

# INVESTIGATION OF COASTAL LANDFORMS ALONG THE SOUTHEAST COAST OF INDIA USING REMOTE SENSING AND GIS TECHNIQUES

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## Abstract

Coastal geomorphology map could help in various coastal zone management planning. Coastal geomorphology map of Gulf of Mannar from Dhanushkodi to Tuticorin was prepared using LISS-III satellite data and Survey of India (SOI) topographic sheets on 1: 50,000 scale and validated by ground truth. Various coastal landform units have been identified and delineated based on the remote sensing data. The coastal landforms in study region are grouped in to marine, fluvial-marine, fluvial, Aeolian and biogenic landforms. Most of the landform units such as spits, beach ridges, beaches, strand line, back swamp, mud flat etc. indicate that the coast is pro-grading towards the seaward side.

## Introduction

The coastal geomorphological maps portray the forms of the surface, the nature and processes of the surface materials and indicate the kind of magnitude of the processes involved. Coastal geomorphological mapping allows an improved understanding of coastal land use planning, harbor area management, coastal resource and coastal zone management etc. A detailed coastal geomorphological map is one of the principal means of studying morphology, genesis, distribution and age of forms, to interpret the geomorphic history of any evolved landscape. The synoptic coverage and high precision of remotely sensed data, coupled with marked coast-effectiveness and time efficiency of the data acquisition and analysis procedures have made satellite based coastal geo-morphological mapping an extremely effective tool for coastal management in the recent time.

About two thirds of the world's population lives within 60 km of the coastline. This proportion is increasing as people seek better standards of living and move away from inland and upland. As a result of increasing stress along the coastal area, anthropogenic impacts on coastal zone have become severe. Coastal resources like coral reef, seaweeds and sea grass and mangrove etc. have been degraded due to various developmental activities and population pressure. In the state of Tamil Nadu, between the year 1988 and 1998, 25.56km<sup>2</sup> of coral reefs and 2.16km<sup>2</sup> of seaweeds were lost in Gulf of Mannar (Thanikachalam and Ramachandran., 2002). Between the year 1986 and 1993, 0.36km<sup>2</sup> area of mangrove in Pichavaram was lost and nearly 2500km<sup>2</sup> of the mangrove were lost in entire India between 1986 and 1994 (Krishnamoorthy., 1995). Apart from the anthropogenic activities, natural causes also play an important role in coastal environment changes. In Gulf of Mannar coast, between the year

1969 and 1998, 4.34 km<sup>2</sup> and 23.49km<sup>2</sup> of mainland coast and 4.16km<sup>2</sup> and 3.31km<sup>2</sup> of island coast were eroded and accreted due to the combined action of anthropogenic and natural agents (Thanikachalam., 2000). In this present study, coastal landforms and coastal geomorphic classification of Gulf of Mannar coast has been attempted using remote sensing and GIS techniques.

## Study Area

The study area (Fig.1), Gulf of Mannar, extending from Tuticorin to Rameswaram Island in the SW-NE direction, lies between 78 ° 5' & 79 ° 30' E longitudes and 8 ° 47' & 9 ° 15' N latitudes, to a length of about 140 km. There are 21 islands, situated at an average distance of about 8 km from the coast and running almost parallel to the coastline. This area is endowed with a combination of ecosystems including mangroves, sea-grass, seaweeds and corals reefs. Different types of reef formations have also been observed in Gulf of Mannar viz. fringing reef, patch reef and coral pinnacles. The coast of Gulf of Mannar is mostly underling by Quaternary to Recent formation. The west of this coastal area is bound by heavy crystalline metamorphic rocks of Pre Cambrian and having breadth of 10-100 km (Ramasamy., 1997). Being a gradient coast it has developed well fabricated network of deltas, backwater, creeks, protruding deltas, estuaries, back swamps and coral reef etc.



