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TEMPORAL COASTAL CHANGES ALONG RAMESWARAM COAST, TAMIL NADU

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Abstract

The coastal ecosystems are under pressure on account of increased anthropogenic activity on the coast, as a result of globalization. It is necessary to protect these coastal ecosystems to ensure sustainable development. This requires information on habitats, coastal processes and natural hazards on a repetitive basis. The modern scientific tools of remote sensing, GIS and GPS are extremely valuable in coastal environmental studies. Multi-date satellite data, Survey of India Topographic map, Naval Hydrographic Chart and convectional bathymetry survey have been used to generate the coastal ecosystem, coastal land use and land cover, shoreline and bathymetry maps. The analysis of multi-date coral reef maps showed that 5.256km² of reef area and 7.951km² reef vegetation in Rameswaram coast have been lost over a period of ten years (1988-1998). The changes in coastal land use/land cover indicate that the major changes occurred in mangrove, crop land, fallow land, agriculture plantation, forest plantation, scrub land, sandy area and tanks. The analysis of multi-date shoreline maps (1969-1998) showed that 2.065km² and 1.436 km² of the mainland coast and 0.545km² and 0.887km² areas of island coast have been eroded and accreted in Rameswaram coast. The analysis of multi-date bathymetry data (1975-1999) indicates that, the depth of seafloor have decreased along the coast and around the islands. The coastal ecosystem particularly coral reef ecosystem is very severely affected by anthropogenic and natural factors. The validation by ground truth has also confirmed these results.

Introduction

Coastal environment play a vital role in nation's economy by virtue of their resources, productive habitats and rich biodiversity. India has a coastline of 7,516 km and nearly 250 million people live within a distance of 50 km from the coast. The coastal zone is endowed with a variety of coastal ecosystems like mangroves, coral reefs, lagoons, sea grass, salt marsh, estuary etc. Coastal ecosystems are important for millions of people around the world as they provide subsistence. The coastal ecosystems are now highly disturbed and threatened due to rapid increase of population and developmental activities along the coast. In the state of Tamil Nadu, between the year 1988 and 1998, 25.56 km² of coral reefs and 2.16 km² of seaweeds were lost in Gulf of Mannar [10 and 11]. Between the year 1986 and 1993, 0.36 km² area of mangrove in Pichavaram was lost and nearly 2500km² of the mangrove were lost in entire India between 1986 and 1994[4]. Apart from the anthropogenic activities, natural causes are also play an important role in coastal environment changes. In Gulf of Mannar coast, between the year 1969 and 1998, 4.34 and 23.49 km² of mainland coast and 4.16 and 3.31km² of island coast were eroded and accreted due to the combined action of anthropogenic and natural agents [11]. Current approaches to the monitoring and management of coastal ecosystem are not capable for sustainable development. Remote sensing has been widely proven to be essential in monitoring and mapping highly threatened coastal ecosystems [1–6]. Availability of repetitive, synoptic and multi-spectral data from various satellite platforms, have helped to generate information on varied aspects of the coastal and marine environment [5]. The present study has been attempted to deduct the coastal changes along the Rameswaram coast using remote sensing and GIS techniques.

Study Area

The coast of Rameswaram (Figure 1) is the part of Gulf of Mannar Biosphere Reserve, is situated in between the latitude of 9º11'00''N and 9º 19' 16''N and the longitude of 79º 10'23''E and 79º 24' 00''E. The coast of Rameswaram encompasses 7 small islands located an average distance of 4km away from the mainland. These islands are built up of calcareous framework of dead corals and coral reefs. The area is endowed with a combination of ecosystem including mangroves, coral reefs, sea grass and seaweeds.

