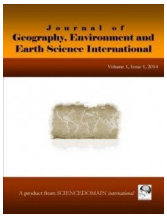

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Evaluating Landuse Change along Thiruvananthapuram Coast, South West Coast of India Using Geo-spatial Techniques

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Coastal zone across the world is typified with intensive multiple human activities. Historic maps and multi-temporal satellite images are helpful in detecting the change in land use over the years. An attempt is made to evaluate the land use/land cover change along the coastal zone of Thiruvananthapuram using Geographic Information System (GIS) and Remote Sensing techniques. Landuse scenarios for 1988, 2000 and 2010 have been generated using Survey of India Topographical Sheets, Landsat ETM+ Image and Quickbird Image respectively. ERDAS software is used for image processing and land-use change is analysed using ArcGis 10.2.1 Software. The reasons and implications of landuse change in the coast are also studied through field investigation and valid conclusions are drawn. Agricultural land, clustered settlement area, a settlement with vegetation, sandy area and rocky area is the broad landuse categories delineated in the coastal zone. The analysis shows that the agricultural land area has decreased from 9.34% to 3.89% while the area under clustered settlement increased from 5.75 % to 25.65% during 1988-2010. This study can provide base information on land use scenario of the coast while framing out the ICZM plan.

Keywords: Landuse change; coastal zone; GIS; Thiruvananthapuram coast.

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1. INTRODUCTION

Coastal zone, the triple interface of land, water and air supports an earth's most dynamic fragile and productive ecosystems, requires pertinent sustainable strategies for the protection of coastal inhabitants and development of its resources. Landuse management plays a crucial part in the management of the coastal zone, as it limits and delimits human activities and utilization of resources within the coast. Use of land for various human activities within the coast is highly conflicting due to high competition among its users and its limited availability for use. Inappropriate and uncontrolled use of land in the coastal zone leads to unscientific use of resources, congestion of human settlements, an increase of pollution, and land degradation. The global climate change and rapidly rising of sea level exacerbate the already prevailing vulnerability of the coastal people and assets to hazards. Reliable knowledge on the coastal lands, its evaluation on the spatial pattern of distribution, and temporal variation are essential inputs in framing out ICZM plans.

Coastal zone is a common property resource. Although it covers only 6.3% of the earth's surface area, it provides about 43% of the estimated value of the world's ecosystem services [1]. About 23% of the global population lives within the coastal zone. The average population density in the coastal zone is 112 persons/km^2 and is several times higher than the average global population density of 44 persons/km^2 [2]. The ever increasing anthropogenic pressure on the coasts over the last century has substantially reduced or depleted many valuable natural ecosystems in the coast. For example, the area under mangrove vegetation of the world has declined from 19.8 million ha in 1980 to 14.7 million ha in 2000 [3]. The area under natural coastal systems is now converting at a faster rate for human inhabitation. Urbanization and tourism development could cause an irreversible change in the coastal landuse in the future. The situation in tropical maritime countries like India is also not different. According to 2011 Census data, nearly 250 million people or 17% of Indian population live within a distance of 50kms from the coast spreading over 66 coastal districts in 9 coastal states. There are 2661 urban centres and 3827 rural villages in the coastal zone of India. The average population density in the coastal zone of India was 455 persons/km^2 in 2001 which has increased to 558 persons/km^2 in 2011 [4]. This warrants effective land-use planning at various scales in the coastal zone in order to effectively manage the coastal resources.

Coastal land use change studies provided a base to coastal zone management even from a very earlier time. Historical maps, aerial photographs and satellite images and field survey are the sources of data traditionally used in land use mapping by the scientific community across the globe. Landuse change detection using Landsat MSS data in the Matagorda Bay estuarine system of Texas coast is one of the earliest attempts in this regard [5]. A Landuse classification scheme developed by USGS is commonly followed in western countries for their land use/landcover investigation purposes [6]. Nayak developed a classification scheme for coastal land use mapping applicable to Indian coastal zone [7]. A land-use zonation scheme developed for Segara Anakan coast of Indonesia applying ICZM principles satisfied the needs of different resource users, preserved ecologically important areas and settled land use conflicts [8]. Landuse change can have a corresponding change in the ecosystem services provided by the coasts [9]. Climatic implications of land-use change were analysed for Godavari Delta region using multi-temporal remote sensing data [10].

