



# Shoreline change study between Vembar and Tharuvaikulam coastal zones along the coast of Thoothukudi district, Tamil Nadu, India, using remote sensing and GIS techniques

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Shoreline change study is very challenging for any coastal scientists because of its dynamic changes. Erosion and accretion processes directly control the shoreline and coastal landforms. The present study is attempted to assess the shoreline changes between the Vembar and Tharuvaikulam coast of the Thoothukudi district, Tamil Nadu, India. Both the places were regarded as two zones *viz.* Vembar and Tharuvaikulam zone. These zones are further sub-divided into three grids to understand and mark the erosion and deposition zones. The shorelines were digitized from satellite images of Landsat – 5 (1997) and Landsat – 8 (2018), and also the base details were extracted from a survey of India (SOI, 1968). These shorelines were taken to Geographic Information System for overlay analysis to determine the extent of erosion and accretion in the study area. The result of this study shows that during the period 1968–1997, Vembar and Tharuvaikulam zones have noticed accretion with a rate of 6.9 m<sup>2</sup>/y and 4.5 m<sup>2</sup>/y, respectively. Whereas, during the period 1997 – 2018, the Vembar zone was subjected to erosion with a rate of -1 m<sup>2</sup>/y. While in the Tharuvaikulam zone, the accretion process has reduced with a rate of 0.1 m<sup>2</sup>/y. The study results have shown that the Vembar zone has undergone erosion, whereas; the Tharuvaikulam zone has undergone both erosion and accretion. The accretion process rate is less compared to the erosion process during 1968 – 1997. The study concludes that the erosion is increasing due to natural and human intervention.

[**Keywords:** Accretion, Erosion, Growth rate, Natural and human intervention]

## Introduction

The shoreline management reduces the shoreline changes, but sometimes it also fails to arrest the changes in decadal to centennial scales<sup>1,2</sup>. It is also controlled by the climate change and its consequences on the coast<sup>3-5</sup>. Generally, the shoreline change study is carried out within 100 m of beach shore. It reveals a lot of changes in the coastal track with respect to timescale analysis<sup>6</sup>. The shoreline change analyses reveal a complicated relationship between the met-ocean compulsion, inherited geological characteristics, and geomorphological controls, as well as human intervention. Seashore change is considered to be the most dynamic activity in the coastal regions<sup>7-10</sup>. The International Geographical Data Committee recognizes the importance of coastal change monitoring<sup>11,12</sup>. Understanding and interpreting coastal processes in the coastal area are essential to describe and monitor coastal changes<sup>13</sup> properly. The coastal changes continue to expand in the coastal areas from decade to century<sup>1,2</sup>, caused by climate change and its effects on the coast<sup>3-5</sup>. The

spatio-temporal analysis of shoreline changes is essential to understand the driving factors of coastal changes. Therefore, the present study is carried out to study shoreline changes in the Vembar and Tharuvaikulam zone along the Thoothukudi district coast using remote sensing and GIS for the years 1968 – 1997 and 1997 – 2018.

## Materials and Methods

### Study area

The study was conducted on the northern part of the Thoothukudi coast. The shoreline of study area extends from Vembar to Vallapatti. It is approximately 43 km long along the Thoothukudi coast (Fig. 1). It lies between 08°56' and 09°04' N latitude and 78°10' and 78°20' E longitude. It is essential to segment the entire shoreline into several zones or grids to better understand the shoreline changes. It is done for effective spatial data modeling and analysis of shorelines. Kairu & Nyandwi<sup>14</sup> also state that an effective coastal classification is a fundamental precursor to any shoreline change study.