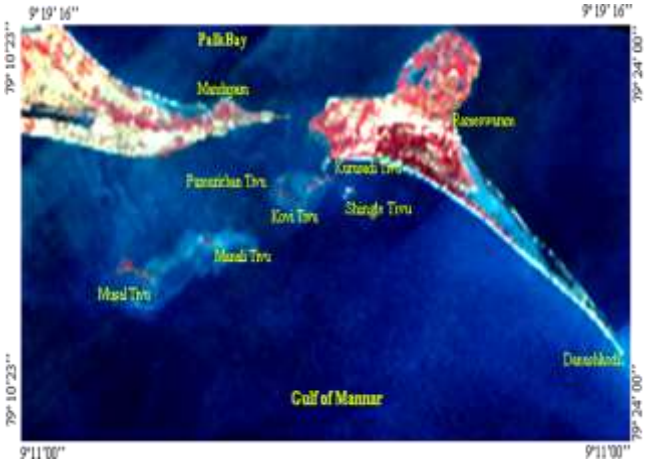

Figure 1: IRS LISS-III Image of Rameswaram Coast

Materials and Method

To fulfill the objectives of this study, the following approaches have been attempted:
(i) Interpretation of multi-date optical remote sensing data for detection and mapping of changes in coral reefs ecosystem, (ii) Interpretation of multi-date remotely sensing data for mapping and change detection in Coastal Land-use/Land cover, (iii) Interpretation of multi-date remote sensing data for mapping and changes in shore line and (iv) Analysis of the multi-date bathymetry data for sea floor changes.

Coral Reef Mapping

Geocoded False Color Composite (FCC) of IRS LISS-2 (April1988) and IRS LISS-3 (May 1998) images on 1:50,000 scale were visually interpreted based on image characteristics, various coral reef categories in the Rameswaram coast have been identified and mapped. In the present study, the classification system developed by Space Application Center (SAC) for the national coral reef mapping project [2] has been adopted. After identification and delineation, an accuracy test based on probability of success/failure of occurrence [6] was made for sample points. The study area map on 1:50,000 scale 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 120 sample points, 116 points have been found to be correctly interpreted and thus giving an accuracy of about 96.6 percent. The geo-referenced coral reef maps were digitized, edited, assigned corresponding labels and projected using GIS. Finally a coral reef map was generated using intercept statistics of coral reef classes in the maps.

Coastal Land use/Land and cover Mapping

Geocoded multi-date (IRS LISS-2 of April 1988 and IRS LISS – III of May 1998) FCC on 1:50,000 scale were visually interpreted based on image characteristics, and various land use / land cover categories were identified and mapped around Rameswaram coast. The basic information like transport network, tanks, rivers etc., are transferred from Survey of India (SOI) topographic sheet. After identification and delineation, an accuracy test was made for 150 sample points on SOI topographic sheet. The study area map at 1:50, 000 scale 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 150 sample points, 144 points were found to be correctly interpreted gave an accuracy of about 96 percent. The geo-referenced multi-date land use maps of 1988 and 1998 were digitized in ARC/INFO and were overlaid using TIC coordinates of the study area. Digitized maps were edited and labeled assigned to the polygons. Finally a temporal land use/ land cover change map was generated using intercept operation of ARC/VIEW.

Shoreline Change Mapping

Geocoded FCC of IRS LISS –3 (May 1998) satellite data on 1:50,000 scale belonging to low tide period and Survey of India Topographic map (SOI 1969) on 1: 50000 scale were used to prepare shore line change map. The low tide line (as shore line) from LISS-II and LISS-III satellite image were extracted and mapped on 1: 50,000 scale by visual techniques. After identification and delineation, coastal villages, some monuments, lighthouse etc., were selected as sample points on SOI topographic sheet for ground truth checking. During the time of ground truth study the entire coast was checked with local people and some necessary corrections were carried out on primary shoreline map. The geo referenced multi date shoreline maps were carefully digitized in ARC/INFO and were overlaid using TIC coordinates of the study area. Digitized maps were edited and labels assigned to the polygons. Finally a temporal shoreline change map was generated using intercept operation of ARC/VIEW, and summary statistic was generated for erosion and accretion areas using STATISTIC program of ARC/INFO. The changes were estimated for a period of 29 years between 1969 and 1998.

Bathymetry Mapping

Bathymetry map of study area on 1: 50,000 scale was prepared manually using 1975 Naval Hydrographic Chart. The prepared bathymetry map was digitized into GIS and a digital bathymetry map was prepared. The prepared bathymetry map was updated during fieldwork, which was carried out during April 1999. The depth of the sea bottom was measured (within 10m depth) using single beam echo sounder and Global Position System (GPS) along the Rameswaram coastal region. The depth values are recorded at a particular location with reference to chart datum (1975). The measured depths values were tide corrected with respect to time and then converted with respect chart datum (0.2m accuracy). Measured tide table from the Tuticorin port was used for final data conversion to chart datum.