Landuse change predictions are now attempted in different parts of the world especially urban areas using various stochastic and cellular models while few of them are in the coastal zone [11]. Landuse change in Abudhabi coastal zone was analysed using remote sensing data [12]. The coastal land use change along with its reasons was evaluated for North Western Egypt [13]. Lo and Gunasiri analysed the impact of land-use change on shoreline change dynamism in Taiwan and established both positive and negative influence of land-use change in causing erosion and accretion [14]. Landuse change mapping within the coastal regulation zone (up to 500 m from High Tide Line) of Kerala was attempted for the year 1995 by Centre for Earth Science Studies [15] and for 2011 by SAC. However, a comprehensive study to detect a change in land use within the coastal zone of Kerala is yet to be attempted. The present study on the Thiruvananthapuram coast is expected to fill this gap.

1.1 Study Site

Thiruvananthapuram, the southernmost district of Kerala on the southwest coast of India supports

75 km long, 5km wide coastal zone between North latitudes of 8°17'39.16" and 8°47'51.77" and East longitudes of 76°40'22.7" and 77°07' 44.14" (Fig. 1). The coastal zone covers a land area of about 345 km^2. The coast is NW-SE in an orientation which deviates slightly from the general NNW-SSE orientation of Kerala coast. This makes the coast unique in terms of climate, hydrodynamics, geology and land use. The geological setting of the coast comprises Archaean crystalline rocks in patches around Veli, Kovalam and Vizhinjam; and the Tertiary and Quaternary sediments in elongated lateritic and sandy coastal plains [16]. About 47% of the area belongs to less than 10 m elevation which is the Low Elevation Zone (LEZ). Well developed beaches, spits, bars, ridge-runnels, estuaries, sandy plains, sedimentary and crystalline cliffs/headlands are the important landforms present on the coast. Neyyar, Karamana and Vamanapuram the three important rivers originating from the Western Ghats pass through the coast and empties into the Lakshadweep Sea. The coast has a chain of backwaters (locally known as 'Kayal) interconnected each other through canals. Poovar Kayal Poonthura Kayal, Veli Kayal, Kadinamkulam Kayal, Anchuthengu (encompassing Moongottu Kayal and Kozhithottom Kayal) and Edava-Nadayara Kayal are the important backwaters present in the coast.

Administratively, the coast spreads over 15 rural panchayats and 2 urban centres. Thiruvananthapuram City, the capital of Kerala and Varkala, a class-II urban centre are located within the coast. The coast is densely populated with an average of 2942 persons / km^2 [17]. As many as 42 fishing villages and 51 fish landing centres are located on the coast [18]. Apart from fisheries, tourism significance of the coast is known across the globe. Kovalam beach, a world-class tourist destination of Asia is positioned on the coast. Techno Park, a multinational IT firm, Vikram Sarabai Space Centre, and Travancore Titanium Products Ltd are also based within the premise of the coast. Agriculture, mining and quarrying, construction works, coir manufacturing, and fish processing are the other important economic activities prevalent in the coast. The proposed Vizhinjam International Seaport Ltd is under the first stage of its building on the coast and is expected to accelerate the economic development in the coast.

2. MATERIALS AND METHODS

The present study analyses land use change within Thiruvananthapuram coast using various geospatial materials and techniques. The extent of the coastal zone has been delineated with the help of salinity measurement data of coastal water bodies published by the National Centre for Earth Science Studies [19]. The salinity measurement data showed that salinity value ≥5ppt recorded up to a maximum distance of 5km from the shoreline in the coast. Hence the width of the coastal zone has been fixed as 5km from the shoreline uniformly throughout the coast. Survey of India Topographical Sheets of 1988 (1:25,000 scale), Landsat image of 2000 (30 m resolution), and Quickbird image of 2010 (0.5 m resolution) are the base materials used for land use change analysis. Due to high scale variability, the land use categories delineated has limited up to the Level –I category of Coastal Land use classification scheme of Nayak [7]. However, the nomenclature of each land use type has been assigned as per the standard scheme developed for land use mapping of Kerala coast by Centre for Earth Science Studies in 1998. The Toposheets are georeferenced with its co-ordinates embedded and projected to Universal Transverse Mercator Projection 43 1/2° N and WGS 1984 Co-ordinate System using ArcGis Version 10.2.1. Both the satellite images are also georeferenced and projected using the same coordinate system. Six land use categories are delineated with the help of onscreen digitisation of SOI Toposheets (1988) and Quickbird image (2010). The growth and reduction in the area of each land use category are demarcated in the Landsat image (2000) with the help of visual interpretation and onscreen digitization. Agricultural lands, clustered settlement area, a settlement with vegetation, water body, sandy area, rocky area are the six land use categories delineated in all three sets of data. The area under each land use types is extracted for 1988, 2000, and 2010 using ArcGis software and their change in percentage has been calculated using the following formula:

