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Research Paper

LAND USE/LAND COVER AND SHORELINE CHANGES ALONG THE SOUTHERN KERALA COAST, SW COAST OF INDIA

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Shoreline represents the dynamic boundary that separates beaches from the continual impact of waves, winds, surge, and tides. This boundary evolves over timescales of hours (e.g., changing tides or wave conditions) to decades. The term land use refers to the human activity or economic function associated with a specific piece of land, while the term land cover refers to the type of feature present on the surface of the earth. An attempt is made to study the land use / land cover and shoreline changes along the coastal tract of Thiruvananthapuram district (length = 70 km) which accounts 12% of the total shoreline of Kerala, confined between N. Lat. $8^0$17' 33" and E. Long. 76^0 40' 18" to 770 5' 45". Survey of India top sheets of 1967 and 1989, digital data products of IRS-P6 of 2005 and IKONOS of 2005 are used for the study. The major land use/land cover categories identified in the decreasing order of abundance are coconut plantation (60%), followed by mixed plantation (25.5%), sandy area (12.37%), water bodies (8.27%) and paddy (2.9%). From the analysis of the shoreline, it has been found that the Kovalam-Poonthura sector (L= 5 km) is highly eroding (-130 m), followed by Vettur-Edava sector (L= 4.5 km) moderately eroding (-90 m) and Mudalapozhi-Mampalli sector (L= 5.15 km), moderately eroding (-50 m).High accretion (+140 m) is observed in the Karumkulam-Chowara sector (=6.19 km) followed by moderate accretion in the Pudukurichi-Mudalapozhi sector (3.0 km).

Keywords: Shoreline, Land use/land cover, Thiruvananthapuram, IRS, GIS

INTRODUCTION

An environmentally sound Coastal Zone Management (CZM) program heavily leans on a precise archival database or sets of baseline data on land use/land cover and shoreline, and their past changes as well as the state-of-the-art. The term land use refers to the human activity or economic function associated with a specific piece of land, while the term land cover refers to the type of feature present on the surface of the earth (Lillesand and Kiefer, 2000). Both the land use and land cover are closely related and are interchangeable. The interpretation of land use-land cover can be directly used for the

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development of the area through land use planning (Sahi *et al.*, 1985).

Shoreline comprises a major element of the earth's landscape and the procedures that shape it are exceptionally complex (Pethick, 1984). Again, it is one of the most rapidly changing landforms of the coastal zone. Geologic processes such as erosion, deposition, sedimentation, periodic storms, flooding and sea level changes continuously tend to modify the shoreline. The accurate demarcation of shoreline is therefore very important for planning conservation measures.

According to Vink (1975) human activities stand out as the single largest force causing land use/land cover changes, and further Singh (1989) suggested that this may occur due to both human action and change in environmental condition. These changes perturb the existing coastal ecosystem and play an important role in controlling the climate of that region. Again, these changes have a key role in carbon cycling through emission of greenhouse gases affecting hydrological and other earth system processes (Mcconnel, 2001).

Another major problem faced by the coastal zone is shoreline recession due to coastal erosion. This causes severe damages to coastal properties and ecosystems. It requires a detailed understanding of the nature and rate of shoreline changes, modifications to coastal ecosystems and changes in coastal land use/land cover to initiate interventions through shoreline management plans to contain the damages due to coastal erosion and land use changes.

The studies of coastal land use/land cover and shoreline changes have become easier with the availability of high-resolution satellite remote sensing data, which have proved to be of great utility in all fields of earth sciences, including the study of coastal processes, coastal zone regulation, coastal zone management and urban and land information system, due to the rapid, repetitive, synoptic and multispectral coverage. Usefulness of remote sensing as a very important tool for gathering land use/land cover changes is well known and well documented (Luque, 2000; Yang and Lo, 2002). Satellite images have been effectively used for monitoring shoreline changes in different parts of India (De Solan *et al.*, 2001).