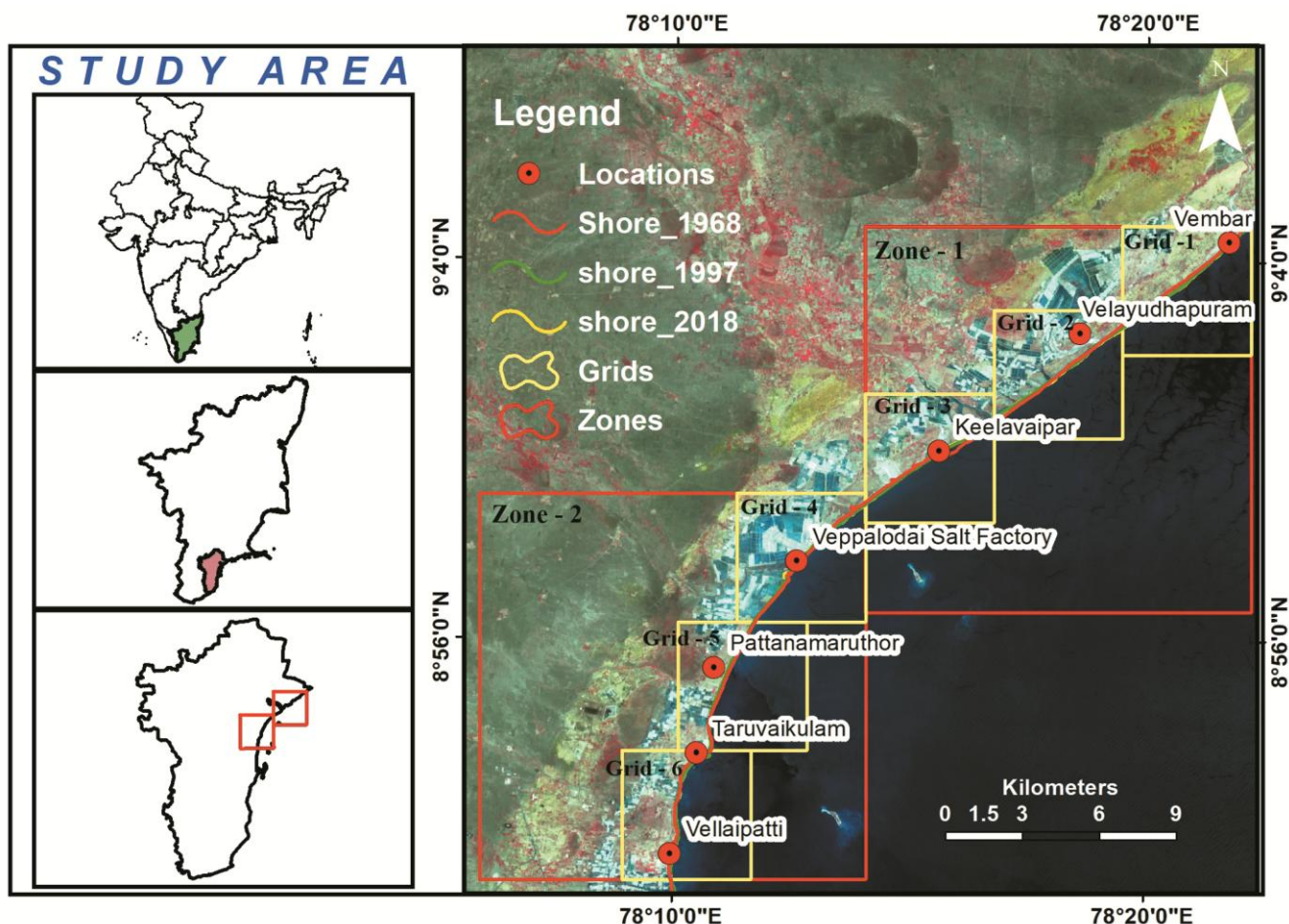


Fig. 1 — Study area

Therefore, the study area is divided into two coastal zones, *viz.* Vembar and Tharuvaikulam. Further, each zone has been sub-divided into six grids, namely grid 1 to 6, respectively. The area of each grid is about 25 km<sup>2</sup>. Headland, salt pans, and estuary were noticed in the Vembar and Tharuvaikulam coastal zones.

#### Methodology

In the present study, satellite images of Landsat 5 and Landsat 8 were used to extract the shorelines for the years 1997 and 2018 (Table 1). Moreover, Indian Topographical maps (SOI) were used to prepare the base map and extracted the shoreline for 1968. The images were geometrically corrected with UTM geographical projection. The Multi-date shorelines were digitized by using ArcGIS software. The digitized shorelines were overlaid and converted into line to the polygon, and thereafter the area of erosion and accretion were calculated for two long-term periods of each grid (one from 1968 to 1997 and another one from 1997 to 2018). Moreover, the net growth has calculated the difference

Table 1 — Data used for shoreline change study

Data	Sensor	Path/Row	Date of acquisition
Landsat 5	TM	143/54	05/28/1997
Landsat 8	OLI	143/54	04/04/2018

between the erosion and accretion during the years 1968 – 1997 and 1997 – 2018, respectively. Finally, the growth rate was determined by the two long-term periods of each grid.

