e-mail: [cprakasam@gmail.com](mailto:cprakasam@gmail.com); [c.prakasam@aus.ac.in](mailto:c.prakasam@aus.ac.in)

R. Aravinth

Institute of Environment Education and Research, Bharathi Vidyapeeth University, Pune 411043, India

S. Sanjeevi Prasad

Department of Geography, University of Madras, Chennai 600005, Tamil Nadu, India  
e-mail: [sanjeevi@unom.ac.in](mailto:sanjeevi@unom.ac.in)

1 had only erosional features, while site 14 had depositional features all along the coastline.

**Keywords** Net shore movement · End point rate · Shoreline change · DSAS · Remote sensing

### 6.1 Introduction

Shoreline change is an ongoing process over millions of years. A beach is an environment that is present between land and sea and is a fragile ecosystem and constantly changing due to various conditions (Kaliraj et al. 2017). Landforms are modified by both natural and man-made processes (Kankara et al. 2015; Lakshmana and Prasad 2018). Changes induced by human intervention tend to alter these natural processes. Construction of harbours, jetties and sea walls have influenced erosion and accretion patterns (Fig. 6.1). Shoreline change analysis is a step towards assessing the vulnerability of coasts and the dominant factors that play a role in it (Dwarakish and Nithyapriya 2016; Kumar et al. 2010). Estimating the causative factors helps in taking precautionary measures while designing coastal structures in future. Coastal structures are constructed to trap longshore sediment to create protective beaches. These structures are found to cause deposition along the up-drift side and erosion along the down-drift side (Mahendra et al. 2011; Maiti and Bhattacharya 2009).



**Fig. 6.1** Effect of hard coastal structures on a shoreline

Numerous scientists and researchers have studied shoreline changes along the Tamilnadu coastline (Natesan et al. 2015; Saravanan et al. 2019; Vivek et al. 2019) and the impacts of coastal structures like harbours and ports along a coastline.

In the present work, ERDAS Imagine, ArcGIS and DSAS tools have been used to calculate the changes along the coast. Layer stack and pan merge techniques were used to interpret satellite imageries. End point rate (EPR), Net shoreline movement (NSM) and Weighted linear regression (WLR) models have been used to identify erosion, accretion rates and map vulnerable areas.

### **Objectives**

The study focuses on assessing the changes along the coastline of Nagapattinam to Ramanathapuram district and also to assess changes in the shoreline induced by the construction of hard structures along this stretch of coastline. We considered the following:

1. Demarcation of shoreline for various years through LANDSAT and Google earth imageries.
2. Estimating erosion and accretion output for EPR, NSM and WLR.
3. Mapping of highest deposition and erosion through EPR methods for long term analysis and changes induced by hard coastal structures.

## **6.2 Study Area**

The study area extends from Kodikarai in Nagapattinam to Rameshwaram in Ramanathapuram district (Fig. 6.2) of Tamil Nadu, India. The entire study covers about 560 kms of coastline comprising the five coastal districts of Nagapattinam, Thiruvarur, Pudhukottai, Thanjavur and Ramanathapuram. This stretch of coastline is characterized by the presence of coastal structures like jetties and dockyards.

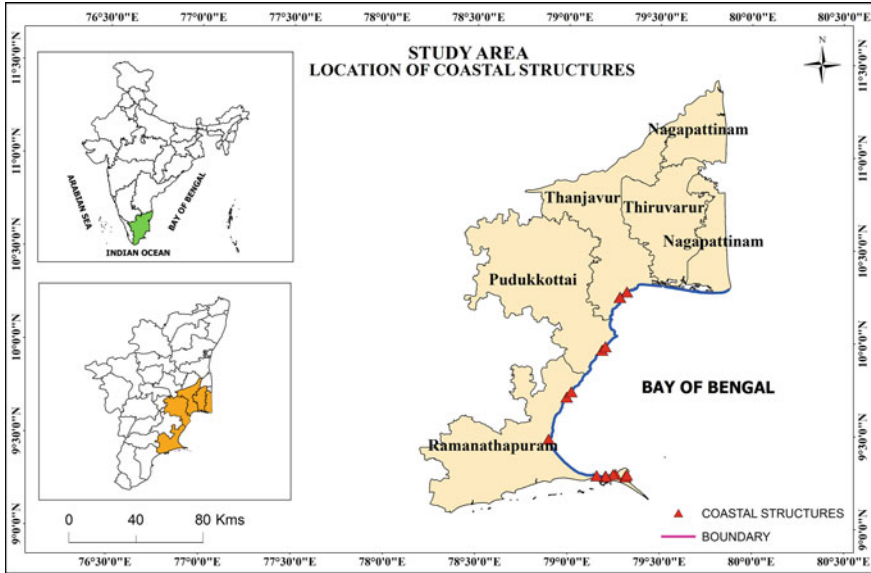


Fig. 6.2 Study area

### 6.3 Materials and Methods

#### 6.3.1 Data Used

Multi-temporal satellite data from LANDSAT (MSS, TM, ETM and OLI) were used. Data for the years 1988, 1992, 1995, 2000, 2005, 2010, and 2016 were used to delineate the shoreline (Table 6.1). Mapping of coastal structures and shorelines along them were achieved using multi-temporal satellite data from Google Earth. The total number of years taken into account for the study area was determined by the availability of Google Earth data.

Table 6.1 Data used for analysis

Sl. no	Data	Year	Source E	Purpose
1	Landsat TM	1992, 1995, 2005,2011	USGS Earth Explorer	Shoreline extraction
2	Landsat 7 ETM	2000	USGS Earth Explorer	Shoreline extraction
3	Landsat 8 OLI	2015	USGS Earth Explorer	Shoreline extraction
4	Google Earth imageries	2000–2016	Google Earth	Shoreline extraction and coastal structures

### 6.3.2 Methodology

Band 5 in Landsat 5 & 7 and Band 6 in Landsat 8 use short wave infra-red that clearly facilitates differentiating between land and water. These bands were used to demarcate the shoreline in the satellite imageries. The digitized shorelines were then assigned respective dates [mm/dd/year]. Thereafter shorelines were exported into a personal database in a GIS environment using ArcGIS ([www.esri.com](http://www.esri.com)). The entire coastline was divided into 100 m transec

ts to calculate shoreline change. The Digital Shoreline Analysis System (DSAS) which is an ArcGIS extension created by USGS was used to analyse the shoreline change rate. The end point rate, net shoreline movement and weighted linear regression were calculated and the results were then exported as a table (Fig. 6.3). These tables were then used to create maps to identify erosional and depositional areas throughout the study area (Sowmya et al. 2019; Sreenivasulu et al. 2016; Vivek et al. 2019).

Analysing the impacts of hard coastal structures along the shoreline requires high resolution satellite imagery. Hence, multi-temporal data from Google Earth were used to identify various coastal structures and delineate shorelines along these structures. A total of 18 structures classified into 14 sites were considered in this study. The year of the study chosen was different for every structure as it was based on the availability of data for that particular structure. The coastal stretch taken along the structures varied from 300 to 1000 m in length. Satellite imageries from Google Earth were found to have geometric errors which were corrected after digitizing all the shorelines. Ground control points (GCP) were collected for all the sites and shorelines were corrected with respect to the acquired GCP points. The digitized shorelines were then assigned respective dates [mm/dd/year] and the shorelines were then exported into a personal geodatabase in ArcGIS environment. The shorelines were then divided into 1 m transects to calculate shoreline change and outputs from the DSAS software were calculated and the results exported as a table (Fig. 6.3). These tables were then used to create maps to identify erosional and depositional areas throughout the study area (Saleem and Awange 2019; Sankari et al. 2015; Saxena et al. 2013).