Results and Discussion

Changes in Coral Reefs

Coral reefs are considered as one of the most important critical resources for various ecological, environmental and socio-economic reasons. Coral ecosystem face many threats, of which some are natural like storms and waves particularly tropical storms and cyclones that cause major damage to reefs. The majority of damage to coral reefs around the world has been through direct anthropogenic

stress [3]. In Rameswaram coast, there are 7 low sandy islands, fringing reefs along the windward side of the islands protects the island from direct wave action. Morphology of these islands is very dynamic. Thanikachalam and Ramachandran [11] carried out extensive work on islands of Gulf of Mannar, and concluded that the Tuticorin group of islands are migrating towards landward side (13.21m/year), whereas Vembar, Keelakkarai and Mandapam group of islands are migrating towards seaward side (3.18, 32.9 and 74.88cm/year). This is caused due to natural as well as anthropogenic factors. As a result of above, coral reef degradation is very severe in Gulf of Mannar. Thanikachalam and Ramachandran [11 and 12] estimated that 25.52km² area of coral reef was lost over a period of ten years (1988-1998). The coral reefs of Tuticorin group of Islands in Gulf of Mannar have been damaged due to the basting and dredging activities result in high sedimentation on the coral reef, discharge of effluents from petrochemical industries along the coast and fly ash discharges from thermal plants (Ramanujam and Mukesh[7]; Thanikachalam and Ramachandran [11].

The total coral reef area in Rameswaram coast based on the present study (1998) is about 29.60 km² and reef vegetation covers 1.944 km². The analysis of multi-date satellite data indicates that nearly 5.256 km² area of coral reef was lost over a period of ten years between 1988 and1998 (Figure 2 and 3). Through remote sensing the demarcation and estimation of the extent of dead and live coral is not possible. However, during the time of ground truth it was identified and estimated that nearly 67.2% of the corals were dead corals, 19% of coral reefs are directly removed by coral mining and the remaining 13% are the live corals.

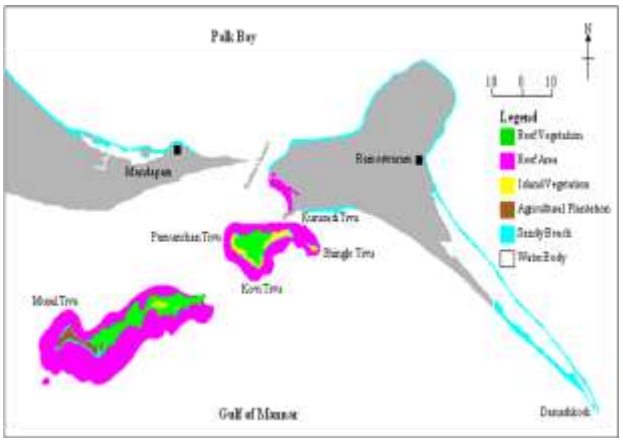

Figure 2: Coral reef maps of Rameswaram during 1988

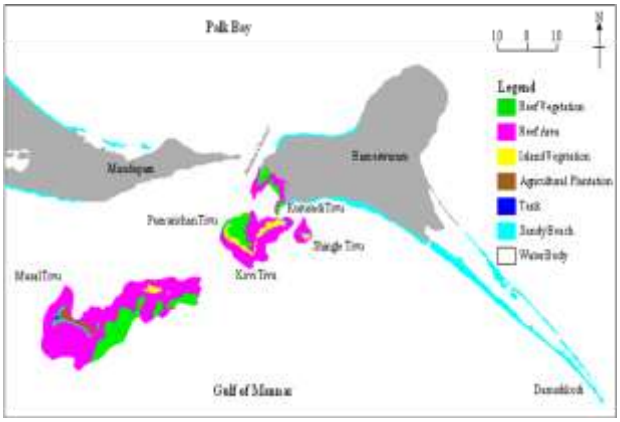

Figure 3: Coral reef maps of Rameswaram during 2000

Changes in Land use and Land cover

Multi temporal satellite data used in the present study enabled to observing the land use and land cover changes in the study area from 1988 to 1998 (Figure 4 and 5). Over the past ten years, areas of some land use classes have increased, areas of some classes have decreased and some categories have changed in to another category in the study area. These changes have taken place due to the increase in population in towns and villages along the coast and various other developmental activities. The major land use/land cover changes have occurred in the following classes: (1) the settlements has increased from 22.07 km² (1.66%) to 34.93 km² (2.62%), (2) the cropland area has decreased from 22.205 km² (40.62%) to 13.413 km² (31.43%), (3) agricultural plantation has reduced from 64.211 km² (13.96%) to 33.916 km² (14.49%), (4) there is no forest plantation in 1988, in 1998 it newly covered an area of 17.841 km²(10.9%), (5) the waste land has reduced from 2.0134 (1.49%) to 1.185 km² (0.5%), (6) the waterlogged land has increased from 3.624 km² (0.27%) to 7.07 km² (0.53%), (7) the scrubland has increased from 1.011 km² to 1.110 km², (8) the sandy area has decreased from 16.546 km² to 14.750 km² and (9) the tanks has increased from 0.616 km² to 1.305 km².