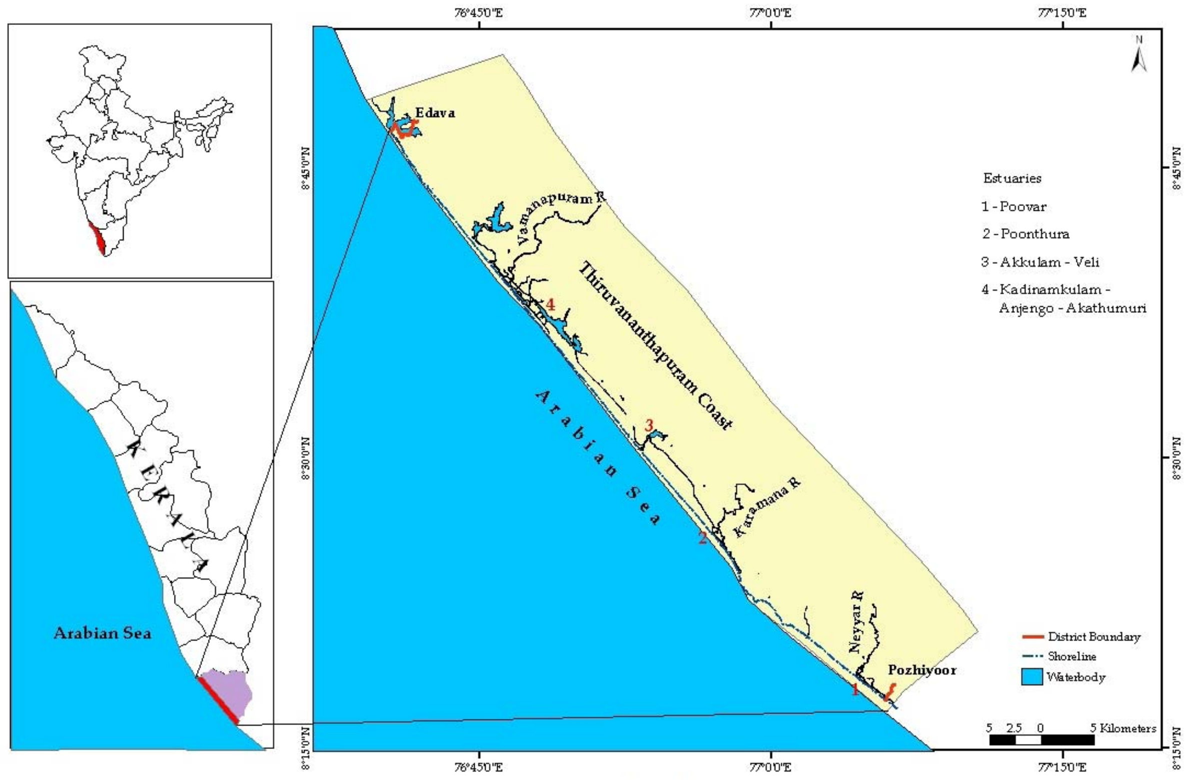
Spatial data analysis, comparison of changes from multi-temporal data and presentation of results have become handy with the advent of Geographic Information System (GIS). Major advantage of GIS is that it allows identification of the spatial relationships between features and temporal changes within an area over a period of time.

The coastal tract of Thiruvananthapuram district (Length = 70 km; Width = ~10.0 km, Area = 700 km^2) has been selected for the present study, and this accounts 12% of the total shoreline of Kerala. It is confined between N. Lat. 8^0 17' 33'' to 8^0 46' 43'' and E. Long. 76^0 40' 18'' to 77^0 5' 45'' (Figure 1). Riverine zones, estuarine systems and canals are the major ecosystems; while beaches and cliffs are the prominent geomorphic units in the study area.

MATERIALS AND METHODS

Data sets on land use/landcover and shoreline changes within the 500.0 m landward of the shoreline of Thiruvananthapuram coast have been identified and gathered from Survey of India toposheets 1: 50,000 (in 1967), 1: 25,000 (in 1989), aerial photographs on 1: 50,000 (in 1990)

Figure 1: Location Map of the Study Area



and satellite imageries of IRS-P6 LISS-IV and IKONOS-MS (in 2005) for analysis in a GIS platform.The study comprises the interpretation of individual bands (B2, B3 & B4) and the False Color Composite (FCC), which is made by the combination of different bands through digital image processing techniques (Lillesand and Kiefer, 2000).

INTERPRETATION OF FCC

The turbid water bodies appear as blue patches, while the deep water appears as black. The brightest features in the FCC are the sandy areas. Agricultural fields, urban areas, settlements, roads and railway tracks appear in light yellowish gray tone. The moist sand and the wet coastal structures like jetties exhibit light greenish yellow color with lighter tone. Thick vegetation and plantation crops appear in dark red color. Since the FCC are produced by the combination of visible (B2 & B3) and near-IR (B4) band, the spectral signatures of the earth surface features are enhanced on FCC. Thus, FCC are extensively used in the study, along with conventional digital processing techniques (Lillesand and Kiefer, 2000).

Land use/land cover study comprises the digital processing of the data products of IRS-P6 and IKONOS to extract terrain features. The ERDAS 8.7 software on Windows XP professional operating system was used for the digital processing of the data investigation. The following steps, viz., image rectification, image enhancement based on Fourier transforms and contrast stretching and image classification have been used in the digital image processing (Lillesand and Kiefer, 2000; Venkatachary *et al.*, 2001).

METHODS FOR SHORELINE CHANGES

Several methods have been suggested to accurately measure the position of shoreline from aerial photographs and satellite imageries with low error factors (Hequelte and Ruz, 1991; Chen and Ruz, 1998). Sea level data have been used as a surrogate data for the development of shoreline position estimations for the ancient and projected shorelines (Crowell *et al.*, 1997). However, among all the methods suggested, the technique of Thieler and Danforth (1994) invokes the entire range of cartographic techniques required for the precise mapping of shoreline and associated geomorphic entities. This method has been adopted in this study in respect of both satellite data and toposheet data.

The key aspects of the methods includes digitizing a series of known geographic coordinates such as the latitude – longitude graticules, digitizing the shoreline depicted on the maps and converting the digitized output to geographic coordinates.