$$LUC = (Ao - A1)/Ao \times 100\%$$

Where,

LUC = area change of each land-use type
Ao = area of Present Period
A1 = area of Past Period

3. RESULTS AND DISCUSSION

Agricultural land, clustered settlement area, a settlement with vegetation, water body, sandy area and rocky area is the broad six land use categories delineated in the Thiruvananthapuram coast. Besides, the land has also been given for infrastructural development like an airport, highway bypass, and other roads meeting the demand of local settlements and tourism. The area under these categories has not been computed separately. The area under airport was computed under clustered settlement category. Landuse change under each category during the 1988-2010 is discussed in the following paragraphs.

3.1 Agricultural Lands

Agricultural land spreads over the flood plains, runnels and low valleys. Both seasonal and perennial crops are cultivated in the coastal track. Coconut is the most important perennial crop cultivated in the coast. Availability of well-drained coastal alluvial soil, salt-laden wind, high rainfall and temperature conditions support the flourishment of coconut farming in the area. Paddy, plantain and vegetables are also cultivated in the coastal tracts of Thiruvananthapuram. However, a drastic reduction in the agricultural land area is observed. The agricultural land constituted 9% of the coastal zone in 1988 (Fig. 2), 6% in 2000 and has further decreased to 4% in 2010 (Table 1). On analysing the percentage of growth rate, it is evident that the maximum reduction in agricultural land (-39%) takes place during 1988 - 2000 periods. Indiscriminate and accelerated reclamation of lowlands to accommodate settlements and other built-up areas after the 1990's has shrunk the agricultural land in the coast. This tendency has continued on the coast and shown a growth rate of -31% for the period 2000-2010. The reduction in agricultural land area for about -58% during short 22 years time limit in the coastal zone would have a multiple adverse effects on the ecosystems and society at this era of global climate change and accelerated sea level rise. Incidents of severe water logging even for small downpours in the coast are posing a serious threat to life and property in the coast. Management measures are required to conserve the remaining 13 km^2 agricultural land as part of the Coastal Zone Management Programme.

3.2 Clustered Settlement Area

Settlement patterns are not uniform in the Thiruvananthapuram coast. They were clustered and concentrated mainly in and around urban centres of Thiruvananthapuram and Varkala along with small patches at Poovar, Vizhinjam and Anchuthengu in 1988 (Fig. 2). Category of land-use characterised with a built-up area of above 50% are included in this category. The area under clustered settlement covered only 6% of the total area in 1988 which has increased to 13% in 2000 (Fig. 3) and 26% by 2010 (Fig. 4). The percentage of growth corresponds to these two decades are 116% and 106% respectively. Settlement area doubled within a decade although the rate of population growth is low. This trend calls for a deeper probe to understand the family structure vis-a-vis dwelling requirements. Clustered settlement area has grown at the cost of agricultural lands and areas of settlement with vegetation. The inter settlement space within the clustered settlements is decreasing. The dominant concentration of clustered settlements in the central sector between Veli and Panathura is due to the phenomenon of urban sprawl (Fig. 3 and Fig. 4). This is clear from the study that the Thiruvananthapuram city has grown laterally along the coastal track invading the nearby lands.

Nearly 70 km^2 land area of the coastal zone is converted into built-up land over the period of 22 years indicating a positive increase of 346%. This type of land-use change comes under the irreversible category as the conversion of this land-use type back to its original state is almost impossible. Hence, strategies and plans are to be worked out to efficiently use this land for future settlement requirements and to minimize its encroachments to surrounding lands.