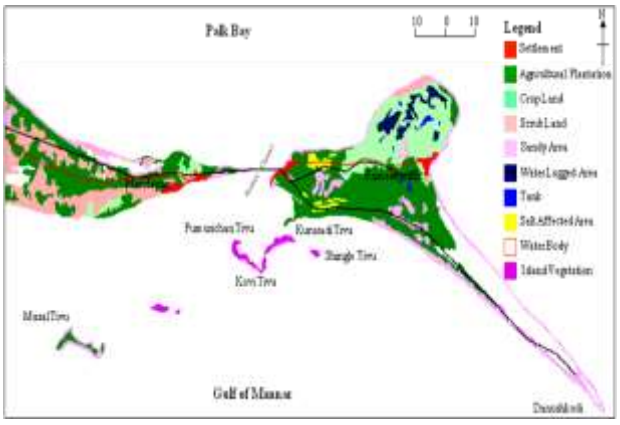

Figure 4: Coastal Land use/ Land cover maps of Rameswaram 1988

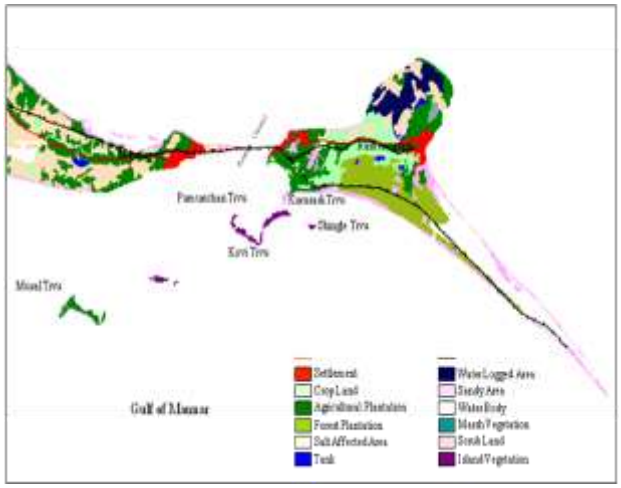

Figure 5: Coastal Land use/ Land cover maps of Rameswaram coast 2000

Coastal Erosion and Accretion

Along the Shore of Rameswaram Island both accretional and erosional features were observed (Figure 6). The areas of erosion and accretion along the coast were approximately 2.06 km², and 1.436 km², respectively, over a period of 29 years (1969 to1998). The rates of erosion and accretion have been estimated from the shoreline map of 1969 and 1998 are 6.23m and 6.54m/year.

West and Northwest coasts of Rameswaram have erosional features like small cliffs. The length and width of this coast are approximately 3.50 km and 196.83m respectively. Southwest and south of Pamban, accretion features like beach and spit have been observed. The width of accretion is 219.45 m and the area is 0.814 sq.km. The eastern part of Rameswaram and southern coast up to Dhanushkodi are erosional shores. The length and width of erosion are 11.48 km and 177.24 m respectively. The total area of erosion is 1.35km², Northern coast of Rameswaram Island from Dhanuskodi to north of Karaiyur, coast of North Pisasu Muna, and coast from Paikarumbu to North of Akkalmatam are accretional shores. The shores of North and Northeast of Rameswaram and Northwest of Aryankadu are erosional shores.