SOI toposheets of 1967 and 1989, and digital data products of IRS-P6 of 2005 and IKONOS of 2005 are used for the shoreline-change-detection study. Shoreline position was digitized from imagery in ERDAS Imagine, and have been geocorrected using GCPs (ground control points) extracted from toposheets such as intersection of roads, channels and some permanent features for geocorrection. The shoreline of 2005 was digitized in ERDAS using Satellite imageries, IR band that is suitable for the delineation of land-water boundary. Then these vector layers were brought to same projection and merged polygon topology was constructed for these merged layers. Then area (erosion, accretion) was obtained from the vector attribute table.

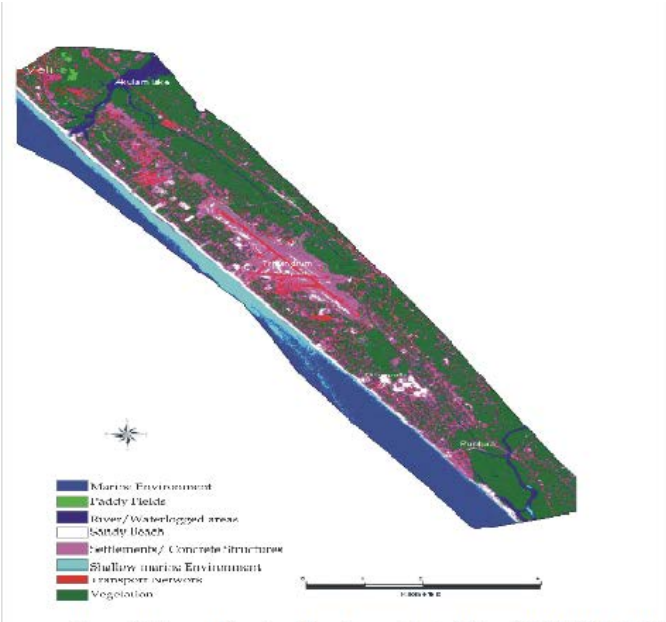
RESULTS AND DISCUSSION

Land Use / Land Cover Study

The land use/land cover aspects of the Thiruvananthapuram coast are given in the Table 1 and Figure 2 and 3. The coastal villages like Poovar, Karumkulam, Vizhinjam, Kulathur, Chirayinkizh and Anjengo are thickly populated leading to large-scale socio-economic problems. Among these, Karumkulam is the most densely populated village (population= 11508/km^2) in the State. The study area is generally constituted by settlement with vegetation and clustered settlements in certain locations (Baba *et al.*, 1998). The study area has a fishing harbour at Vizhinjam and an international airport at Shankhumugam. The Vikram Sarabhai Space Centre (VSSC), the Travancore Titanium Products (TTP) and the English Indian Clays Limited are located in this coastal land zone.

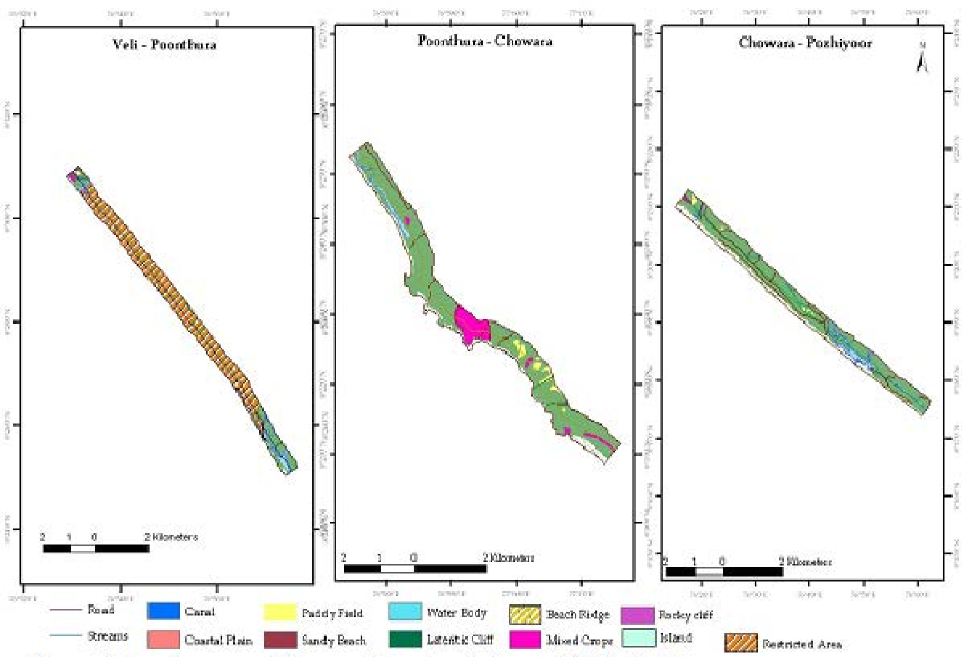
In general, the study has discriminated the following five categories of land use/ land cover pattern and are sandy beach, river and water logged area, vegetation, built up area and marine environment (Figure 2). The major land use categories identified in the decreasing order of abundance (Figure 4) are coconut plantation (= 60%), followed by mixed plantation (25.5%), sandy area (12.37%), water bodies (8.27%) and paddy (2.9%).