3.3 Settlement with Vegetation

As in the case of Kerala coast, Thiruvananthapuram has also its major share of land for settlement with vegetation land-use category where half of the area is built-up or half falls under vegetative cover. This type of land use is predominant in the rural areas of the coast in the southern and northern sectors where population density is comparatively low and per capita availability of land is high.

Majority of the land area belonged to a settlement with vegetation (79%) in 1988, 75% in 2000 (Fig. 3) and further decreased to 64% in 2010 (Table 1). The percentage of growth rate for both the periods registers negative values of -4% and -16% respectively. The massive change

Table 1. The area under different land use categories, Thiruvananthapuram coast

Sl. no.	Landuse categories	1988		2000		2010		Rate of change (%)		
		Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	1988-2000	2000-2010	1988-2010
1	Agricultural lands	32.23	9.34	19.35	5.66	13.31	3.89	-39.4004	-31.27	-58.35
2	Waterbody	18.13	5.25	18.13	5.30	18.11	5.29	0.952381	-0.19	0.76
3	Rocky area	0.66	0.19	0.31	0.09	0.40	0.12	-52.6316	33.33	-36.84
4	Sandy area	1.09	0.32	2.46	0.72	4.17	1.22	125	69.44	281.25
5	Clustered settlement	19.83	5.75	42.53	12.43	87.76	25.65	116.1739	106.36	346.09
6	Settlement with vegetation	273.15	79.15	259.32	75.80	218.35	63.83	-4.23247	-15.79	-19.36
Total		345.10	100.00	342.10	100.00	342.10	100.00	-	-	