## Results and Discussion

#### Shoreline change analysis

Seabed resuspension alters the environment affecting the benthos and water quality<sup>20-23</sup>. The shoreline change can erode the important marsh habitat and damage or destroy the human infrastructure<sup>19</sup>. The shoreline changes and its predictions study were carried out by Young<sup>17</sup> and also along the coast of India by Bhaskaran *et al.*<sup>18</sup>. Sheik<sup>24</sup> has reported that the Kanyakumari and Ovari coastal zones have experienced more erosion activities due to natural and

man-induced activities. He has also emphasized that the Tuticorin coast has noticed more accretion due to the Thambraparani River's presence, a significant sediment discharge system. Moreover, the Tiruchendur coastal zone also experienced more accretion during the period 1999–2006. During the south-west monsoon, the wave break is generally found in the northern direction. Whereas, during the north-east monsoon, the movement of wave break is normally in the southern direction<sup>24,25</sup>. NE monsoon is associated with variations in the sediment loads and discharge of river currents<sup>26</sup>. Therefore, the sediment drifts mostly towards the north from March to September and towards the south from October to February. The sediment drifts along the northerly direction are taken as positive values indicating accretion. At the same time, the drift along the southerly direction is taken as negative values indicating erosion<sup>24</sup>. Similarly, the Thoothukudi coast of Vembar and Tharuvaikulam zones are examined in this study using multi-time data of years 1968, 1997, and 2018. The study area shoreline length has been changing from year to year. The coastal length of the Vembar zone is decreased by -0.5 m from 1968 to 1997 (Table 2). Simultaneously, the coastal length of the Tharuvaikulam Zone is decreased by -2.5 m from 1968 to 1997. However, the coastline's length has increased by 0.1 m per zone from 1997 to 2018 (Fig. 2). These changes indicate either erosion or accretion.

Coastal regions	Length of the shoreline (km)			Length of the shoreline change (m)	
	1968	1997	2018	1968-1997	1997-2018
Vembar	18.9	18.3	18.4	-0.5	0.1
Tharuvaikulam	20.3	17.8	17.9	-2.5	0.1

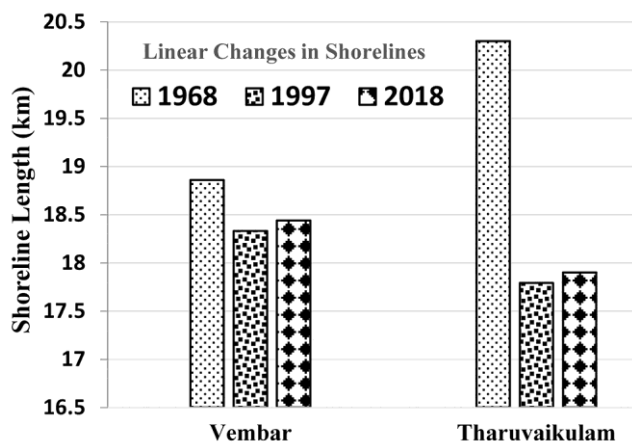


Fig. 2 — Length of shoreline changes

#### Vembar zone

The Vembar zone is covered with three grids (1, 2, 3) (Fig. 3A – C). During the period 1968 – 1997, the erosion was noticed in 0.7 km<sup>2</sup> area, and accretion was observed in 0.9 km<sup>2</sup> area. Its net growth rate is 0.2 km<sup>2</sup>. It indicates accretion process with a growth rate of 6.9 m<sup>2</sup>/year (Table 3). From grid-wise analyses, accretion was noticed in 0.6 km<sup>2</sup> area in the 1<sup>st</sup> grid, and no erosion was found in this grid (Fig. 4a). Vembar and Pachiyapuram areas are covered in this grid. In grids 2 and 3, erosion was dominated due to the natural and human activities and the presence of estuary, saltpan, and fishing harbours. In grid 2, erosion was observed in 0.3 km<sup>2</sup> area, and accretion was noticed in the 0.1 km<sup>2</sup> area. Its net growth is -0.2 km<sup>2</sup> (Table 3). It is indicated that the erosion process in this grid is with a growth rate of -6.9 m<sup>2</sup>/year. In grid 3, 0.4 km<sup>2</sup> area was noticed as erosion in the Keelavaipar estuary mouth, and accretion was noticed in 0.2 km<sup>2</sup> area. The net growth rate is -0.2 km<sup>2</sup>. It indicated that the erosion in this grid is with a growth rate of -6.9 m<sup>2</sup>/year (Fig. 5).