Figure 1. Study area (Gulf of Mannar)

## Materials and Methods

Geocoded imagery of LISS-III May 2013 (Fig 2) and Survey of India (SOI) toposheets have been used in this study. Geocoded LISS – III imagery on 1:50,000 scale were visually interpreted based on image characteristics, and various

coastal geomorphic categories were identified and mapped along the coast of Gulf of Mannar. In the present study, an image interpretation key indicating tone/colour, size and pattern developed by Space Applications Center, Ahmedabad was used (SAC, 1991). The basic information like transport network, tanks, rivers etc., are transferred from SOI toposheet. After identification and delineation, an accuracy test was made for 118 sample points on SOI toposheet. The study area map was divided into grids and intersecting points of each grid within the study area were taken as sample points for validation of classified satellite data in ground truth checking. Over the ground, out of the 118 sample points, 105 points were found to be correctly interpreted giving an accuracy of about 90 per cent. The geo-referenced geomorphology map was digitized; edited, labeled and projected using ARC-GIS. Finally, a coastal geomorphology map was generated using intercept operation of ARC/VIEW. The area statistics of coastal geomorphology in the map were generated.

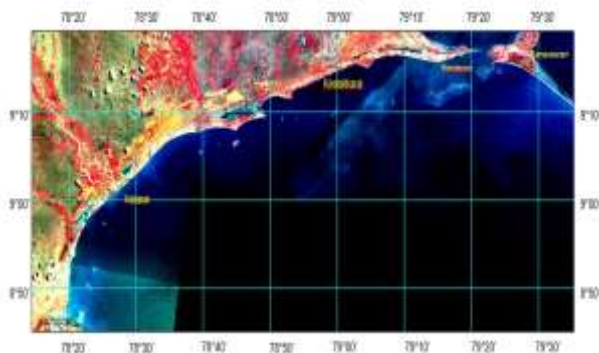


Figure 2. IRS LISS-III Imagery of Gulf of Mannar

## Result and Discussion

### Coastal Land form

The coastal plain between Dhanuskodi and Tuticorin has various geomorphic units with different types of configurations (Fig. 3). The geomorphic units, interpreted from remotely sensed data and checked subsequently through fieldwork, have been categorized into four genetic classes – marine, fluvio-marine, fluvial, aeolian and biogenic landforms.



Figure 3. Coastal geomorphology map of Gulf of Mannar derived from IRS LISS-III satellite data

### Marine Landforms

In the coastal zone various marine landform features such as beaches, spit, beach ridges, swales and backwater zone, mudflat, offshore islands, coral reefs, wave cut platform, sea cliff, sea cave, water logged land and strand lines have been identified.

Beaches are extensively developed along the entire coastline of Gulf of Mannar with an average width of 105.35 m. The shore between Tuticorin and south of Sippikulam (2.04 km<sup>2</sup>), Vaippar River and Gundar River (2.56 km<sup>2</sup>), Gundar River and Palar River, (2.64 km<sup>2</sup>), Palar River and Kottakkarai River (2.189 km<sup>2</sup>), Kottakkarai River and Marakkayarattanam (2.18 km<sup>2</sup>), southern coastal parts of the Rameswaram Island (2.91 km<sup>2</sup>) and the western part of the Rameswaram Island from Pamban to Peikkarumbu have important beach areas in Gulf of Mannar coast. All along the shore the beach is observed to be gently sloping and marked with altered crusts and troughs that are formed due to wave action.