## 6.4 Result and Discussion

### 6.4.1 Assessment of Long—Term Change in Shorelines

Long-term shoreline change was estimated from Kodikarai in Nagapattinam to Mandabam in Rameshwaram district through visual image interpretation and shoreline delineation for the years (1988 to 2015) of post-monsoon season. The output was differentiated into three types namely erosional and depositional features and no

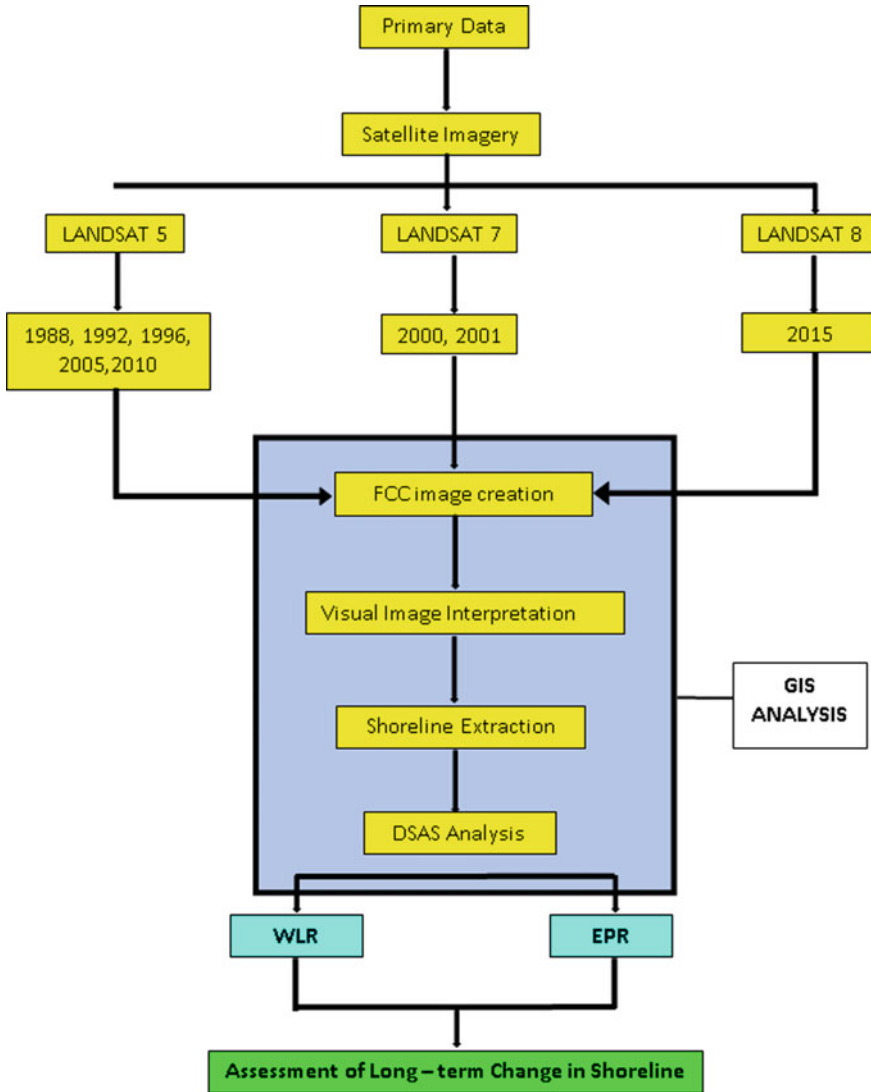


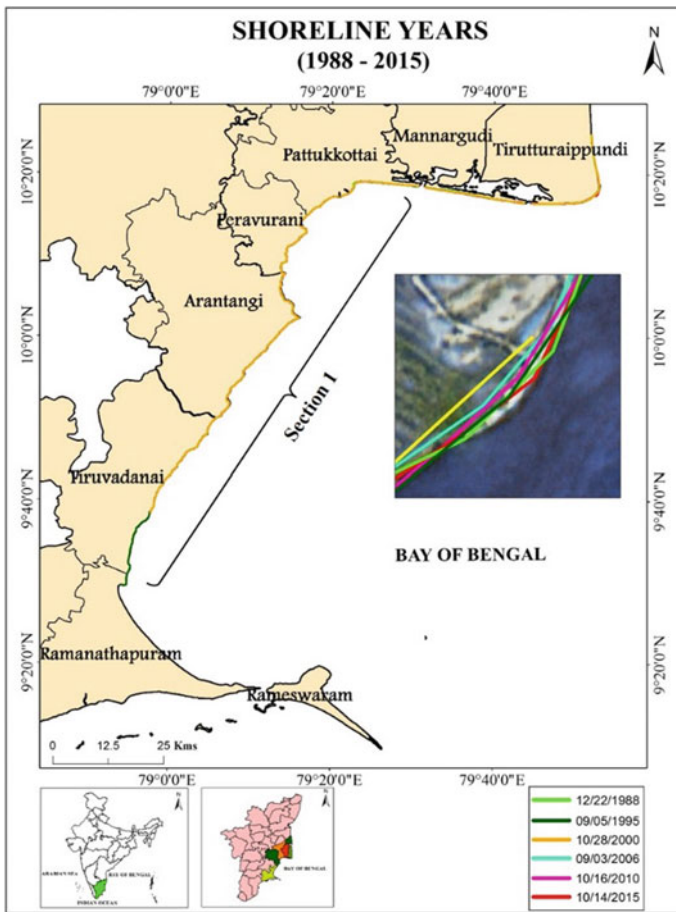
Fig. 6.3 Overall research methodology

change. The entire shoreline was categorized into two sections as they spread into two different Landsat scenes.

**Section 6.1** extends from Kodikkarai in Nagapattinam to Pathanendal in Ramanathapuram district (Fig. 6.4). The total shoreline extent is 336 kms covering Nagapattinam to Pathanendal of Rameshwaram. A total of 6 years were taken for this study (1988, 1996, 2000, 2005, 2010 and 2015) over a span of 27 years. Shoreline change was calculated between each year and overall change was calculated

during 1988 to 2015. The results were generated and outputs were presented as maps. **Section 6.2** is located in Ramanathapuram taluk (Fig. 6.5). The total shoreline extent is 40 kms covering the entire Ramanathapuram taluk. A total of 6 years were taken for this study (1988, 1996, 2001, 2005, 2010 and 2015) across a span of 27 years.

Along Sect. 6.1, during 1988 to 1995 alternating erosion and depositional shorelines were formed. The highest deposition and erosion were identified along the coast of Tirutturappundi and Peravurani. Most depositional features were found along the coast of Pattukotai, Mannargudi and Tirutturappundi. Between 1995 and 2000 alternating erosion and depositional shorelines were formed, while peak deposition and erosion was identified along the coast of Mannargudi and Arantangi. Most of the erosional features were found along the coast of Tirutturappundi, Mannargudi,