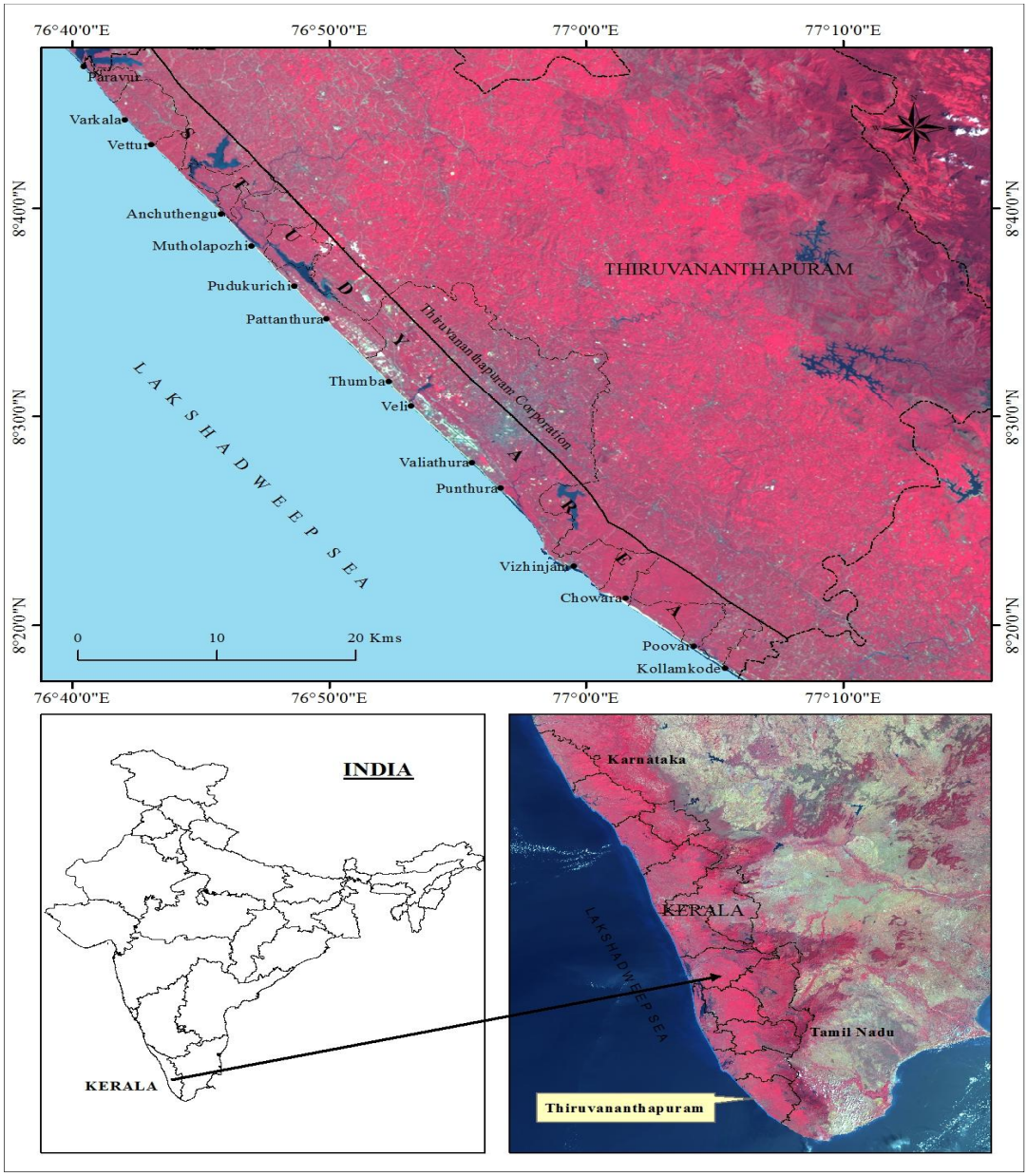

Fig. 1. Study area - location

has taken place during 2000-2010 periods indicates that land scarcity in the urban coastal areas leads to encroachments of rural lands for settlement purposes and related land reclamations. Hereditary fragmentation of landholdings associated with population increase and increasing demands for settlements in rural areas have also contributed to the reduction of area under clustered settlements with vegetation at a faster rate. Since this category of land use is based on the tertiary sediments with varying relief on the coast, management plans are required for their sustainable use.

3.4 Waterbodies

Water bodies including backwaters, lakes, estuaries and rivers together account for about 5% of the total area of the coast and maintain their status except for the period 2000-2010. Encroachment of water bodies particularly backwaters and estuaries are prevalent in the

coastal zone around Akkulam and Kadinamkulam. The beds of these water bodies are mined indiscriminately for sand and gravel. This is degrading the rivers and their surrounding lands. This problem is not addressed in this study and this requires field measurements of bed characteristics of water bodies. Since coastal water bodies support highly sensitive ecosystems like mangroves and islands, special attention has to be given in the ICZM.

3.5 Sandy Area

The area under sand comprises beaches, spits and bars. About 61% of the coastline is sandy in Thiruvananthapuram and nearly half of this coastline is eroding. However, the area under sand increased from 0.32% in 1988 to 0.72% in 2000 and further increased to 1.22% in 2010 (Table 1). This increasing trend is mainly due to the accretional activity, accelerated locally,

