Land Use Change and Its Impact on the Coastal Ecosystem

A Case of Mararikulam Panchayats, Kerala, India

Gayathri Devi Pandurangan

Thesis for a Bachelor of Natural Resources

The Degree Programme in Integrated Coastal Zone Management

Ekenäs 2012

BACHELOR'S THESIS

Author: Gayathri Devi Pandurangan

Degree Programme: Integrated Coastal Zone Management

Specialization:

Supervisors: Srikumar Chattopadhyay, Purba Pal

Title: Land Use Change and Its Impact on the Coastal Ecosystem
A Case of Mararikulam Panchayats, Kerala, India

Date: 26 April 2012 **Number of Pages:** 33 **Appendices** 4

Abstract:

Kerala, situated at the west coast of the Indian peninsula, faces coastal erosion and degradation of coastal vegetation and various natural hazards. Furthermore, Kerala's coast is the centre for major economic activity and exhibits a much diversified land use pattern. This study attempts to find the land use changes and its impact on the coastal ecosystem of Kerala.

After analysing the coastal ecosystem in Mararikulam South and North panchayat (a village council) in Kerala through a socio-economic survey, the impact of land use change and development activities on those ecosystems as well as the possible consequences have been outlined. As the prime objective of the study is to find the changes in the land use, Geographic Information Systems (GIS) technique helped to pasteurize and estimate the current trends and the status of land use in the study area.

The result shows that the changes in the land use is one of the main causes of coastal erosion, coastal accretion and degradation of coastal vegetation in both panchayats, and the steps taken by the government to mitigate these issues resulted in serious drawbacks. Hence, a future course of action that includes planning and development guidelines considering Integrated Coastal Zone Management is recommended.

Language: English

Key words: ICZM, Land Use, Coastal ecosystem, Coastal Zone, Coastal erosion, Coastal vegetation, GIS, Mararikulam North, Mararikulam South, Kerala, Coastal vegetation, Coastal flooding, Coastal pollution, Coastal resources, India

---

Table of Contents

1 Introduction

The coastal zone, a triple interface of land, ocean and air, is an important geographic existence both in terms of resources and human habitation due to intense ecosystem interaction (Brahtz 1972). As many as 22 cities out of 35 cities of the world's largest cities (> 1 million inhabitants) are in the coastal zone and over half of the world's largest cities are ports most of which are located at the mouth of a river . Accommodating more than half of the world´s population within a distance of 60 km from the shoreline, it is the coastal area, which records population growth at a faster rate compared to the other inland areas (Pirazzoli, 1985).

The coastal zone is a part of the coast covered by coastal waters and the adjacent shore lands that include the inter-tidal and supra-tidal zones, coastal flood plains, mangrove swamps, marshes, tidal flats, beaches and ridges. It is a zone where marine influences can be seen in landward areas and terrestrial influences can be seen on the sea. Estuaries, creeks, river discharges, and human activities directly influence the coastal ecosystems. The coastal area generally faces the danger of destruction and depletion of natural resources due to major problems like coastal erosion, coastal accretion, coastal flooding, salt water intrusion, coastal pollution, etc. Thus, coastal areas and coastal waters are biologically and ecologically important and also have great economic potential.

It is not very difficult to perceive how important the coastal environment is for sustaining life on earth but it requires painstaking research to understand the sensitivity of the coastal environment, mutual interdependence of various coastal ecosystems and the impact of human intervention (Chakrabarty 1987). Not only the subsequent global climate change will have a far reaching impact on the coastal belt, but also the patterns of coastal resource use and their impact on the environment due to intense human activity, where conflicts arise very often in the matter of resource use.

This study attempts to understand the coastal ecosystem and its characteristics to find how it is affected due to the changes in the land use practices in two coastal areas in Panchayats of Kerala in India. 'Panchayat' literally means a village council or an institution of local self government at the village level in Indian political System. Panchayat also refers to a

council of elected members taking decisions on issues of a village's social, cultural and economic life: thus, a panchayat is also a village body of elected representatives. As the main aim of the study is to find out the probable trend of the changes in the land use, developing a cadastral map of the study area using Geographic Information Systems (GIS) technique helped to pasteurize and estimate the current trends and the status of land use in the study area. Cadastral map or cadastral record is a comprehensive register of the boundaries and property lines of a country. A cadastral map commonly includes details of the ownership, the precise location (some include GPS coordinates), the dimensions and area, the cultivations if rural, and the value of individual parcels of the land. A detailed study of the development activities and their impacts as well as governance issues in the study area helped in recommending an appropriate Coastal Zone Management Plan for Mararikulam Panchayats.