**Fig. 6.4** Section 6.1 of study area

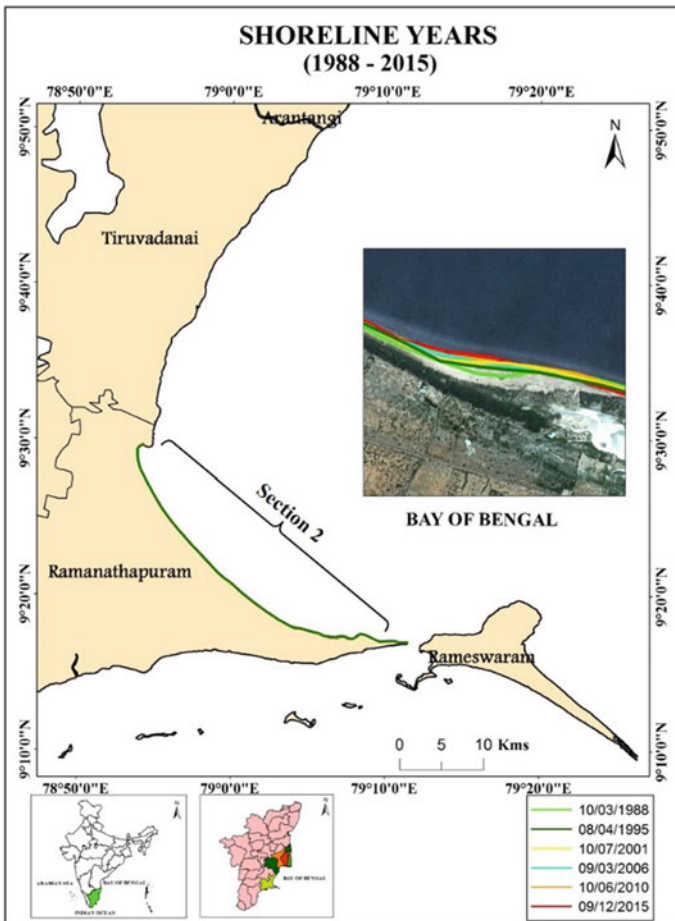


Fig. 6.5 Section 6.2 of study area

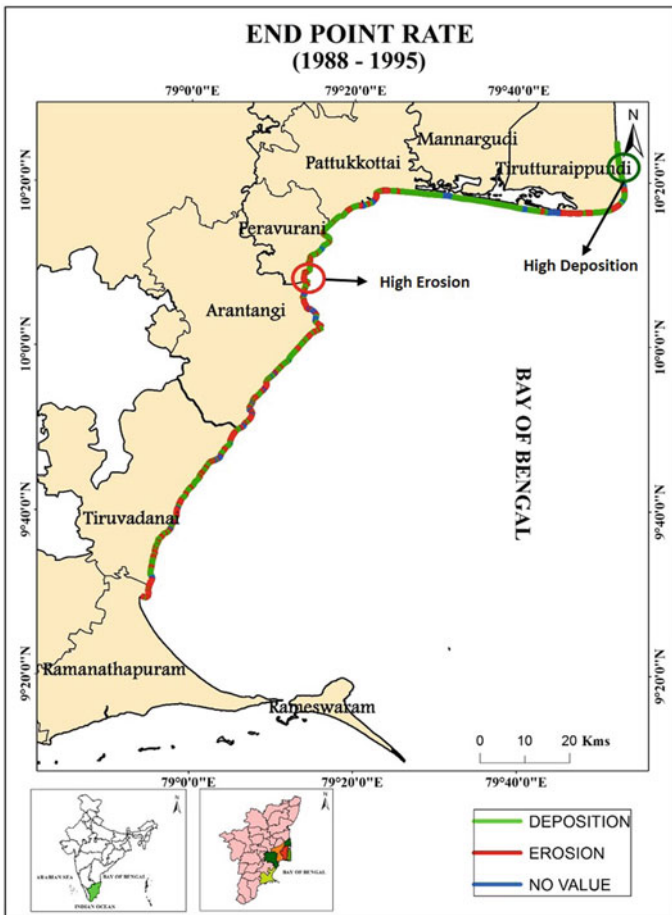
Pattukotai, Peruvanai and Arantangi. Between 2000 and 2006 alternating erosion and depositional shorelines were formed and pronounced deposition and erosion occurred along the coast of Pattukotai and Tiruvadanaï. Between 2010 and 2015 alternating erosion and depositional shorelines were formed (Table 6.2) and peak deposition and erosion were identified along the coast of Tirutturappundi (Figs. 6.6, 6.7, 6.8, 6.9, 6.10 and 6.11).

In Sect. 6.2, between the years 1988 and 1995 alternating erosion and depositional shorelines were formed. The highest deposition and erosion were identified along the coast of Mandabam. Most of the deposition occurred along Devipattinam. Between 1995 and 2001 alternating erosion and depositional shorelines were formed. Highest deposition and erosion were identified along the coast of Uchipuli. During 2000 and 2006 alternating erosion and depositional shorelines were formed with pronounced



**Table 6.2** Erosion and accretion rates of shoreline (Sect. 6.1)

Section 1					
Sl. no	Year	Deposition	Place	Erosion	Place
1	1988–1995	11.9	Tirutturaippundi	–11.5	Peravurani
2	1995–2000	12.2	Mannargudi	–11.0	Arantangi
3	2000–2006	10.9	Pattukkottai	–10.7	Tiruvadana
4	2006–2010	10.9	Tiruvadana	–11.8	Mannargudi
5	2010–2015	10.9	Tirutturaippundi	–10.9	Tirutturaippundi
6	1988–2015	8.4	Mannargudi	–5.4	Tirutturaippundi



**Fig. 6.6** EPR (1988–1995)

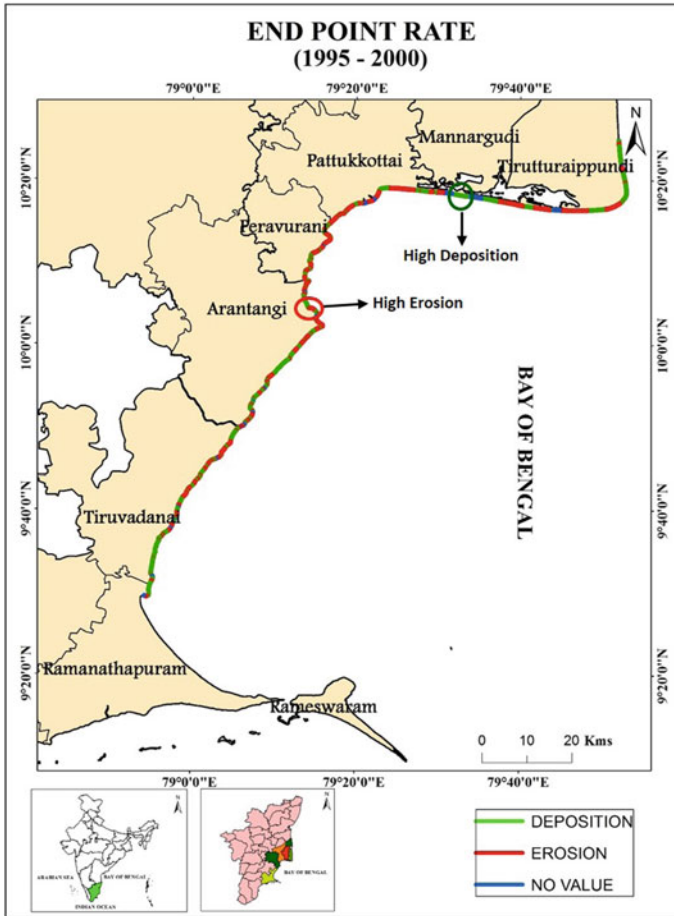


Fig. 6.7 EPR (1995–2000)

deposition and erosion activity registering along the coast of Uchipuli and Mandabam. Between 2010–2015 (Table 6.3), erosion and deposition at Devipattinam and Mandabam accrued (Figs. 6.12, 6.13, 6.14, 6.15, 6.16 and 6.17).