Figure 2: General Landuse/Landcover Derived from IKONOS Satellite Imagery (2005) in Between Coastal Stretches Between Poonthura and Veli



The sector-wise land use/land cover pattern (Figures 2 and 3) shows that in Edava–Varkala sector the prominent land use is coconut plantation, followed by sandy beaches, Paddy

Figure 3: Landuse map of the Coastal Sectors Between Veli and Pozhiyoor



fields and mixed crops, whereas, in the Varkala–Perumathura sector the coconut plantation again dominate, followed by the water bodies and paddy field. However, the Perumathura–Veli sector is dominated by mixed crops, followed by coconut plantation and paddy field. In the Veli–Poonthura sector majority falls in the restricted area due to the presence of Thiruvananthapuram International Airport and VSSC. In the southern sectors like Veli–Chowra and Chowra–Pozhiyoor, coconut plantation is the major land use, followed by mixed crops, paddy fields and well developed sand beaches.

The most important driving forces that influence the change in land use/land cover are industrialization, population dynamics, tourism and ecosystem services, extreme events and natural hazards, external market forces and globalization of economy, change in cultural and life style patterns, and policy regulations and interventions (Anderson *et al.*, 1976). High population density and hot spot area of rapid and intense socio-economic and environmental changes that demand fast policy responses characterized this costal region. Thus, integrating information on existing land use/land cover, its spatial distribution and change are essential factors for planning (Dhinwa *et al*., 1992). The data obtained from the land use/land cover studies can be directly used for the development of the terrain through scientific planning (Sahai *et al.,* 1985).

SHORELINE CHANGES STUDY

Based on the analysis of data pertaining to short-term (1989-2005) and long-term (1967-2005) shoreline changes, it has been inferred that the coastal land in the study area demonstrates very significant variations in terms of the intensity of erosion and/or accretion. As a result, it has been possible to segment the coastal area into different sectors and the short-term and long-term shoreline changes in the different sectors of the study area are given in Table 2 and Figure 5 to 10. The current trend in shoreline change is obtained from the short term changes from 1989 to 2005. In all sectors (except Poonthura-Veli sector, L= 10.4 km) the long term and current trends are the same. In the following text, the long term changes in the shoreline are discussed for various sectors.

The shoreline sectors upto 50 m change are taken as 'low', between 50 and 100 m are considered as 'moderate', and above 100 m as 'high' erosion/accretion zones. Accordingly, the southernmost sector of the study area from Pozhiyoor to Karumkulam (stretch= 5.13 km) low erosion (-20 m.) is observed, but a high accretion

Table 1: Land Use/Land Cover Pattern in the Coastal Zone of the Study Area

S. No.	Land use	Area(Hectares)	Area (%)
1	Paddy	114.48	2.90
2	Coconut	2008.26	60
3	Mixed Plantation	1004.98	25.5
4	Sandy beach	487.59	12.37
5	Water bodies	326.14	8.27

Table 2: Shoreline Changes at Different Locations from Pozhiyoor to Edava Along the Thiruvananthapuram District Coast

S. No.	Location	Length (Km)	1968-2004(in metre)	1989-2004(in metre)
1	Pozhiyoor - Karumkulam	5.13	(-)20	(-30)
2	Karumkulam-Karichal	4.42	(+)100	(+)55
3	Karichal- Chowra	1.77	(+)175	(+)80
4	Chowra- Vizhinjam	4.5	Stable (Rocky cliff)	
5	Vizhinjam- Kovalam	3	Stable (Rocky cliff and pocket beaches)	
6	Kovalam-Poonthura estuary	4	(-)130	(-60)
7	Poonthura estuary- Poonthura	1.5	(-)150	(-) 80
8	Poonthura - Beemapally	2.63	(-)75	(+) 30
9	Beemapally- Vettukkad	5.6	(-)75	(+) 20
10	Vettukkad - Veli estuary	2.22	(-) 80	(+) 20
11	Veli estuary - Pallithura	5.3	(-50)	Stable
12	Pallithura- N. Vettukkad	2.9	(-) 40	Stable
13	N. Vettukkad - Channankara	2.28	(+) 10	Stable
14	Channankara- Pudukurichi	3.75	(-) 40	Stable
15	Pudukurichi - Mudalapozhi	2.94	(+) 60	(+)55
16	Mudalapozhi - Mampalli	5.15	(-) 50	(-) 50
17	Mampalli - Kozhitottam	0.75	Stable	Stable
18	Kozhitottam - Vettur	4.7	(-) 60	(-) 30
19	Vettur - Edava	4.5	(-90)	(-) 50
20	Edava - N. Edava	0.75	Stable	Stable
21	N. Edava - Kappil estuary	1.1	(-)80	(-) 50