There are 4 islands between Mandapam and Rameswaram. These islands are sedimentary landforms. Fringing reef along the windward side of the islands protects the islands from direct wave action. Morphology of sandy islands is very dynamic. The morphological variations of islands occur due to natural and anthropogenic agents. The natural agents include erosion, accretion, wave, current, sea level variation etc. Anthropogenic impacts are construction of breakwaters, discharging of effluents, mining of coral reef etc.,

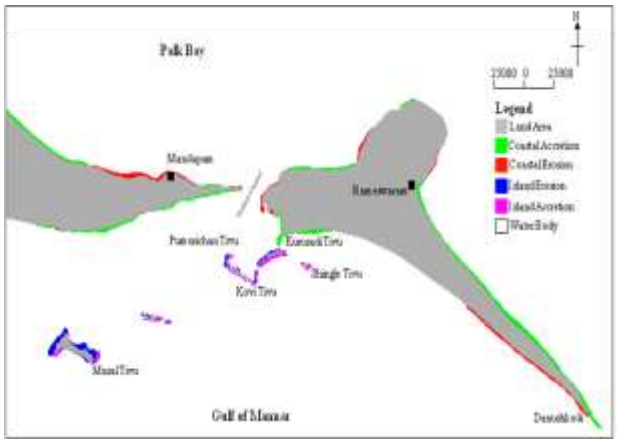

Figure 6: Shore line erosion and accretion map of Rameswaram shore

Table 1: Changes in Size of Rameswaram Group of Islands during 1969 and 1998

Name of the Island	Area in km²		Change km²
	1969	1998	
Pumurichan	0.197	0.181	-0.016
Kovai	0.485	0.562	+0.077
Kurusadai	0.563	0.740	+0. 177
Shingle	0.107	0.191	+0. 084

The comparison of 1998 map with 1969 map of islands of Rameswaram shows changes in their shape and size (Tables 1 and Figure 7) and these have been caused by erosion and accretion. The total areas of erosion and accretion were calculated as0.545 km² and 0.887 km² respectively for last 29 year period (1969 to 1998).

Island erosion and accretion are caused mainly by the action of wave and wave-induced current and long shore current along the shores of islands. In the study region the waves are in the northeast and southwest direction and wind direction is similar to that of wave direction. Based on the present study the islands in the study area are seen to move towards south (seaward side). The island erosion has been mostly identified along the northern side of the islands (landward side). Evidences of sharp edged coasts are found along the northern shores of these islands (Figures 7). This is because the long shore current and tidal current flow towards south, along the northern shore of islands, then erode the coast, this eroded materials are transported and deposited on seaward side of the coast.

While high velocity waves are moving towards northern shores of islands with the littoral sediments and

coming across the coral reefs, these sediments will be dropped on the coral reefs, wave speed reduces and turn into a wave-induced current. By repeated action of such processes the area between Islands and reef edge get shallow and reefs have submerged. Evidence of submerged reefs is identified along south east of Kursadai Island.

The Pumurichan Island is located 3.70 Km from the coast of Thoniturai. The eastern side of this island has been observed as an accretional shore, while the western shore is an erosional shore. The areas of erosion and accretion along the coast of islands are 0.138 km², and 0.123 km² respectively. The estimated widths of erosion and accretion are 158.04 m and 194.43 m. The areal extents of this island during 1969 and1998 were estimated as 0.197km² and 0.181 km² respectively.

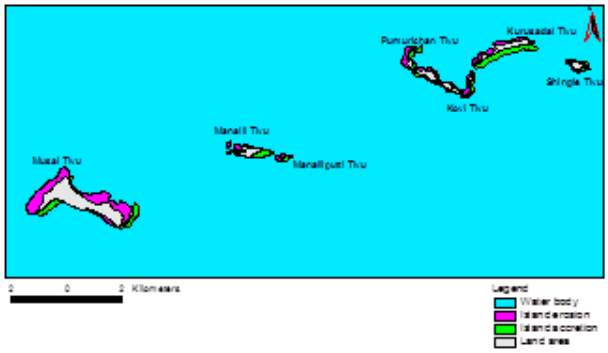

Figure 7. Island Erosion and Accretion in Rameswaram Group of Island (1969 to 1998)

Figure 8. Eroded Coast observed at north of Musal Tivu.

The Kovai Island is situated 4.73 km from Thoniturai. Northern shore of this island is an erosional shore; whereas the southern and eastern coasts are accretional shores. The area of erosion and accretion are 0.165km² and 0.243 km² respectively. The estimated widths of erosion and accretion are 139.92m and 113.83m. The total area of this island is approximately 0.485 km², and 0.562 km², as calculated from the 1969 and 1998 shoreline map of this island.