### 6.4.2 Assessment of Shoreline Change Along Coastal Structures

Shoreline change along coastal structures was estimated from Nagapattinam to Ramanathapuram district wherein a total of 19 coastal structures classified into 13 sites. The structures were mostly dockyards and a few jetties. The span of shoreline

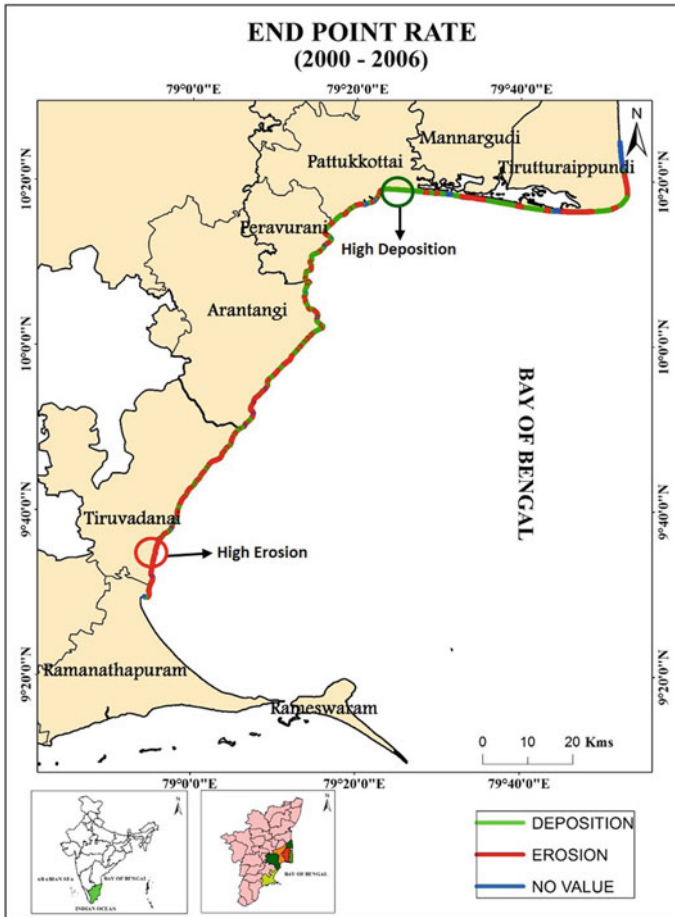


Fig. 6.8 EPR (2000–2006)

length taken into consideration varied for each site (Natesan et al. 2014; Raj et al. 2019; Rangel-buitrago et al. 2017) (Table 6.4).

Overall change in the shoreline at Site 2 deposition was observed on the southern side of the structure and both erosion and deposition were observed on the eastern side of the structure between the years 2010 and 2016. At Site 3 overall change shows deposition on both sides of the structure for the years 2013 and 2016. At Site 4 deposition was observed along the western side of the structure and some erosion was observed along the eastern side of the structure for the years 2013 and 2016. At Site 5 the overall change in shoreline shows deposition along the southern side and erosion along the northern side of the structure during 2008–2016. At Sites 6 and 7 there was mostly deposition over the years 2008 and 2016, though nominal erosion also occurred at Site 7 on the eastern side of the jetty between 2004 and 2016. At

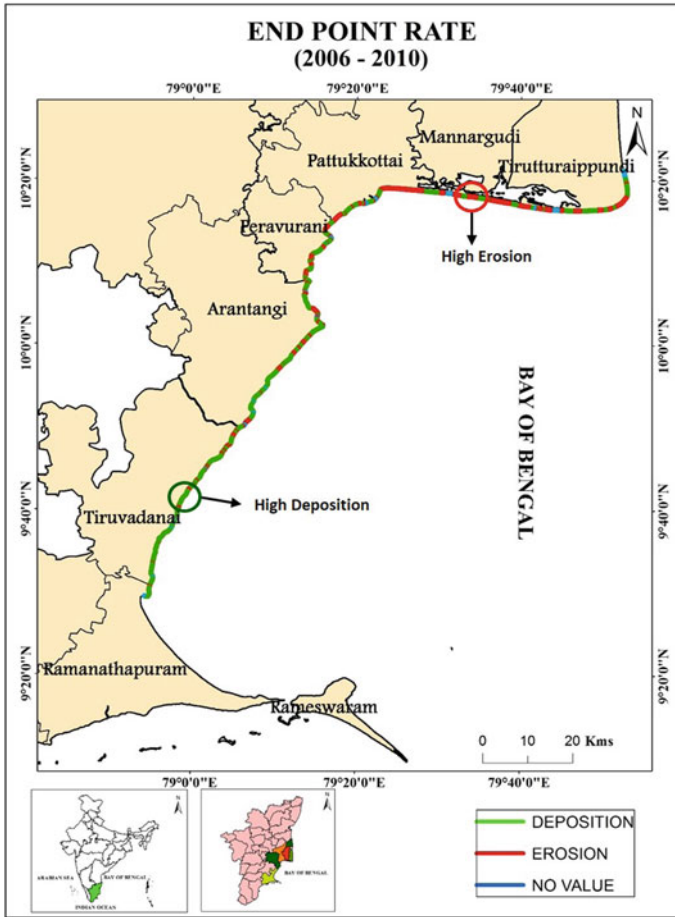
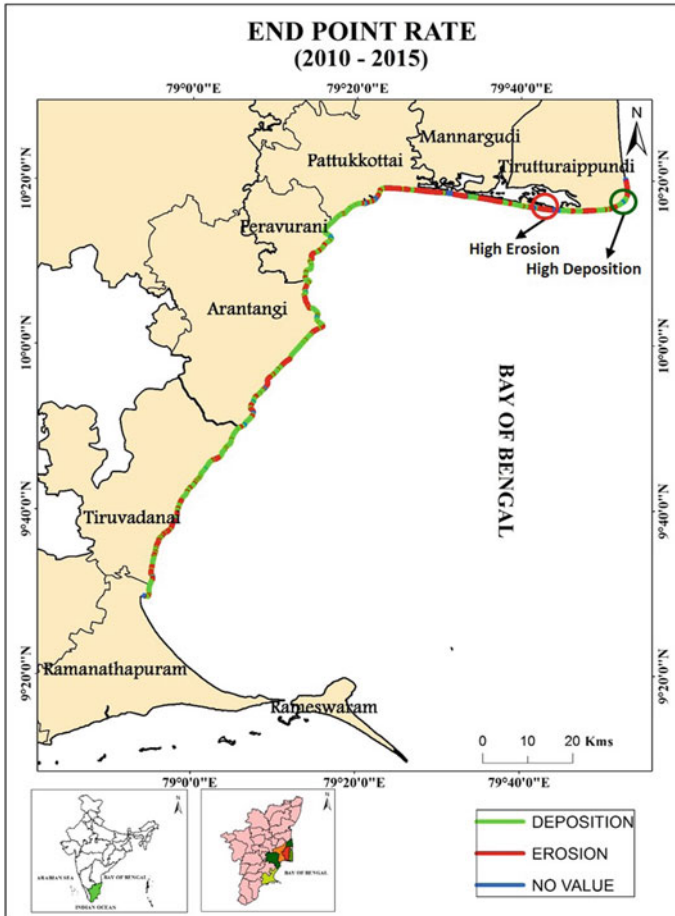


Fig. 6.9 EPR (2006–2010)

Site 8 most of the depositional features were found along the southern side of the structure and at the northern side alternated with deposition along with erosion during 2004–16. Site 9 saw both erosional and depositional features accruing, with more deposition than erosion. At Site 10 mostly erosion was observed along either side of the jetty. Small amount of deposition was observed along the southern side of the jetty during 2002–16. At Site 11, erosional features were observed along the southern side of the structure and along the northern side of the structure, both erosional and depositional features were observed. The predominant feature was erosion for the years 2003–2016. At Site 13, along the southern side of the structure, both erosional and depositional features were observed and along the northern side it was mostly erosion and a few depositional features observed close to the structure. At Site 14, erosional features were observed along both sides of the structure during the years



**Fig. 6.10** EPR (2010–2015)

2003–2016 (Figs. 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28 and 6.29).