Among the various depositional landform features the formation of spit is a significant feature of recent age. Normally the formation of spit has been attributed commonly to the movement and deposition of materials by long shore current. South of Tuticorin coastal area two spit formations have been observed with 0.75 to 2 km long and tongue shaped. It appears to have been built by the sediments brought by long shore current during southwest monsoon. As the Gulf of Mannar is on the lee of the northeast monsoon, there is no long-shore drift from the northeast that might be the cause for the inward curving of this spit (Ahmad, 1972). It can be explained that the Tuticorin spit might have been the result of the long shore currents during monsoon and the sediments discharged by Tamiraparani River. Geocoded LISS-III imagery taken in the year of 2013 has shown a well-developed spit near Valinokkam (Fig. 4a), but the toposheet of the year 1969 does not show any indication of spit. This spit maybe formed due to the long shore current from south west, probably under the influence of the south west monsoon. The southwestern shore of Rameswaram has a tongue shaped spit. SOI toposheet of the year 1969 does not show any spit but recent LISS-III imagery (2013) clearly shows the spit (Fig. 4b). It may be assumed that these spits are recently formed. It can be explained that the Rameswaram spit may have been the result of littoral current from Palk Bay to Gulf of Mannar during northeast monsoon period.

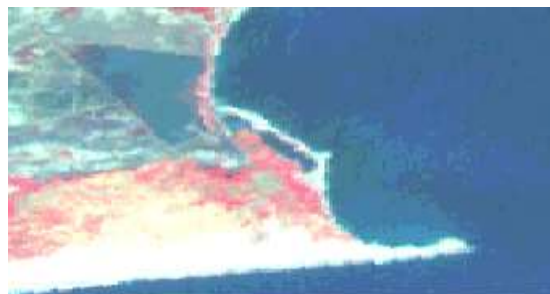
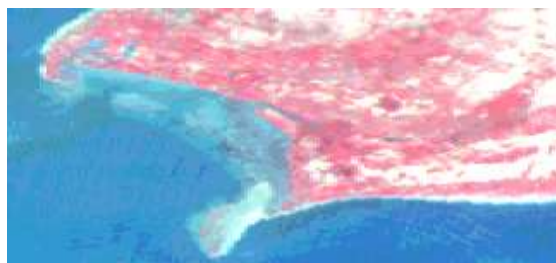


Figure 4.a Spit near Valinokkam



**Figure.4.b Spit at south west of Rameswaram Island**

Beach ridges are moderately undulating terrain features of marine depositional type, formed during Pleistocene to Recent age. They are low, essentially continuous beach or beach dune materials (sand, gravel and shingle) happed up by the action of wave and currents on the backshore of a beach beyond the present limit of storm waves or the reach of ordinary tides, and occurring as a single or as one of a series of approximately parallel deposits (Loveson and Rajamanickam., 1987). According to Short et al. (1989) beach ridges are linear sandy–Shelly swash deposits with intervening sandy plain, occurring parallel or sub parallel to the shoreline formed by periodic wave impounding action (Short. et.al, 1989). Well-developed twelve beach ridges are seen between Mandapam and East of Vaippar River. Almost all beach ridges in this area are parallel to each other, and cover an area of 155.49 km<sup>2</sup> and trend from east to west and northeast to southwest direction. On the basis of the nature and dispositions of beach ridges, it can be grouped into (i) Beach ridges south of Vaigai River, (ii) Beach ridges between Kotangudi River and Palar River, (iii) Beach ridges between Palar River and Gundar River, (iv) Beach ridges between Gundar River and Vaippar River and (v) Beach ridges south of Vaippar River. These ridges are clearly indicating the emerging of coastal land in Gulf of Mannar area. Swales and backwater zones are seen between Mandapam and Kottakkarai River. These are branched and arranged in series of linear patterns and situated almost parallel to the present coastline. Prominent backwater zones have been observed in the coastal plains between Valinockkam and Vaippar River, Mandapam and Southeast of Tiryppullani. The coastal areas between Mandapam and Tinaikkulam, Valinokkam and Krishnapuram and North of Terku Mukkaiyur and Tukurankulam consist of prominent and wide backwater zones. These three backwater zones are connected by small, linear and narrow swales to the sea by means of few creeks, which supply water from sea to backwater channels during high tide. The basin bed is composed of silt and mud. The adjacent low lying area, as a part of swale zone is used at present for salt production.