During the year 1997 – 2018, grid 1 has experienced erosion (0.1 km<sup>2</sup>) and accretion (0.1 km<sup>2</sup>). The Pachaiyapuram has noticed more accretion. Its net growth (0.02 km<sup>2</sup>) revealed that, erosion and accretion process is balanced in this grid with a growth rate of 0.7 m<sup>2</sup>/year (Fig. 5). In grid 2, accretion (0.1 km<sup>2</sup>) occupied more area, and erosion is covered in 0.02 km<sup>2</sup> area. Its net growth is 0.1 km<sup>2</sup> indicating accretion in this grid with a growth rate of 5.2 m<sup>2</sup>/year. In grid 3, erosion was observed more (0.2 km<sup>2</sup>), whereas; accretion was occupied in the minor area. It is 0.02 km<sup>2</sup> area (Fig. 4b). The minor accretion was noted along the Sippikulam coastal area (Fig. 6a). The grid 3 net growth is -0.2 km<sup>2</sup> (Table 4). It indicates erosion in this grid with a growth rate of -7.3 m<sup>2</sup>/year. Overall, the Vembar zone has shown an erosion process with a growth rate of -1 m/year during the years 1997 – 2018. The mouth of the Keelvaipar estuary and the south side of the Vembar estuary has noticed erosion due to both natural and human activities, including the jetties along the Vembar estuary (Fig. 6b). On each side of jetties, erosion was observed in the Vembar zone (Fig. 6b).

#### Tharuvaikulam zone

Tharuvaikulam zone covered three grids viz. 4 to 6 (Fig. 3D – E). Overall, the results revealed that the process of accretion dominated covering an area of 0.7 km<sup>2</sup>, whereas; erosion was covered by a 0.5 km<sup>2</sup>