### 6.5 Conclusions

The study sought to analyse long term changes in shoreline during the years 1992 to 2015 and the impacts of the construction of hard structures along the coast of Nagapattinam to Ramanathapuram. Shorelines were demarcated using LANDSAT imageries. The entire coastline was segmented into 100 m transects. Shoreline accretion and erosion rate were calculated at a five-year interval between 1992–2015. The

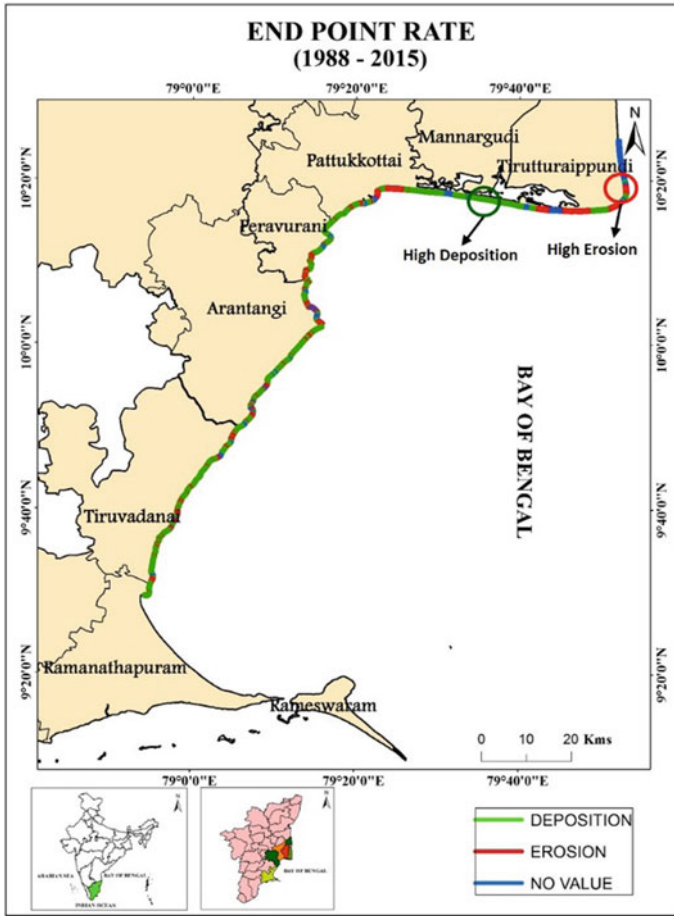


Fig. 6.11 EPR (1988–2015)

Table 6.3 Erosion and accretion rates of shoreline (Sect. 6.2)

Section 6.2

Sl. no	Year	Deposition	Place	Erosion	Place
7	1988–1995	6.9	Mandabam	–12.3	Mandabam
8	1995–2000	6.4	Mandabam	–10.4	Mandabam
9	2000–2006	9.8	Mandabam	–11	Mandabam
10	2006–2010	6.3	Mandabam	–11.5	Mandabam
11	2010–2015	8.3	Devipattinam	–7.5	Mandabam
12	1988–2015	4.4	Mandabam	–6.6	Mandabam

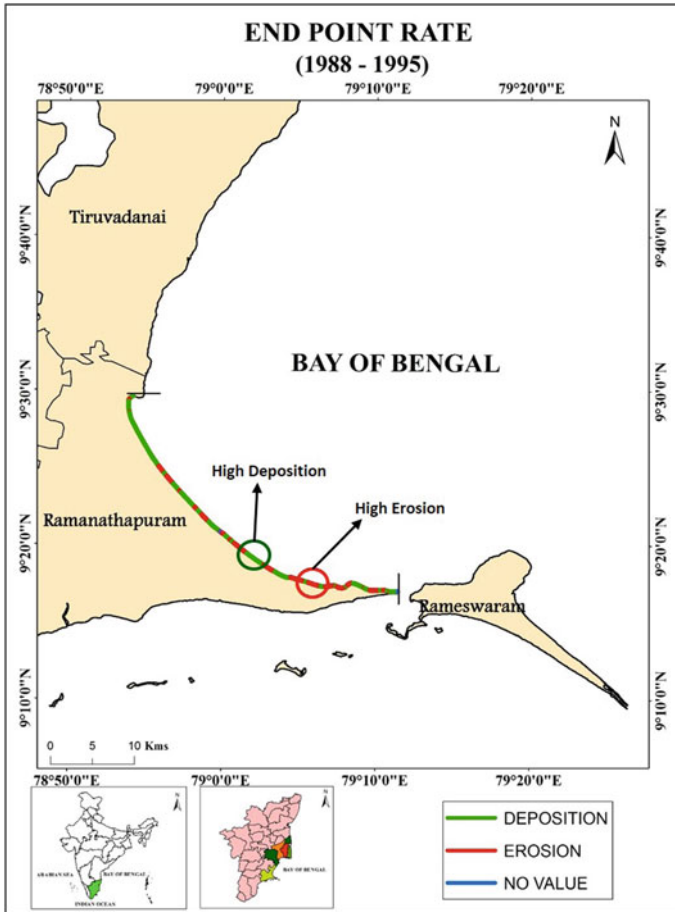


Fig. 6.12 EPR (1988–1995)

end results were then tabulated and maps were prepared for every output demarcating the highest rates of erosion and deposition. To determine the impacts of hard coastal structures a total of 18 structures along 14 sites were examined. Coastal structures and shorelines were demarcated from Google Earth imageries. The following conclusions were drawn from the present work:

1. Along the coast of Nagapattinam to Ramanathapuram depositional were observed prominently in Mannargudi, Arantangi, Tiruvadanaï and Ramanathapuram taluk. The highest amount of deposition (upto 12.17 m) was observed in Mannargudi taluk. Erosional features were observed all along the coast in small magnitudes and tended to be higher in Tirutturappundi, Pattukotai and Ramanathapuram taluk. The highest amount of erosion upto (–12.3 m) was observed in Ramanathapuram taluk.