Mudflat is a flat area containing a fluid to plastic mixture of finely derived particles of solid material mainly silt and clay water. They are always associated with silted environments like lagoons, estuaries and other embankments. Mudflats are formed by the deposition of fine inorganic material and organic debris in particulate form. Mud flats are wide expanse of deposit of clay, silt, ooze, etc. It ends in oscillation

of a mass of mud near mouths of estuaries and lagoons. Repetition of these processes causes the development of mud flats. The mudflats are very common in Vaippar River mouth, around Valinokkam backwater lagoon, Kallar River mouth and Gundar River mouth. The area covered by mudflat has been estimated to be 14.50 km<sup>2</sup>.

A chain of 21 low islands have been observed along the offshore region of Gulf of Mannar. They extends from south of Rameswaram to Tuticorin. All islands are made up of a calcareous framework of dead reef and sand. They have a low and narrow sandy coast and some of them have rocky coast. Around all offshore islands, well-developed coral reefs (Fig.5) have been noticed. Geomorphologically, coral reefs in this area are of fringing type, though some patchy corals are also observed in between Appa Island and Pilliyarmuni Island, and in some areas like Bharathi nagar coast and southeast coast of Kariya Shuli Island.



**Figure.5. Coral reefs near Kurusadai Island**

Along the rocky beaches, frequent wave cut platforms are observed. These features indicate marine erosional formative processes and represent flat to moderately undulating platform, predominantly made up of beach rocks and sometimes-calcareous rocks. Wave cut platforms have been observed along the coast of Mandapam, Ramaswami Madam, Pudumatam, Valinokkam etc. At Pudumatam coast, hard and tough sandstone platform occupies the in-tertidal zone (Fig. 6).



**Figure.6. Wave-cut platform at south of Mandapam coast**

Along the coast of Gulf of Mannar, sea cliffs have been observed in Mandapam, Rameswaram, Pudumatam and Appa Island coastal areas. Generally the sea cliff and caves are made up of calcareous sandstone and located at the high

water level. Due to intensive action of waves on cliffs at some places sea caves are formed. Such cases have been observed near Mandapam coastal area and Southwestern and Southern coastal areas of Appa Island (Fig. 7). At some places, these features have been destroyed due to slumping of upper cliff materials.



**Figure.7. Sea cave and cliffs at north of Appa Island**

Water logged land is the area where the water is at or near the surface and has been stagnant for most part of the year. Such lands usually occupy low-lying areas. In the study area around the northern part of Rameswaram Island some water-logged lands have been observed. In the areas like Pillaikulam, Surantidal and Mangaud, this type of features have been observed. The total water logged land in the study area has been calculated as 5.96 km<sup>2</sup>.

All along the coast strandlines are so common especially in between Tiruppullani to Mandapam, eight series of strandlines in curvilinear form have been observed. The general trend of the strandline is in the east to west direction. In the south of Rameswaram area also, curvilinear strandlines have been observed.

## Fluvio-Marine Landforms

Deltaic plains are very common landform along the coast of Gulf of Mannar, which is predominantly controlled by Fluvio-Marine processes. These deltaic plain are considered to be of Pleistocene to Recent age (Loveson. 1993). The areas around the river courses of Vaippar, Gundar, Palar and Kottakkarai Rivers, had vast deltas, but at present they are found to be inactive. The deltaic plains are marked by flat and vast areas, having vegetation cover. Number of tanks has been noticed on the deltaic plains. The total area has been estimated to be about 221.69 km<sup>2</sup>.

## Fluvial Landforms

In the coastal zone of Gulf of Mannar various fluvial landform features such as floodplains, natural levees and Flood basin have been identified. Well-established rivers usually have their floors covered with alluvium, in which the normal flow channel is covered. The surface of low relief on the alluvium from the banks of the low-water channel to the base of the valley walls is called the flood plain of a river. Flood plain and their major morphologic subdivisions are primarily deposited landforms. Floodplains have been very clearly observed along the riverbanks of Kallar, Vaippar and Gundar Rivers in study region. These flood plains are inac-

tive, which is covered with thick vegetation. The total estimated area of flood plain in study region is 24.43 km<sup>2</sup>.