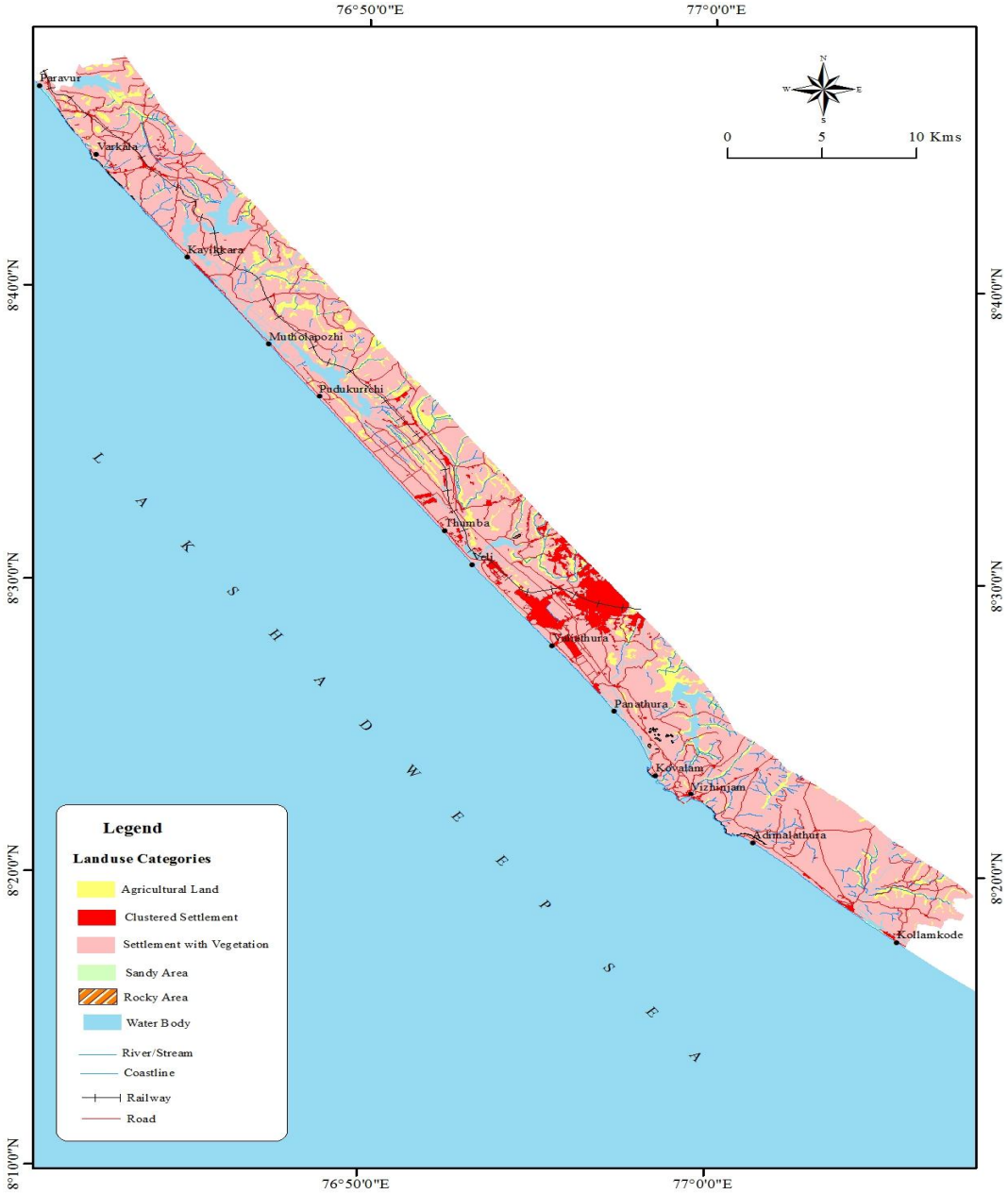

Fig. 2. Landuse (1988) of Thiruvananthapuram coast

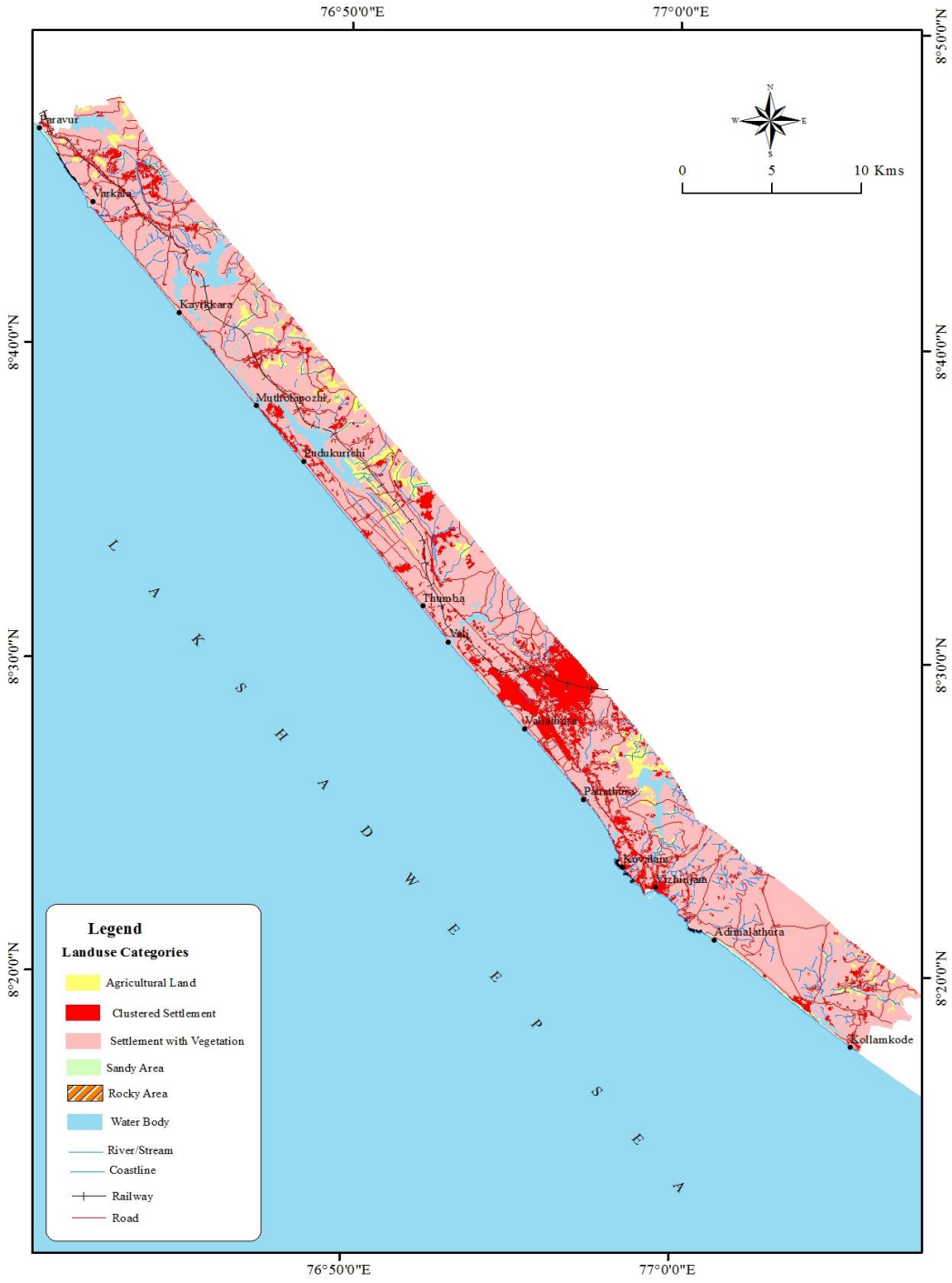

Fig. 3. Landuse (2000) of Thiruvananthapuram coast

due to the influence of coastal structures like groynes and breakwaters. The major increase in the sand area is noticed from South of Panathura breakwater and at Adimalathura where accretion is taking place at a faster rate. Panathura breakwater constructed during 2002-2003 has caused severe accretion in its updraft side and erosion in its downdraft side. However, strategies to conserve the new accreted sandy areas of Thiruvananthapuram coast are to be worked out as part of ICZM.

3.6 Rocky Area

Rocky area includes cliffs, rock exposure and rock outcrops. Rocky area has decreased to 0.12% in 2010 from 0.19 in 1988 showing a reduction of about 37% (Table 1). About 19% of coastline in Thiruvananthapuram coast is rocky. Rocky coastline is mainly seen in the northern and southern portions around Varkala, Vizhinjam and Kovalam. The area under rocky area category shows decrease trend mainly due to the cliff slumping, erosion, mining and quarrying. Rocky coastline of Thiruvananthapuram supports unique intertidal biodiversity. Management actions are also required to protect this ecosystem as part of ICZM.