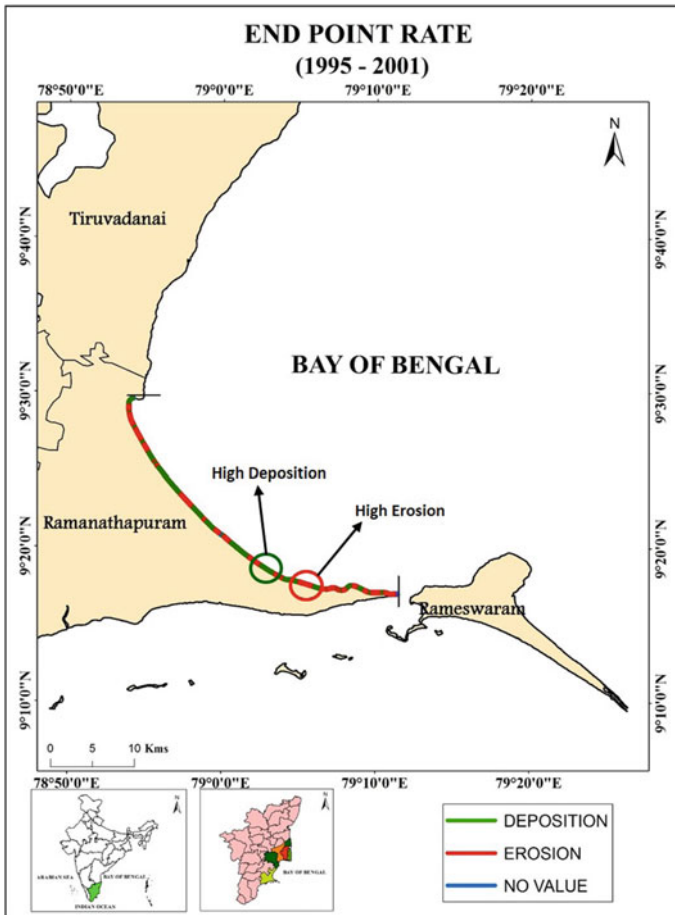
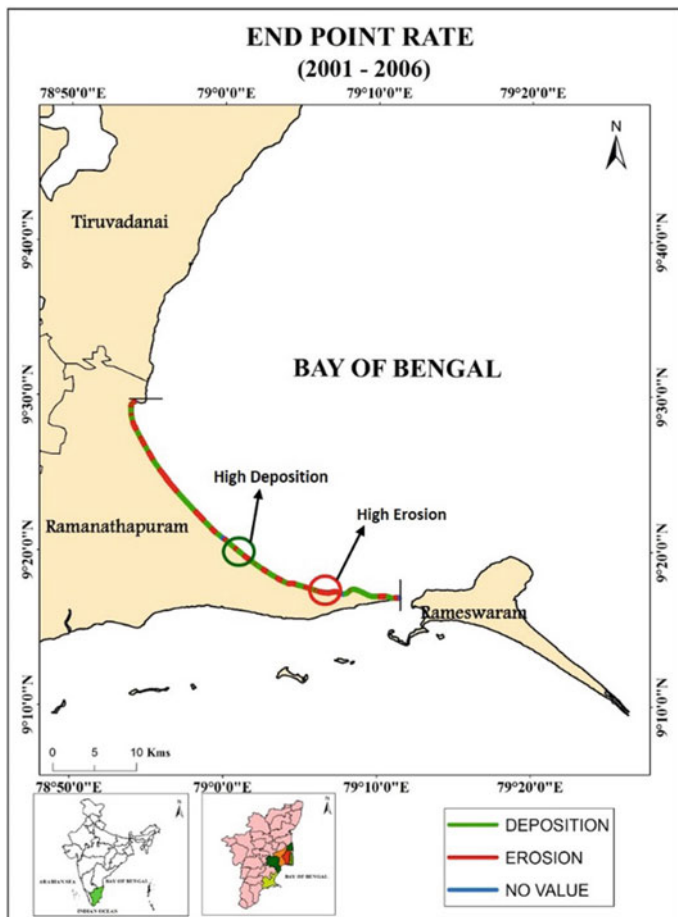


Fig. 6.13 EPR (1995–2000)

- For the structures present in Rameshwaram taluk, depositional features were observed prominently along all the structures. In some structures, erosion was observed along the eastern side. For Ramanathapuram taluk, depositional features were observed prominently along the structures and erosion in some structures along the northern part. In Arantangi, erosional features were observed prominently along the structures and depositional features on the northern side. In Pattukottai, erosional features were prominent along the structures along with nominal deposition along the southern side.





**Fig. 6.14** EPR (2000–2006)

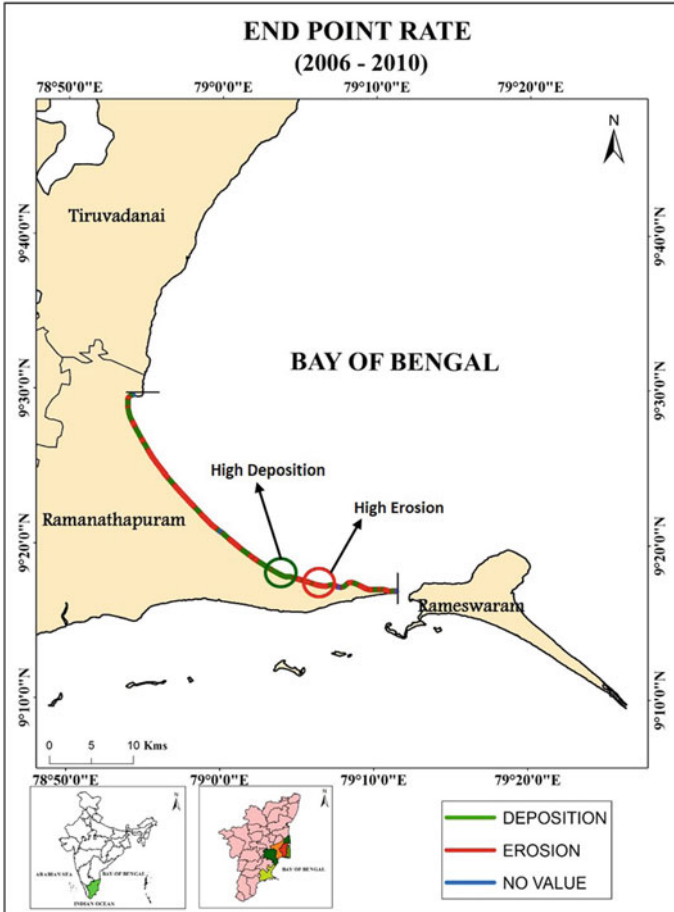


Fig. 6.15 EPR (2006–2010)

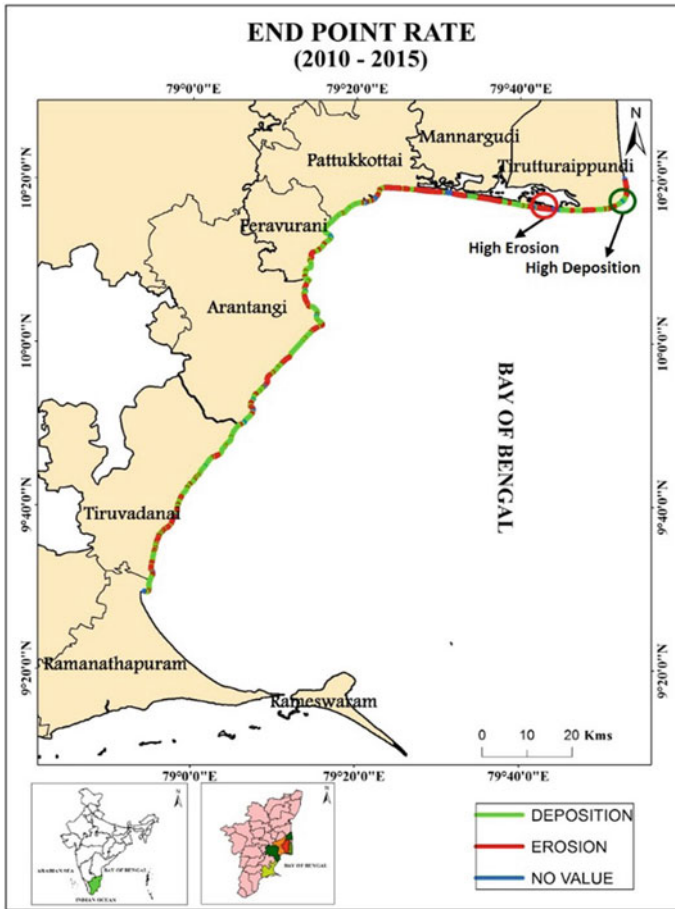


Fig. 6.16 EPR (2010–2015)