2 Aims and objectives

This study aims to provide details covering the overall condition of the coastal resources and their use, associated problems, opportunities, and the impact of development activities, and land use on the coastal ecosystem in Mararikulam Panchayats. The analysis will be based on the available data, published reports, maps, government documents and the data that are collected through the field work. And this report will outline the factors that contribute to loss of land due to coastal erosion, destructive land use practices, ecological and social problems in the study area, the driving forces, and finally the recommended course of action for mitigating these problems.

The main objectives of the study may be listed as follows:

- to analyze the overall condition of the coastal resources and their use; associated problems and governance issues in the study area
- to highlight the destructive land use practices in order to determine their impacts on the coastal ecosystem
- to determine the key coastal problems and the drivers of changes in the coastal ecosystem
- to assess a brief ecological and socio-economic overview of the study area

- to recommend a future course of action that includes planning and development guidelines considering ICZM (Integrated Coastal Zone Management)

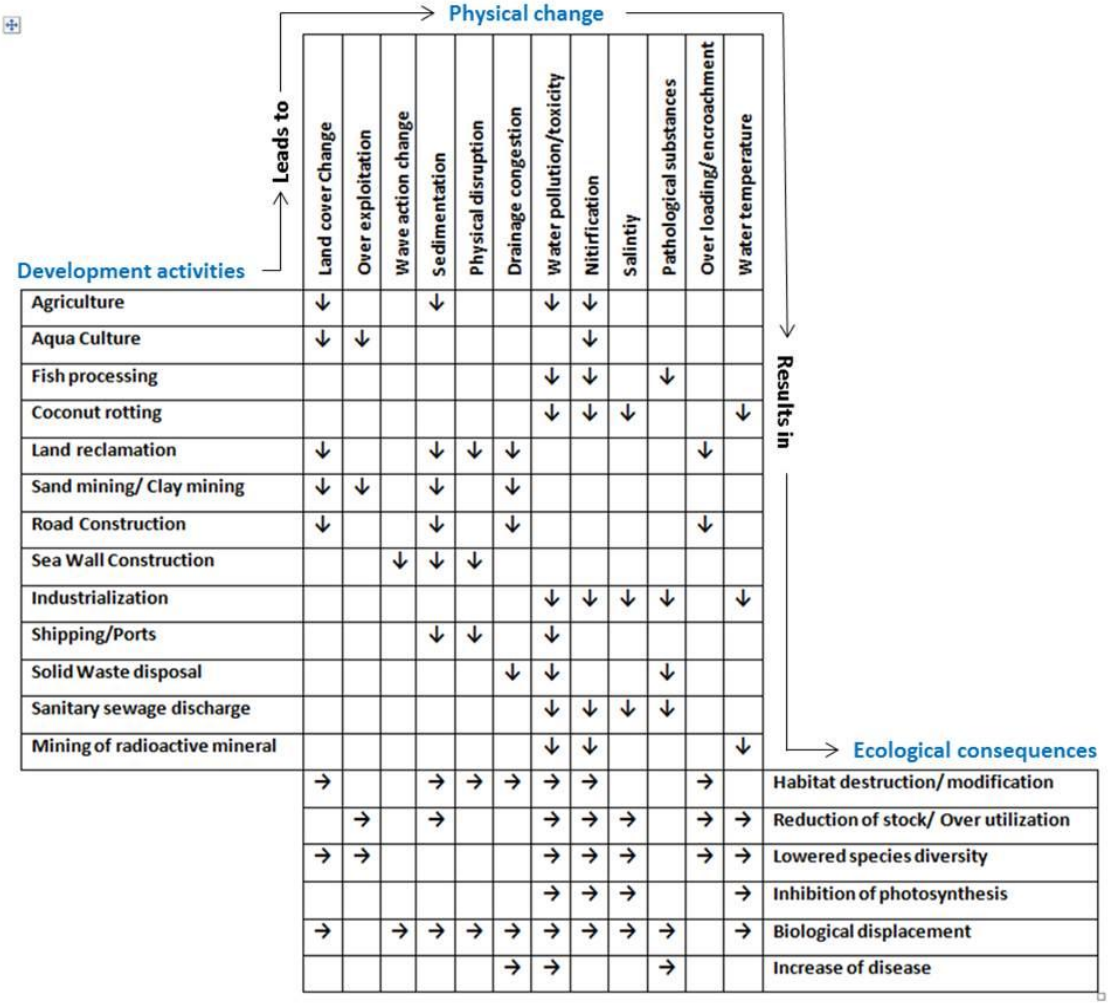
3 Theoretical background

3.1 Development activities and their impacts on coastal zone

Developmental activities in the coastal zone cover a wide spectrum ranging from subsistence fishing to mining of radio-active minerals. The impact of development activities on ecosystems is not uniform. Several projects are likely to affect the same ecosystem and a single project may affect a number of ecosystems. The development activities cause physical change in the first place, which subsequently results in ecological or biological stress, and ultimately, it affects the socio-economy of the country (Maragos, 1983).