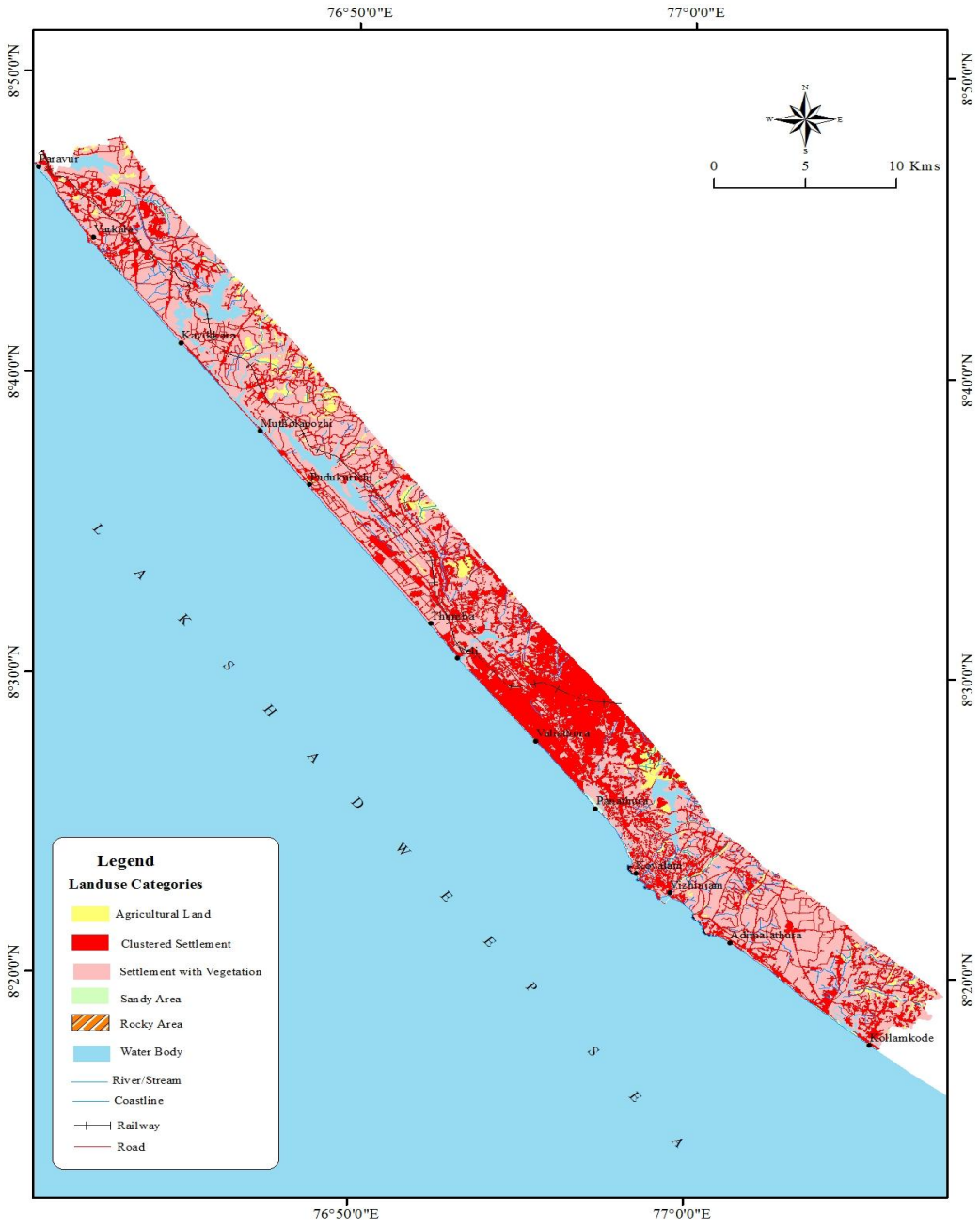

Fig. 4. Landuse (2010) of Thiruvananthapuram coast

Landuse zonation and planning are two essential aspects of Integrated Coastal Zone Management. Field validation of land use maps helps in analysing the impact of land-use change on the environment. Landuse is essentially a footprint of human use of land and land use change reflects the change of human activities within land spatially and temporally. The present inventory derived shall help in framing out efficient management strategies for coastal land use planning in Thiruvananthapuram Coast as part of an evolving ICZM plan.

4. CONCLUSION

Agricultural land, clustered settlement area, a settlement with vegetation, sandy area and the rocky area is the broad land use categories delineated in the coastal zone of Thiruvananthapuram. Change in land use for a period of twenty-two years has evaluated using geospatial data and techniques. The analysis shows that the agricultural land area has decreased from 9.34% to 3.89% while the area under clustered settlement increased from 5.75 % to 25.65% during 1988-2010. Clustered settlement area has increased at the cost of agricultural lands and area under a settlement with vegetation. Sandy area showed an increasing trend while a decreasing trend is noticed for the rocky area. Significance of land-use management as part of ICZM is also highlighted. This study is expected to provide a baseline database to develop land use zonation schemes and management strategies for Thiruvananthapuram coast as part of ICZM.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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