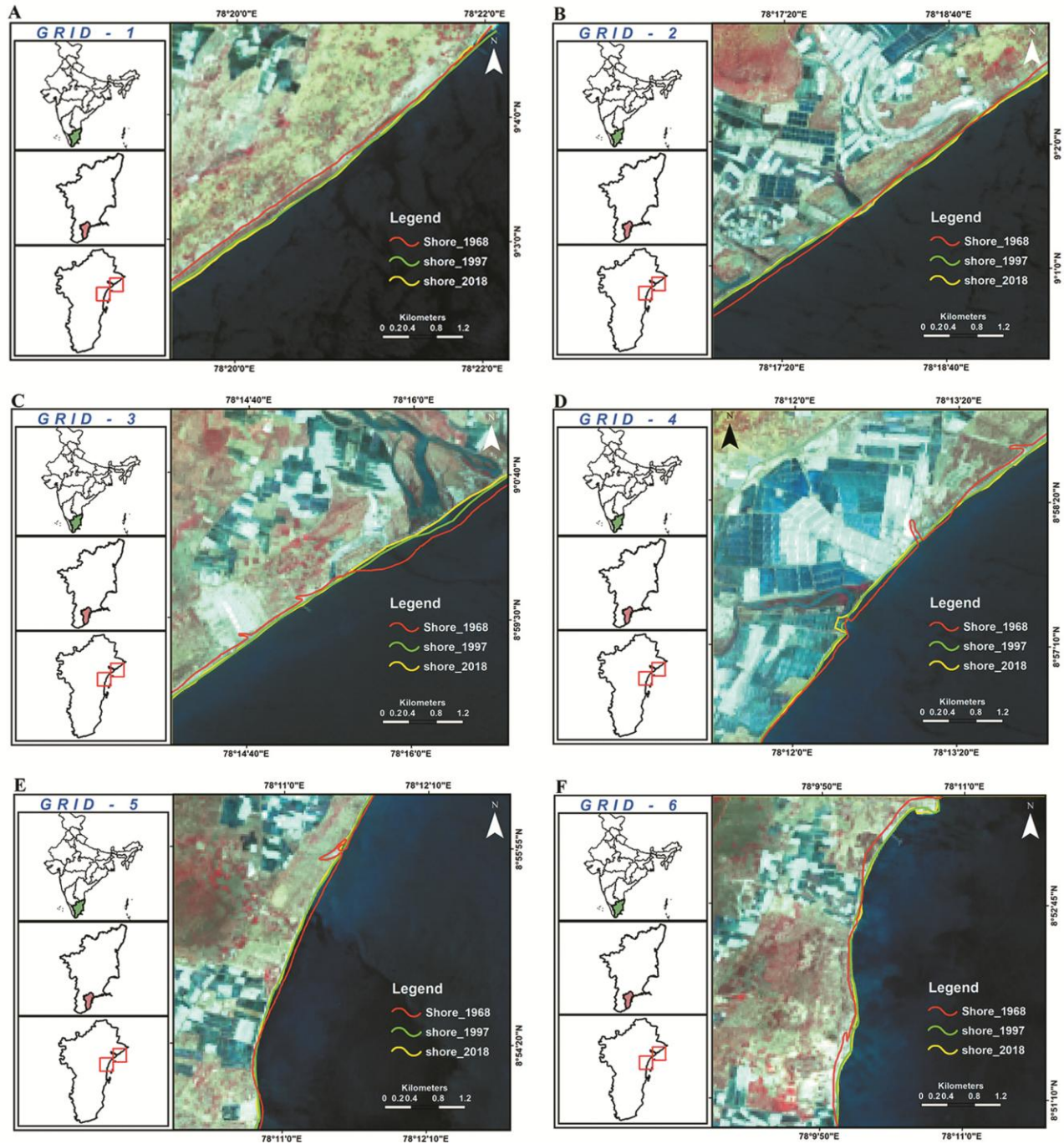


Fig. 3 — (A – F) Shoreline change analysis maps

Table 3 — Grid wise shoreline change analysis during 1968 – 1997

Coastal region	Grid No.	Erosion and accretion during 1968 – 1997							
		Erosion (km <sup>2</sup> )		Accretion (km <sup>2</sup> )		Net growth (km <sup>2</sup> )		Growth rate (m <sup>2</sup> /year)	
Vembar	1	-	-	0.6	-	0.6	-	20.7	-
	2	0.3	0.7	0.1	0.9	-0.2	0.2	-6.9	6.9
	3	0.4	-	0.2	-	-0.2	-	-6.9	-
	4	0.3	-	0.2	-	-0.1	-	-3.4	-
Tharuvaikulam	5	0.2	0.5	0.05	0.7	-0.2	0.1	-5.2	4.5
	6	0.02	-	0.4	-	0.4	-	13.1	-

area (Table 3). This net growth of 0.1 km<sup>2</sup> in this grid indicated accretion with the growth rate of 4.5 m<sup>2</sup>/year during the years 1968 – 1997. In the Tharuvaikulam zone (grid: D – E), headland, the fishing harbour, saltpan, and boat construction factories are found. In grid 4, erosion is more prominent (0.3 km<sup>2</sup>), and accretion is about 0.2 km<sup>2</sup> (Fig. 4a) with a net growth of -0.1 km<sup>2</sup>. It is indicated that the erosion process in this grid is with a growth rate of -3.4 m<sup>2</sup>/year. The erosion was perceived in the