Table 1 shows the major development activities in the coastal zone, their physical consequences and ecological response.

Table 1. Development activities, their physical change and ecological response in the coastal zone.



This table is prepared following the example of Maragos et al (1983).

3.2 Integrated Coastal Zone Management

Integrated Coastal Zone Management (ICZM) is an emerging tool to achieve sustainable development in the coastal areas (Vallega, 1993). ICZM is mainly based on a rapidly evolving set of concepts, principles and decision support tools designed to provide guidance for the planning and management of human activities in coastal areas. Coastal management is integrated when a single program covers the whole extent of one ecosystem or a set of contiguous ecosystems that can be identified and brought under a single framework (Brommer, M.B. & Burgh, 2009).

AGENDA 21 identified ICZM as an instrument to handle both environmental and socio-economic problems faced by the coastal belt. The ICZM approach is concerned with long term anthropocentric perspective area development plan. It attempts to bridge the gap

between ecology and economy, environment and development and the reality and of interdependence not among the sectors alone but also among communities and nations (Agenda 21, 1992). Therefore, an ICZM Plan must be based on proper understanding of the ecosystem interaction between natural and artificial systems, the relationships between coastal environmental components and purposeful human activities, existing load and potential of the area under consideration.

To work out a functional management plan within the conceptual ICZM frame outlined above considers the following aspects:

1. Defining the coastal zone and its characteristics
2. Setting up of goals, objectives and policies
3. Inventory and mapping of the coastal resources and use that covers ecological, economic and social issues (Chakrabarty, 1987)
4. Identification of ecosystem units, subunits and characterization
5. Environmental assessment and ecosystem wise listing of problems, opportunities and needs
6. Drawing up of specific policies and plans for each ecosystem unit
7. Setting up procedures and methodology for implementation of the policies and plans
8. Draft plan preparation; linkage with other organizations, government departments and public hearing
9. Revision, finalization and adoption of ICZM Plan
10. Alternatives / Developing Environmental Impact Assessment (EIA)
11. Implementation of the plan and monitoring
12. Developing a Coastal Zone Information System (Chakrabarty, 1987)

Activities undertaken through these steps will generally help involving planning for avoidance, mitigation, compensation and remedial measures as well. Apart from these,

land use zonation, flood zonation, creating a buffer zone and general conservation practices can also be introduced as institutional mechanisms.

3.3 GIS technology and coastal management

For a sustainable land use, nowadays, Coastal Zone Management (CZM) requires more and more data integration, multi-disciplinary and complex analysis, and needs faster or more precise information for the participants in the CZM approaches. Certainly, Geographic Information Systems (GIS), which has a strong capacity in data integration as well as analysis and visualization, become the main tool to support CZM (Falconner, 1990). Creating basic information on coastal areas using the latest technologies like remote sensing and GIS is envisaged for better management and planning of the coastal environment and its resources (Nayak, 2002).

Determining the accurate length of the coastline is important for shoreline classification, monitoring the erosion and accretion, mapping coastal resources, habitat assessment and for the planning and response to natural and man-made disasters (Nayak, 2002). Coastal zone management, by definition, is mainly spatial management (Falconner, 1990). Geo referenced spatial data is a map data in a digital form, which means that each of the earth's features that is stored as spatial data has a unique geographic reference corresponding latitude and longitude. Through GIS, not only scientific data, maps and pictures would be collected, but even a database for infrastructures such as ports, coastal highways and breakwater structures will also be developed.

The increasing use of GIS (Geographic Information Systems) by organizations and researchers is a tool for solving the planning and management issues in the coastal zone. There are many different Geographic Information Systems in use today and they tend to differ in certain aspects such as "how they link geographic location with the available information about those locations, the accuracy with which they specify geographic location, the level of analysis they perform and the way they present information as graphic drawing" (Falconner, 1990).