Figure 4: Land use Pattern of the Thiruvananthapuram Coastal Zone

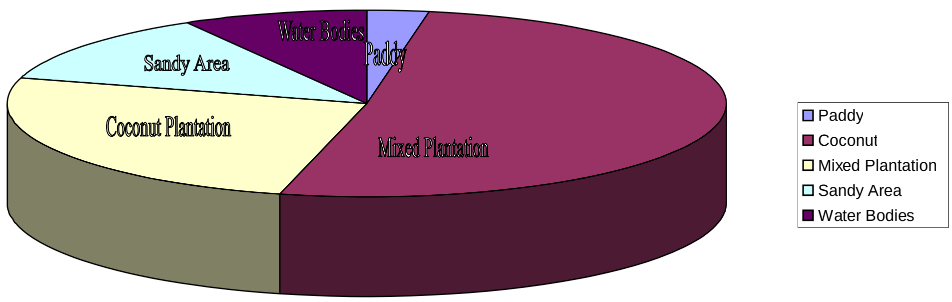
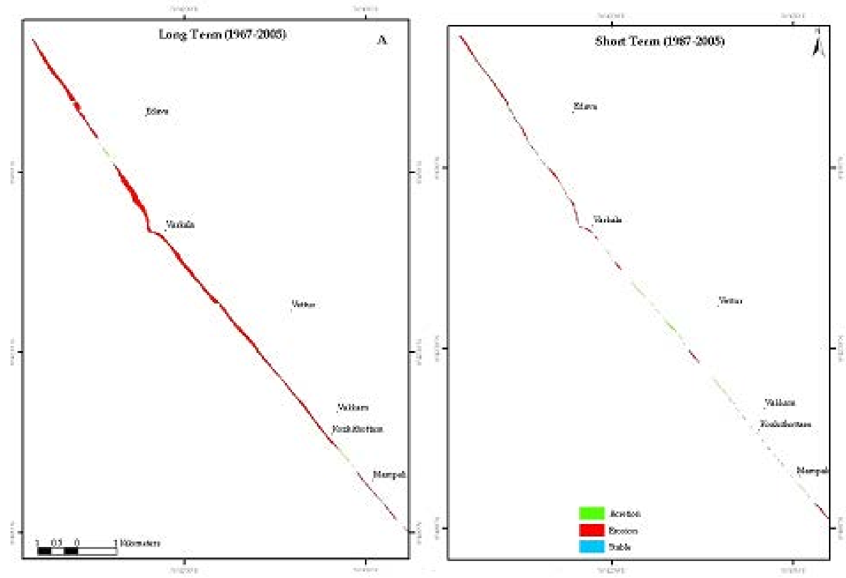


Figure 5: Shoreline Changes from Edava to Mampalli



(+140 m) is observed in the immediate northern sector, i.e., Karumkulam-Chowara sector (=6.19 km). However, the Chowara –Vizhinjam–Kovalam sector (L= 8.0 km) is stable due to the presence of rocky cliff (Figures 9 and 10). This blockage of sediments by the Chowara-Vizhinjam headland might be resulting in the high accretion in the Karumkulam-Chowara sector. Again, the Kovalam, Vizhinjam and Mulloor-Pulinkudi promontories protect this section from the monsoonal waves and littoral drift causes accretion towards its south. Pocket beaches have been observed south of Kovalam headland (Figure 9). Beaches between Poovar and Chowra are backed by lateritic cliffs and the erosion is comparatively less in this sector.

The stretch between Kovalam and Poonthura estuary (=4 km) recorded high erosion of -130 m. immediately north of the Poonthura estuary up to Poonthura (=1.5km) erosion is occurring at a faster rate (-150 m) with highest at Panathura area (Figures 7 and 8). Since the Kovalam headland acts as a barrier for sediment transport and anthropogenic activities might have contributed to the sever erosion. In this area, throughout the year there is no frontal beach seaward of seawalls. Further north, the stretch between Poonthura and Veli estuary (=10.4 km) is found to be under moderate erosion. In spite of the presence of two backwater systems (viz., Poonthura and Veli) in this stretch, the erosion is moderate probably due to the wider beaches (hence large sediment buffer) and low backshore relief.

The sector from Veli estuary to Vettucad (= 8.2 km) recorded low erosion (-40 m). However, from Vettucad to Pudukurichi (= 6.03 km) is stable and low erosion is noticed. In this sector human intentions such as construction of coastal structures, mining of beach sands are minimum. These might have supported the shoreline to remain more or less stable. Further north, a stretch of moderate accretion from Pudukurichi to Mudalapozhi (=3.0 km) is noticed. The construction of breakwater at Mudalapozhi, which act as a barrier for the littoral drift causes the sediment to deposit to the updrift side.