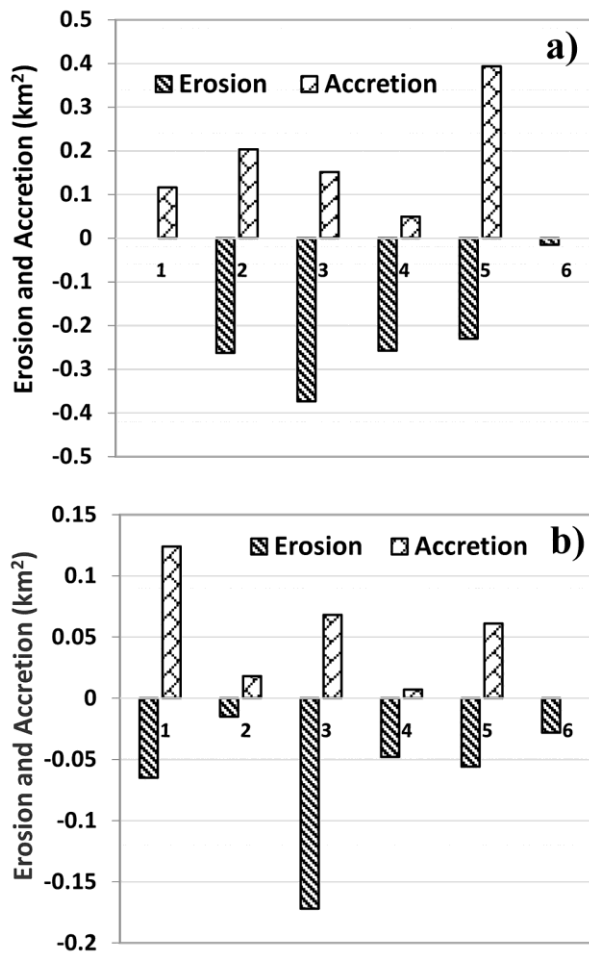


Fig. 4 — Shoreline change during the period a) 1968 – 1997, and b) 1997 – 2018

Veppalodai salt factory region. Grid 5 also exhibited more erosion (0.2 km<sup>2</sup>) and accretion of about 0.05 km<sup>2</sup> with a net growth of -0.2 km<sup>2</sup> and erosion with a growth rate of -5.2 m<sup>2</sup>/year (Fig. 5). But in grid 6, it experienced more accretion (0.4 km<sup>2</sup>) and a 0.02 km<sup>2</sup> area of erosion. Its net growth is 0.4 km<sup>2</sup> and indicating accretion with a growth rate of 13.1 m<sup>2</sup>/year during the years 1968 – 1997.

During 1997 – 2018, in grid 4, more accretion (0.1 km<sup>2</sup>) was observed, and the erosion (0.05 km<sup>2</sup>) was also apparent at the Veppalodai salt factory. In grid 5, Pattanamaruthor and the northern part of Tharuvaikulam headland has noticed more erosion (0.1 km<sup>2</sup>) compared to accretion (0.01 km<sup>2</sup> area; Table 4) with a net growth of erosion of -0.05 km<sup>2</sup> and with a growth rate of -2.3 m<sup>2</sup>/year (Fig. 4b). Similarly, in grid 6, more accretion (0.1 km<sup>2</sup>) and less erosion (0.03 km<sup>2</sup> area) have noticed. The Tharuvaikulam headland was noticed with erosion (Fig. 6c). This grid has shown a net growth of 0.03 km<sup>2</sup> and an accretion growth rate of 1.6 m<sup>2</sup>/year (Fig. 5). Overall, the Tharuvaikulam zone has experienced both accretion (0.1 km<sup>2</sup>) and erosion (0.1 km<sup>2</sup>). Its net growth indicated a balanced activity of erosion and accretion with a growth rate of 0.1 m<sup>2</sup>/year.

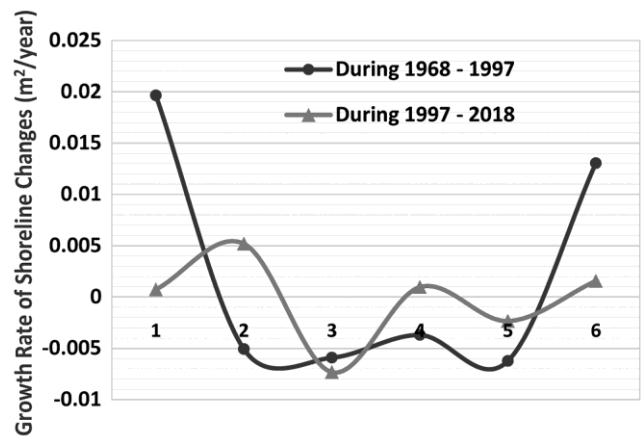


Fig. 5 — Growth rate of shoreline changes of Vembar and Tharuvaikulam zone

Table 4 — Grid wise shoreline change analysis during 1997 – 2018

Coastal region	Grid No.	Erosion and accretion during 1997 – 2018				Net growth (km <sup>2</sup> )	Growth rate (m <sup>2</sup> /year)		
		Erosion (km <sup>2</sup> )	Accretion (km <sup>2</sup> )	Erosion (km <sup>2</sup> )	Accretion (km <sup>2</sup> )				
Vembar	1	0.1	0.1	0.1	0.1	0.02	0.7		
	2	0.02	0.3	0.1	0.2	0.1	-0.03	-1	
	3	0.2	0.02	0.02	0.2	-0.2	-7.3		
Tharuvaikulam	4	0.05	0.1	0.1	0.1	0.02	1		
	5	0.1	0.1	0.01	0.1	-0.05	0.0	-2.3	0.1
	6	0.03	0.1	0.1	0.1	0.03	1.6		