The Kursadai Island is situated 1.12 km from Kundhugal. The northern shore of this island has been observed to be an erosional shore, while southern side is an accretional shore. The areas of erosion and accretion sites along the northern and southern coast of this island are 0.221 km² and 0.416 km². The estimated widths of erosion and accretion are 123.14m and 207.88m. The total areal extent of this island was calculated as 0.563 km² and 0.740 km² during 1969 and 1998.

The Shingle Island is situated 1.87 km from Kundugal. Northwest, north, east and southern parts of this island are accretional shores, while northern and southwestern coasts are of erosional nature. The estimated widths of erosion and accretion are 72.62m and 137.11m.The areas of erosion and accretion of this island were calculated as 0.021 km² and 0.105 km².

Seafloor Changes

Recent depth contour map (1999) has been compared with bathymetry map of 1975; it reflects that the seafloor level decreased along the coastal and around the islands in the study area. It may be due to sediment deposit and emerging of land or lowering of sea level (due to tectonism). In very few places particularly at river mouths and in island areas, the sea floor level has increased, which may be due to erosion caused by anthropogenic activities.

The average depth reduction of seafloor along the coast of the study area has been estimated as 0.51m over a period of 24 years. The average decrease and increase of depth around the islands in the study area have been calculated as 0.56m and 0.38m respectively. Assuming that the rate of change of depth of sea floor is uniform over a year, the rate of decrease of depth is estimated as 0.021m/year along the coast and 0.023 m/year around the island, and also the rate of increase of depth as 0.015 m/year around the island. Basanta Kumar Jena[15] estimated the annual sediment deposit on Gulf of Mannar sea floor as 0.001m/year, so it will become 0.024m for a period of 24 years. As found from the present study, the decrease of depth for the period of 24 years (1975 to 1999) is 0.51m. Out of this 0.51 m of decrease of depth, sedimentation will account for about 0.024m. The remaining 0.486 m reduction in depth may be due to emerging of land or lowering of sea level (by tectonic activities). From this, the rate of emerging of land or lowering of sea level can be estimated as 0.02m/year.

In the coast between Pudumadam and Thoniturai, the sea floor is almost plain having a depth of 2 to 3m. This plain extends 6.95km from the coast. Near Senniappa Dargah and Thoniturai this plain is encountered at 2m depth and it extends to an average distance of 2.17km from the coast of Senniappa Dargah and 0.50km from Thoniturai coast. Along this plain some low elevated continental rise (79°5’19’’E-

9°12’14’’N) and chain of islands have been observed. From Senniappa Dargh to 6.65km towards south, an island namely Musal Island having an elevation of 3.5m from sea floor is encountered. Around this island fringing corals have developed very extensively to a depth of 2m, they extend 1.45km towards north, 1.75km towards northwest, 1.69km towards west and 1.42km towards south from the coast of the island. Around this island the sea floor slopes gently upto a depth of 2m. On the seaward side of this island, the sea floor slope is very steep to 10m depth and to an average distance of 2m. About 6.18km away from Marakkayarpattinam, there are two islands namely Manalli and Manalliputti Islands (79°7’26’’E-9°12’23’’N and 79°8’16’’E-9°12’23’’N). Around these islands, the sea floor is encountered at 1m depth and the topography of the sea floor around this island has a moderate gradient. On the seaward side of this island, the sea floor slope is very steep, between 3m and 6m depths. The width of this slope is 0.73km. At a depth of 6m to 7m a plain having a width of 3.52km. is encountered The sea floor slopes gently between 7m and 30m depths. In the area between Thoniturai and Pamban canal, the sea floor is encountered at a depth of 1m and extends to an average distance of 1.07km from the coast of Thoniturai and Velupilliyarkovail. In this area the sea floor slopes very gently upto 2m depth. In between 2m and 3m depths, there is a vast plain sea floor extending 3.80km from north to south and 23.3km from east to west. Along this plain there are low elevated chain of islands (79°10’28’’E-9°14’28’’N and 79°14’16’’E-9°13’28’’) namely Pumurichan, Kovai, Kurusadai and Shingle islands. Around these islands the sea floor is encountered at a depth of 0.5m and extends to an average distance of 0.49km towards north, 1km towards south, 0.19km towards east and 0.27km towards west. In the north of these islands the sea floor slope is steep (till a depth of 1m) whereas it is very gentle in the south (till a depth of 3m). In between 3m and 10m the sea floor slope is steep having a width of 1.83 km. From 10m to 30m the sea floor slopes moderately. In the area between Dhanuskodi and Kundugal the sea floor is at a depth of 6m and slopes moderately up to 30m depth. The width of the continental shelf in this area has been measured approximately as 26.25 km.