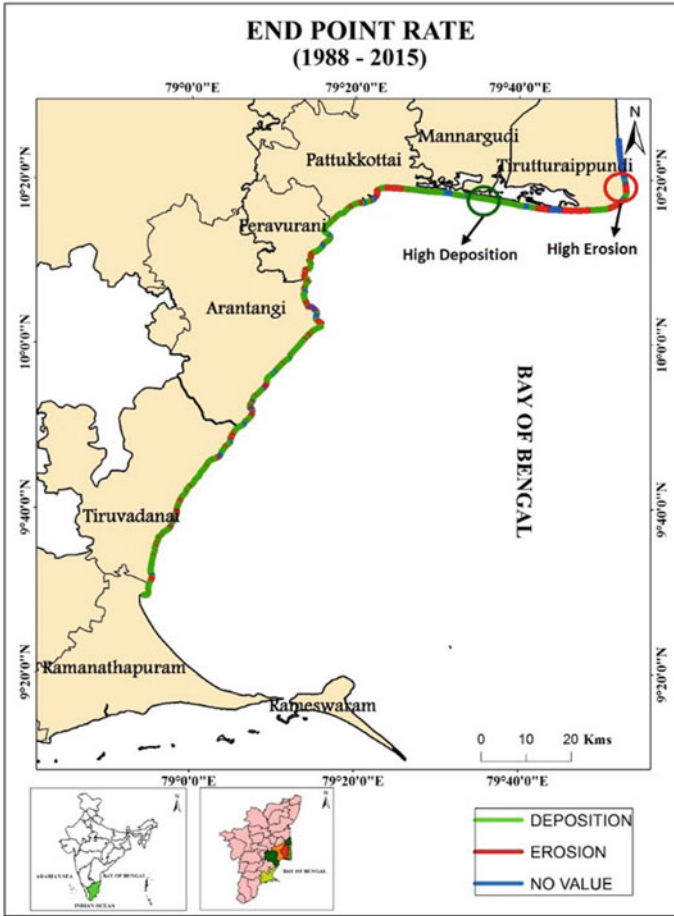


Fig. 6.17 EPR (1988–2015)

**Table 6.4** Highest erosion and deposition (NSM) and (EPR)

Site	NSM		EPR	
	Erosion	Deposition	Erosion	Deposition
1	-15.7	16.7	-36.7	28.6
2	-24.2	22.3	-57.6	53.02
3	-6.2	31.9	-10.3	17.7
4	-9.7	14.1	-16	16.2
5	-8.9	17.8	-4.06	6.3
6	-8.7	16.06	-2.3	6.3
7	-7.3	12.3	-3.8	6.09
8	-17.8	11.3	-10	19.6
9	-12.5	11.1	-8.2	13.7
10	-12.5	10.5	-6.6	8.3
11	-18.2	14.6	-11.3	3.1
12	-5.6	12.8	-11.2	7.4
13	-5.5	14.8	-6.5	5.4