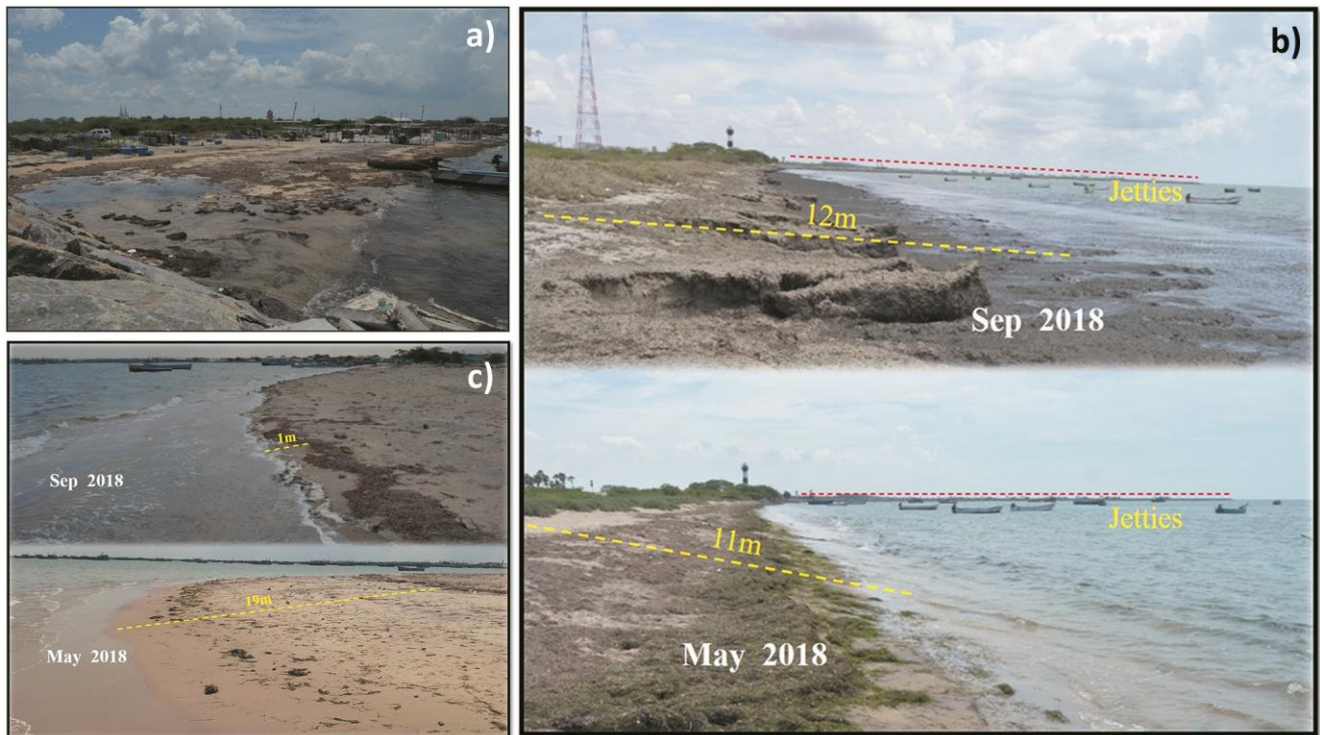


Fig. 6 — a) Accretion in Sippikulam; b) Erosion in Vembar and jetties constructed along the Vembar; and c) Erosion in Tharuvaikulam

### Conclusion

The shoreline change studies were carried out in the Vembar and Tharuvaikulam zones on the coastline of Thoothukudi district. The study concludes that both the zones have undergone accretion between the years 1968 and 1997. At the same time, both zones showed less amount of erosion in grids 2 – 5. Whereas, during the period 1997 – 2018, the Vembar zone was eroded and the Tharuvaikulam zone has experienced both erosion and accretion. However, in the Vembar zone, grids 1 and 2 showed minimal erosion. Overall results conclude that the Vembar zone has undergone erosion and the Tharuvaikulam zone has undergone erosion in some grids. Therefore, this study has recommended protecting erosional areas along the Vembar and Tharuvaikulam coastal zones.

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### Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Author Contributions

The first author collected data, analyzed and wrote the manuscript. The second author revised the manuscript.

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