Figure 6: Shoreline Changes from Mampalli to Channakkara

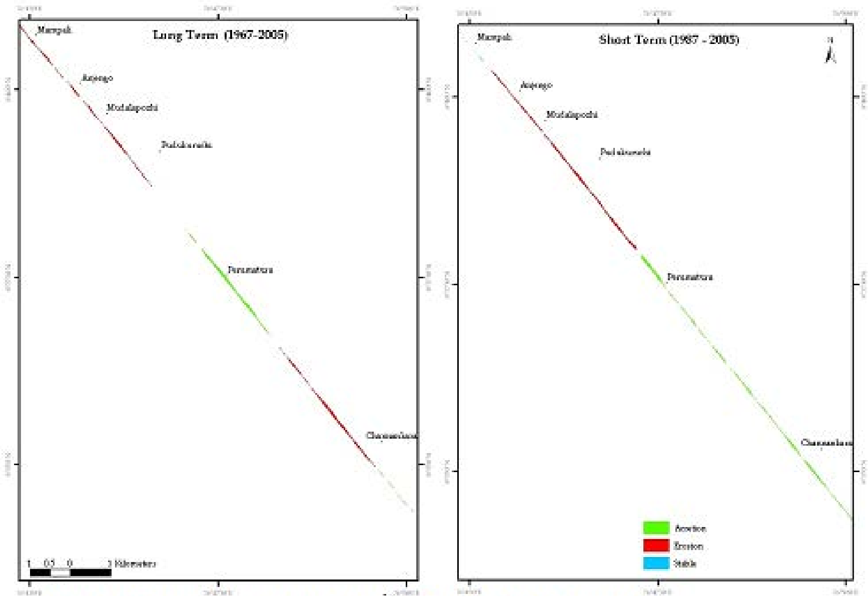


Figure 7: Shoreline Changes from Channakkara to Kochuveli

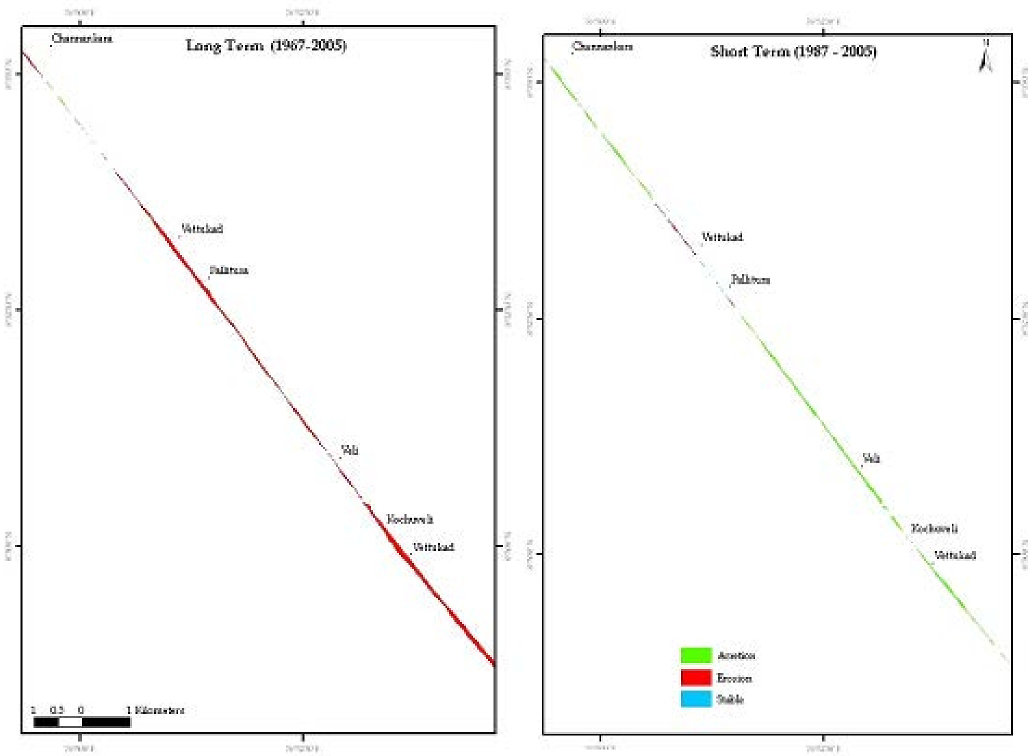


Figure 8: Shoreline Changes from Kochuveli to Kovalam

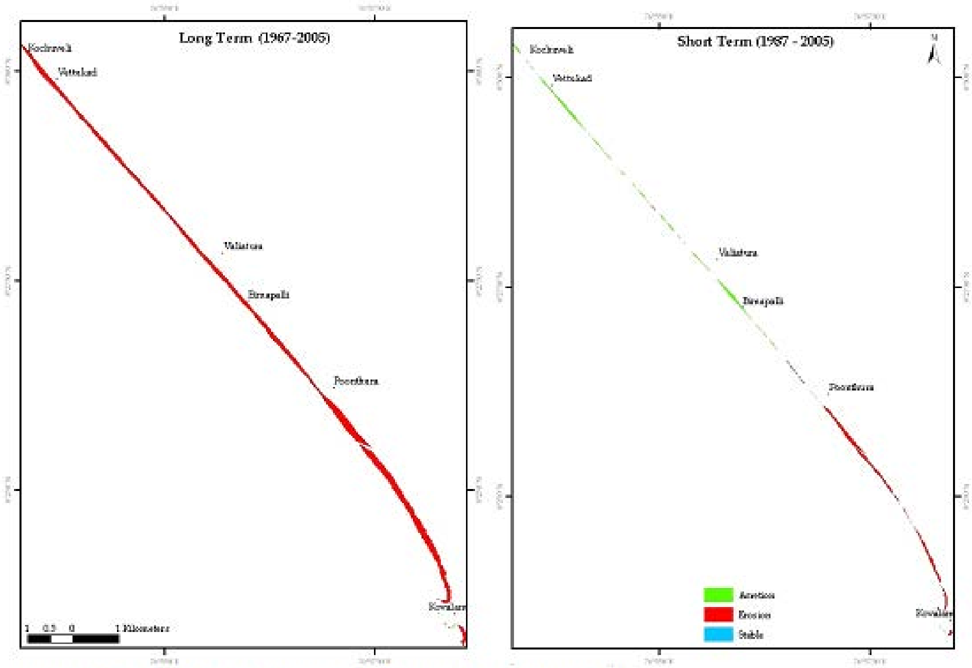


Figure 9: Shoreline Changes from Kovalam to Pullavilla

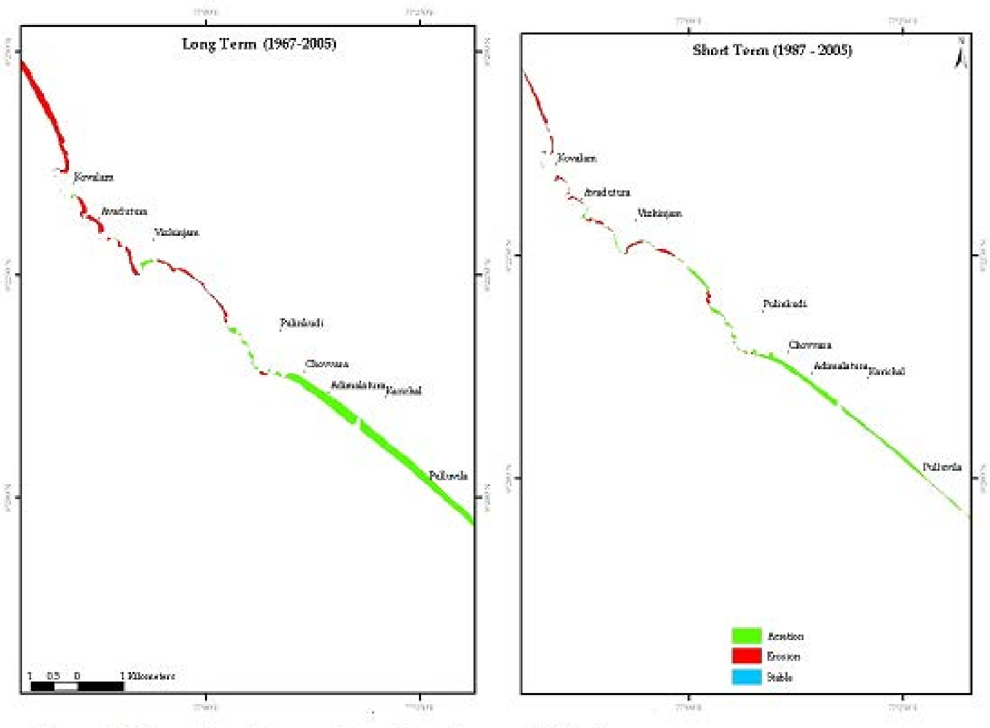
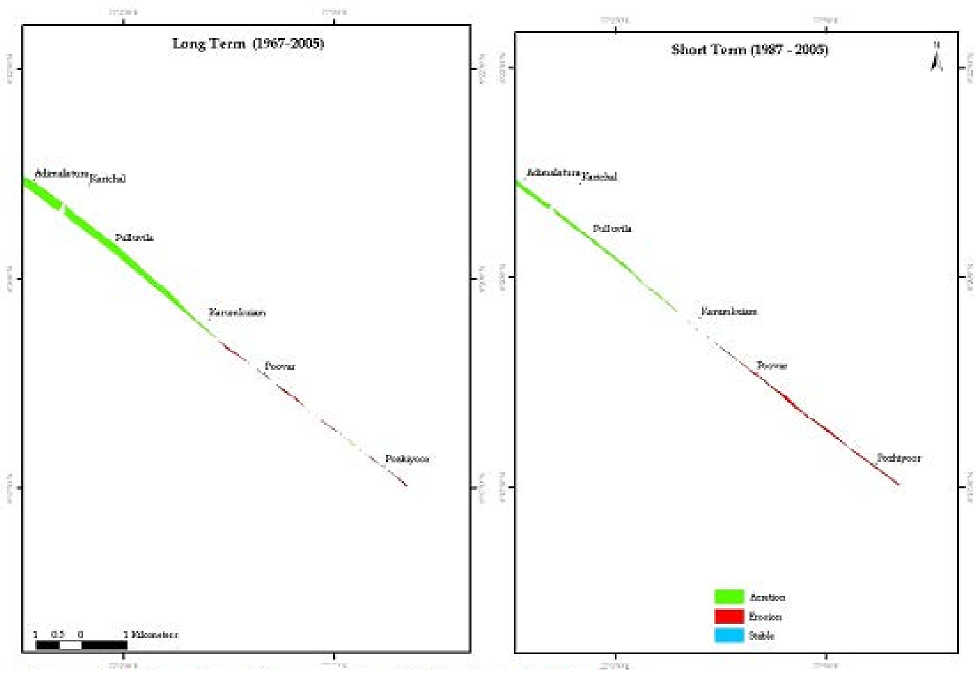


Figure 10: Shoreline Changes from Pullavilla to Pozhiyoor



The stretch from Mudalapozhi to Mampalli (=5.1 km) is under moderate erosion (-50 m) due to the lack of sediment supply from the south due to harbour construction, i.e., erosion is noticed in the downdrift side of the harbour. Towards the north a stretch of stable to low erosion from Mampalli to Vettur (=5.4 km) is noticed. From Vettur to Edava (=4.5 km) the cliffed shoreline is under moderate erosion (-90 m), of which the cliffed shoreline (Figures 5 and 6) at Varkala is highly eroding (-110 m). From north of Edava to Kappil (northernmost sector) the beach is under moderate (-80 m) to nearly high erosion (-90 m). The presence of inlet and the Varkala cliff may have a role in inducing erosion in this sector. Further, the coarse sediments do not reach the inner shelf because of their impounding in the estuaries and the shore face is starved of littoral material. This is an important factor contributing to active coastal erosion and is directly related to the transgressive phase of the sea.