The sea floor has raise with reference to chart datum along 8 transects off the coast of Mandapam area may be due to emerging of land and sediment deposition. This part the of study area is very dynamic and during the southeast monsoon period a long shore current transports large amount of sediment from Palk Bay to Gulf of Mannar through Pamban Channel and deposit the sediment . In addition during the low tide period the tidal current move towards south and deposit some amount of sediment in this part. New spit formation near Kundugal is the evidence for deposition of sediment. The average rising of sea floor along Mandapam coast is found to be 0.68m over a period of 24 years (1975-1999). Around the Mandapam group of islands, the raise of sea floor was noticed at the seaward side of the island. It may be due to sedimentation caused by wave induced current. At the seaward side of Kurusadai, Kovai, Pumurichan, Musal, Manalli and Manalli Putti Islands the reef edge was found at an average distance of 1km away from the shores of the island towards sea. The reef acts as a wave breaker and when the high velocity waves hit against the reef edge, it reduces the velocity of waves and the wave induced current moves towards north, distributing the littoral sediments on these coral reefs. By such repeated action, the area between islands and reef edge gets shallow. The average rising of sea floor at seaward side of Pumurichan, Kovai and Kurusadai Islands was calculated as 0.23km for the past 30 years and the rate of rising of sea floor is 0.009m/year. Towards the seaward side of Musal, Manalli and Manalli Putti Islands the sea floor depth has decreased by 0.36m over a period of 24 years. The rate of rising of sea floor in this area is estimated as 0.015m/year. The sandbar formation between Manalli and Manalli Putti Islands, occurrence of spits along the coast and rising reefs in Mandapam and Keelakkarai groups of islands are the evidences for rising of the sea floor.

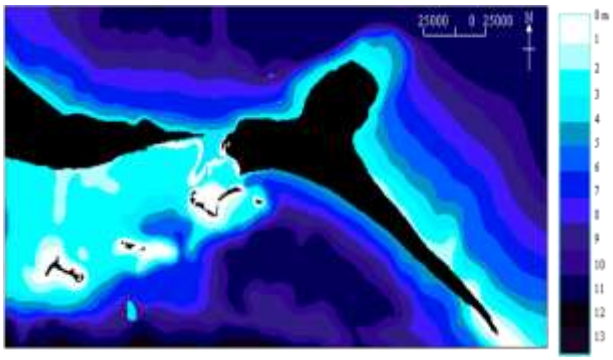

Figure 9: Bathymetry map of Rameswaram Near shore area during 1975

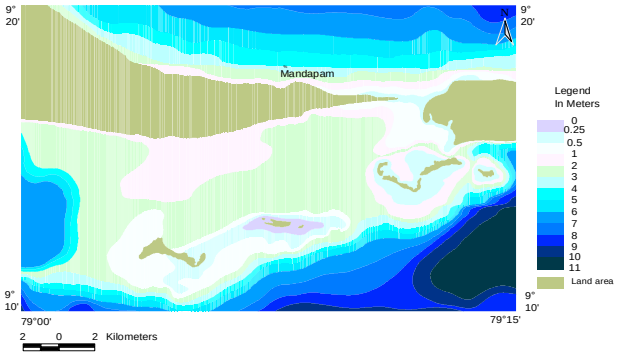

Figure 10: Bathymetry map of Rameswaram Near shore area during1999

Conclusion

The present study reveals that remote sensing and GIS techniques have unique capability to detect the coastal changes over a period of time between 1969 and 1999. There is a substantial decrease in coral reef, reef vegetation and changes in coastal land use/land cover classes. These changes have taken place due to increasing human population and urbanization. Over a period of twenty nine year between 1969 and 1998, there are fifteen accretion and ten erosion sites have been identified along the study area coast. The islands in Rameswaram group have been migrated towards seaward side. Over a period of time the depth of seafloor decreased along the mainland coast and around the islands in the study area. It may be due to emerging of land which causes by tectonic movement. The results, which are thus derived, can be very useful in the coastal ecosystem management, which is greatly required for the sustainable use, development, and protection of the coastal and marine areas and resources. Immediate conservation measures (Coastal Regulation Zone) are recommended so that the coastal ecosystem can be saved from further degradation and brought back to its normal state.

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