**Fig. 6.18** Site 2

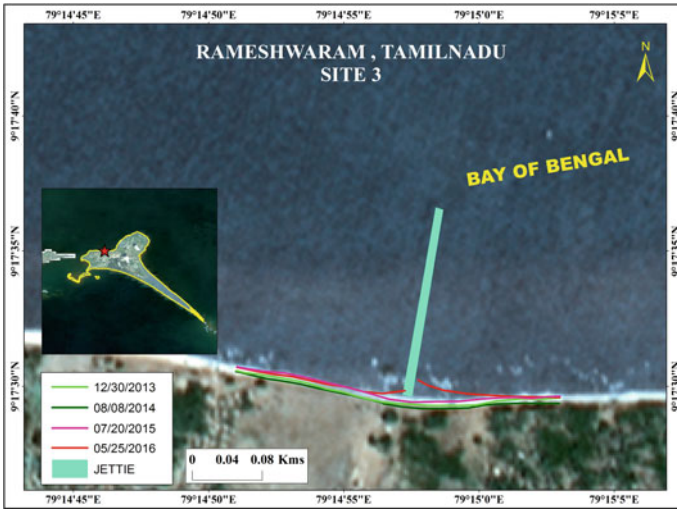


Fig. 6.19 Site 3

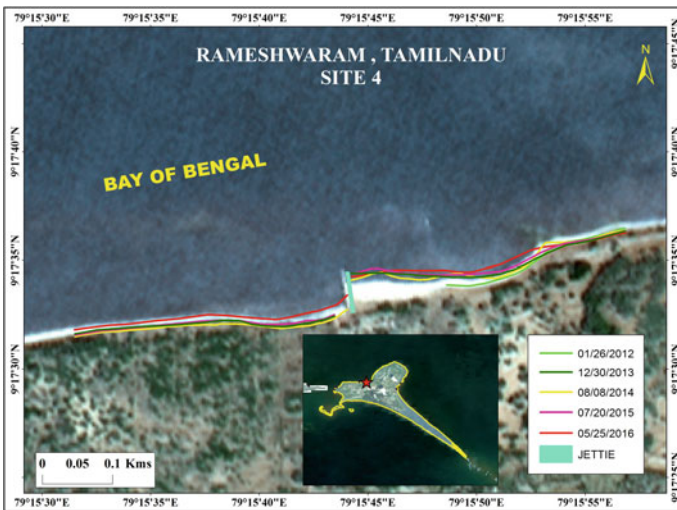


Fig. 6.20 Site 4

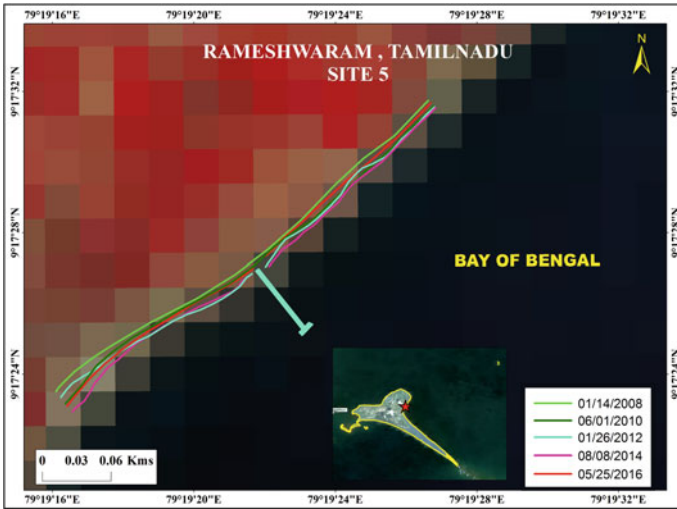


Fig. 6.21 Site 5

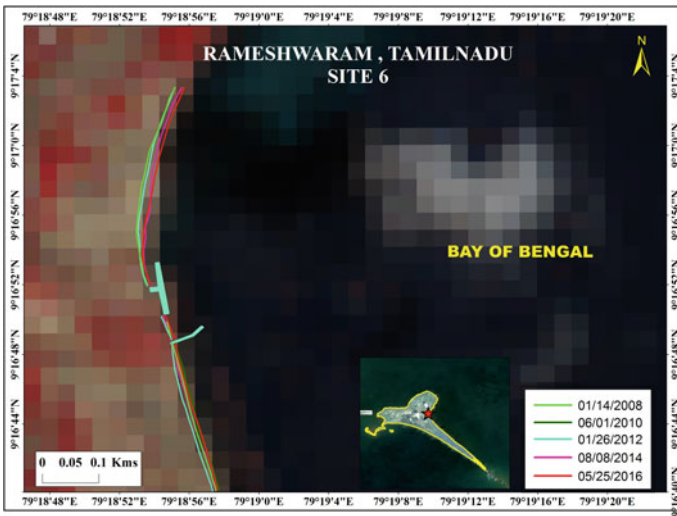


Fig. 6.22 Site 6

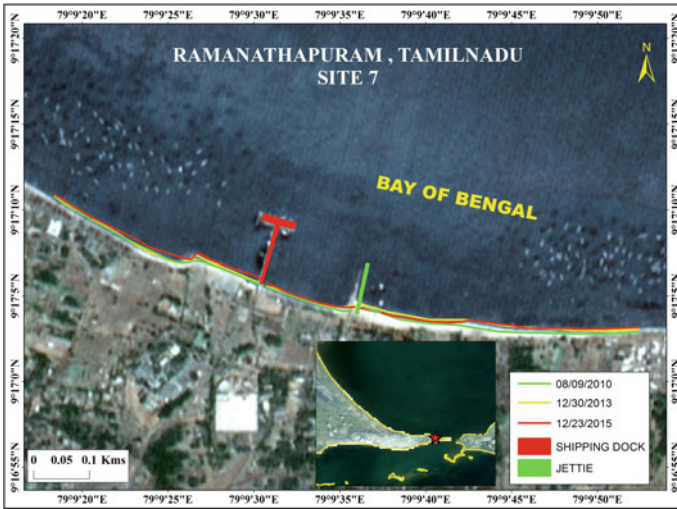


Fig. 6.23 Site 7

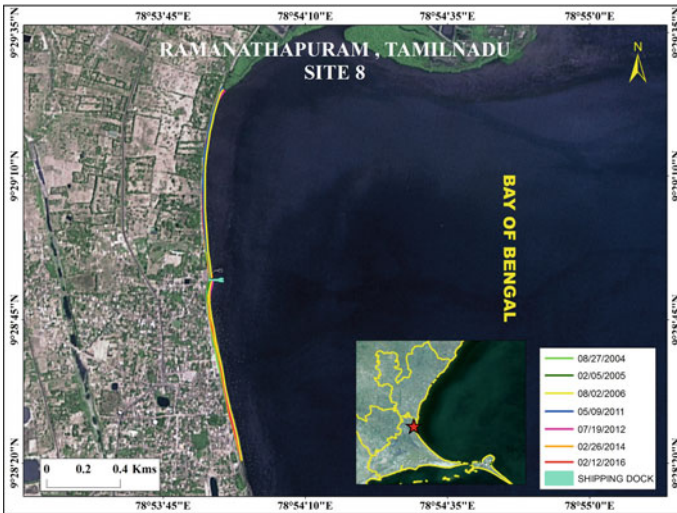


Fig. 6.24 Site 8



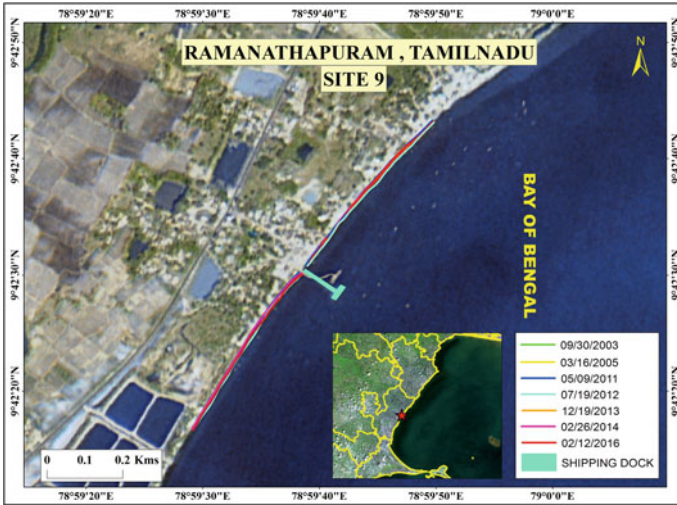


Fig. 6.25 Site 9

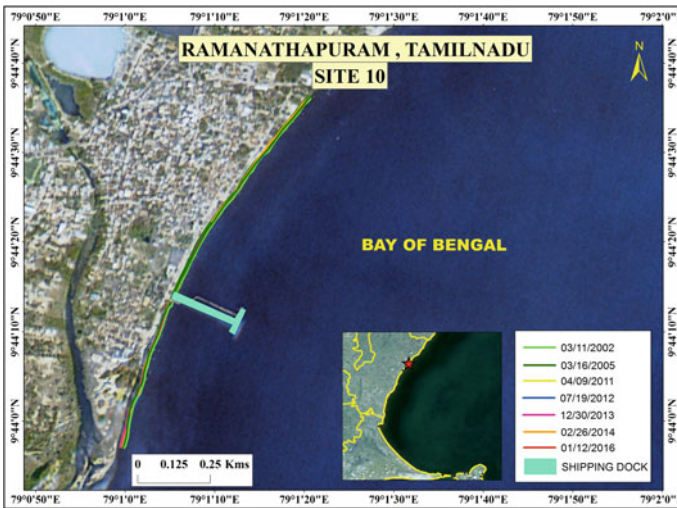


Fig. 6.26 Site 10

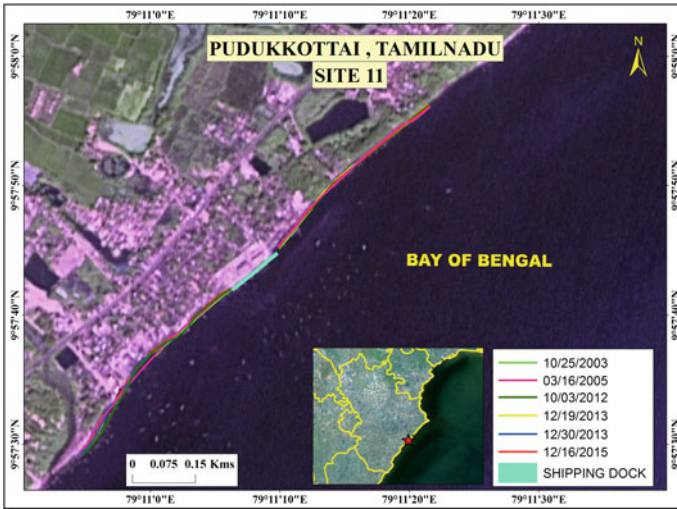


Fig. 6.27 Site 11

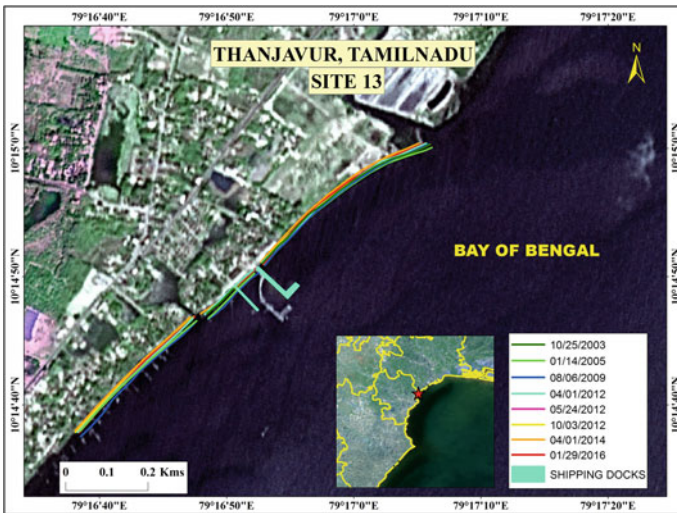
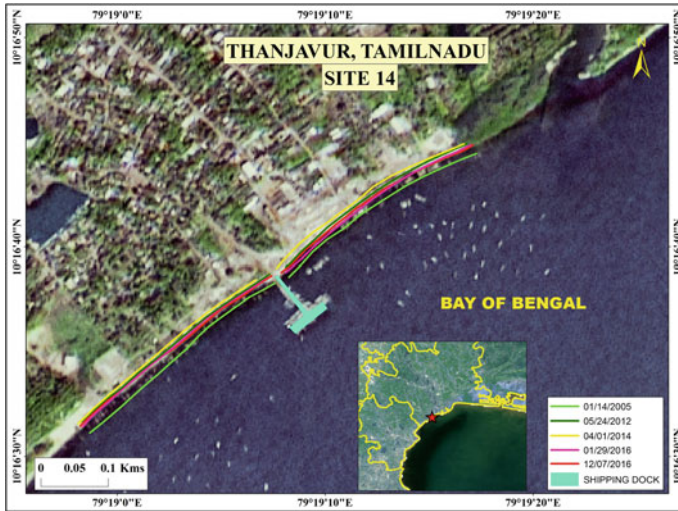


Fig. 6.28 Site 13



**Fig. 6.29** Site 14

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