Land forms in deltaic regions include natural levees bordering river channel and backed by lowering of the swamp or flooded depression in the lower parts of the river valleys (Bird., 1984). The over bank deposits are located more or less parallel to the riverbank. Generally, the levees are mainly seen adjoining the meandering course of the rivers. A natural levee has been observed in the Gundar River basin. The width of these levees encountered ranges from 2 to 3 km. and covers an area of 1.10 km<sup>2</sup>.

Flood basin occupying the shallow reaches of the flood plain consists of mostly gray and brown sandy, silty-clay and clay. Kottakkarai River surface has a flood basin with an area of 26.83 km<sup>2</sup>.

## Aeolian Landforms

Sand dunes and Teri dunes are the most common Aeolian land forms in the coastal zone of Gulf of Mannar area. Almost entire coastal plains in the study area are covered by sand dune (Fig.8).

The area in between swale system and shoreline is marked by dune complex. The area covered by dune complex has been estimated to be about 469.10 km<sup>2</sup>. However, extensive spread is observed around Rameswaram Island, Mandapam, Mangudi, Bharathinagar, Valinokkam, Thunamariyur, Terku Nerippaiyur, Tuticorin, Taruvaikkulam and Sippikkulam. In other places the areal spread is less. Aeolian process is dominating in this zone and its migrating dunes are seen in Tuticorin coast. Thruvaikkulam and the other above-mentioned areas also exhibit features similar to those in Tuticorin area. In the coastal plains between south of Vaippar River and Tuticorin near Maravanmadam seven patches of teri dunes have been observed with a thick cover of vegetation. North of Panaiyur, oval shaped teri dunes with sparse vegetation have been observed. The areal extent of this dune has been calculated to be 6.27 km<sup>2</sup>. Another two teri dunes have been observed near Kumarapuram. They cover an area of 2.67 km<sup>2</sup>. Near Pandiyapuram, rounded dune complex has been observed with thick vegetation. The area of this dune has been estimated as 4.27 km<sup>2</sup>. Near Milavittam small rounded patches of teri dune complex covering an area of 2 km<sup>2</sup> has been observed. Two other teri dune complexes have been observed near Maravanmatam area with thick vegetation. They cover an area of 3.08 km<sup>2</sup>. All teri dune complexes in this area are trending in the northeast to southeast direction.



**Figure.8. Sand dunes at south of Rameswaram Island**

## Biogenic Landform

Back swamp is very common biogenic landform along the coast of Gulf of Mannar. It occurs in marshy areas along the coast; they particularly occur at the edge of the tropical or sub-tropical seas, in bays lagoons and estuarine regions (Gerlech., 1973). Small back swamp areas have been observed in the areas near the mouth of Korampallam odai around Tuticorin coast (Fig.9) and west of Rameswaram Island. They cover a total area of 1.87 km<sup>2</sup>. These swamps are covered by mangrove vegetation.



**Figure.9. Back swamp and mangrove vegetation in the mouth of Korampallam odai near Tuticorin**

## Conclusion

Interpretation of LISS-III imagery aids in demarcating various coastal geomorphologic features like beach, spit, beach ridges, swales, mudflat, back swamp, dune complex, teri sand, natural levee, flood plain, deltaic plain, flood plain, strandline, etc. All the coastal geomorphologic features, in particular, spit, beach ridges, strandlines, swales and back-water system, back swamp, mud flat etc. indicate that the Gulf of Mannar coast is getting emerging.. In addition, Geographical Information System is found to be a useful tool for mapping geomorphology and calculation of areal extent of various geomorphologic features.

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