Shoreline changes, in general, are caused by both natural and anthropogenic factors. It is observed that shoreline changes are more guided by natural processes such as waves, tidal currents, littoral drift and long-term accretion due to sea level changes. The monsoonal waves are responsible for rampant coastal erosion and for recent shoreline changes. Long-term shoreline changes are attributed to marine transgression and regression and neotectonics (Morton, 1979; Vaidyanadhan, 1981; Bhat and Subramanian, 1993).

The anthropogenic activities like large-scale deforestation in upper catchment areas, urbanization and infrastructure development (like harbours, groins) have generated major impact on coastal environments by accelerating erosion rates and affecting changes in sediment inputs. Further, the sediment supply from the river sources has been drastically affected by stream regulations, reservoirs and mining of riverbeds (Roy *et al*., 1994).

A previous study by Mallik and others, in 1987, indicates uniform erosion between the Thiruvananthapuram and Kollam coast. However, from the sectoral studies of Thiruvananthapuram coast (Thomas, 1986; Arunkumar and Sabu Joseph, 2004), it is observed that the coast is affected by seasonal and cyclic erosion/accretion process induced by monsoonal and non-monsoonal waves.

From the foregoing long-term and short-term analysis of the shoreline in the study area using GIS (overlay analysis) it has been found that the Kovalam-Poonthura sector (L= 5.5 km) is highly eroding (-130 m). Within the study area from Kovalam to Veli the southern side is eroding at a faster rate. More than 100 m of beach area has been eroded by strong wave attack particularly from Kovalam to Panathura region. At Panathura, there is an estuary where Karamana ar meets with Arabian Sea.

A headland at the southern side and a tidal inlet at the northern side bound the entire stretch from Kovalam to Panathura. The littoral drift in this region mainly comprises of longshore and shore perpendicular transport. The predominant longshore current is towards north, due to which the impermeable Precambrian crystalline rocks exposed along the beaches at Kovalam act as a barrier causing hindrance to the sediment movement in the northern side and erosion in the downdrift side.

Intensive sand mining from Karamana ar has a profound effect in reducing the sediment carried by the river and hence increasing erosion. In the northern side of Panathura tidal inlet, i.e., in Poonthura region also erosion is occurring at a rapid rate, varies from 50-100 m. The longshore sediment transport is directed towards north, most of the northern areas are accreting. It seems that rip currents and offshore-onshore transport are also the dominant factors in sediment transport process along this coast (Thomas, 1988).

Sandy coastal areas commonly exhibit temporal and spatial variations in the shorelines. A large sediment flux to the coastal region comes from Neyyar, Karamana and Vamanapuram rivers, which debouch in southern, central and northern part of the study area. The deposition on the southern side of the inlets, and erosion on its northern side support the observation of Finkelstein (1983) that the deposition occurs on straight coasts when a large amount of littoral drift becomes trapped updrift of a boundary, usually an inlet or estuary mouth. In order to maintain the equilibrium, the downdrift limb of the inlets gets eroded and the inlet migration occurs laterally. If the accumulation of sediment at the updrift arm completely balances the erosion at the downdrift end, a straight inlet develops.

The processes responsible for accretion of sediments at the inlet may be the swell waves that can contribute to the shoreward transport of sediments during the non-monsoon season, the long period low swells waves cause net shoreward transport and bring back the material to the foreshore region, and finally leads to the growth of the beach/spit (Veerayya *et al.*, 1973; Liu and Hou, 1997).

CONCLUSION

The major land use/land cover categories identified in the study area in the decreasing order of abundance are coconut plantation (60%), followed by mixed plantation (25.5%), sandy area (12.37%), water bodies (8.27%) and paddy

(2.9%). From the analysis of the shoreline, it has been found that the Kovalam-Poonthura sector (L= 5 km) is highly eroding (-130 m), followed by Vettur-Edava sector (L= 4.5 km) moderately eroding (-90 m) and Mudalapozhi-Mampalli sector (L= 5.15 km), moderately eroding (-50 m). High accretion (+140 m) is observed in the Karumkulam-Chowara sector (=6.19 km) followed by moderate accretion in the Pudukurichi-Mudalapozhi sector (3.0 km).

An in-depth examination of the coastal erosion problem of Thiruvananthapuram suggests that it is neither uniform nor induced by the same processes at different locations. It can be a part of the erosion-accretion cycle followed during the SW monsoon or in some locations anthropogenic influences are superimposed on seasonal cycle causing net erosion.

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