Nowadays, GIS has been applied at the coast in order to monitor the wide range of natural and human-induced changes , including:

- changes in the extension and ecology of wetlands (Nayak, 2002)
- analysis of shoreline changes like erosion and accretion (Chattopadhyay, 1996)
- assessment of potential and actual flood hazard and damage (Nandakumar & Muralikrishna, 1998)
- monitoring the changes of land use in the coastal hinterlands, in particular the growing urbanization of the coastal fringe (Falconner, 1990)
- monitoring the behavior of oil spillages in coastal environments

4 Previous research

On a global level, coasts comprise 20 percent of the Earth's surface, yet they host a significant portion of the entire human population, approximately 50 percent of the human population live within 200 km of the coast (UN, 2002). Coastal ecosystems are highly productive and contain high biological diversity, rich fishery resources and significant seabed minerals. Coasts also support a wide range of related industries like fisheries and aquaculture, tourism, shipping, oil and gas industries which provide enormous economic productivity. However, the shared demands placed by densely populated coastal regions impose stresses on coastal systems and resources. For example, at a global level, 48 percent of fish stocks are fully exploited and 28 percent are depleted, overexploited or recovering (FAO, 2001).

Water quality is impacted by pollution from ships and pollution from land-based sources for example intensification of agricultural practices contributes to the impact of nutrient loading and eutrophication of estuaries and bays (GESAMP, 2001). Fossil fuels continue to exacerbate global climate changes with severe consequences for coastal ecosystems and coastal inhabitants (IPCC, 2001).

Development pressure on the coastal area continues as a result of social and economic driving forces such as urban expansion, tourism industries, etc. For example, coastal tourism has led to increases in the number of marinas, golf courses and residential buildings near the coast. There is insufficient information by which to judge the current rate and long term environmental implications of coastal development (EPA, 2000).

It is now recognised that the regional impacts of climate change are becoming more severe (IPCC, 2001). Climate studies in CMRC and the Department of Geography, University College Cork, indicate that increased impacts from storminess are likely to be significant for Ireland. If the sea level rises in tandem with greater and more frequent storms, coastal flooding and erosion problems will become exacerbated in vulnerable coastal areas (Devoy, 2000).

What is now widely recognised in the literature as Integrated Coastal Zone Management was conceived in the early 1970s as Coastal Zone Management. USA, since 1972, took serious efforts for CZM and various legislations have been enacted to effectively implement coastal zone management plan (Clark, 1991). The inclusion of ICZM as one of the principal recommendations of Agenda 21, at the United Nations Conference on Environment and Development (UNCED) – the Earth Summit - in Rio de Janeiro in 1992, gave the concept both international prominence and political legitimacy.

5 Study area

5.1 Kerala

5.1.1 General background

India is one of the highly populated countries in the world. India has a coastline of 7,516 km and nearly 250 million people live within a distance of 50 km from the coast (Thanikachalam and Ramachandran 2002). The demographic pressure, rapid industrialization and urbanization in coastal cities have added a variety of coastal problems to the Indian coastal ecosystem. The development activities in the coastal zone, coupled with the population increase in the narrow stretch of land, pose enormous stress on the coastal environment, thus affecting the ecological balance of the coastal zone.

In India there are nine coastal states and two coastal union territories. Among all the coastal states in India, Kerala has the highest concentration of people living in the coastal belt, as much as 42 % of the state population (Chattopadhyay, 1995). Thus the major issues related to the coastal erosion, degradation of coastal vegetation, coastal resource management and intense economic activities in Kerala warrants special attention. And experiences so far obtained in implementing a Coastal Zone Management plan in Kerala

indicate that there are perceptional differences in handling the issues, resulting in serious drawbacks (Chattopadhyay, 1996).

Kerala is an Indian state located at the extreme southern tip of India. Kerala is bordering on Karnataka to the north and north-east, Tamilnadu to the east and south and the Arabian Sea in the west. The state has an area of 38,863 km^2 that is lying between northern latitudes 8°18' and 12°48' and eastern longitudes 74°52' and 77°22'. As Kerala is situated along the southwest coast of India it has long sea shore of 590 km that includes sandy beaches, mud banks, rocky cliffs, lagoons, estuaries and barrier islands. Kerala's coastal belt is relatively flat, and is crisscrossed by a network of interconnected brackish water canals, lakes, estuaries, and rivers.

Fig 1. Location Map of Kerala
http://www.thekkottil.com/pradeep/aboutkerala.html

5.1.2 Coastal ecosystem in Kerala

Kerala, located in the south-western part of the Indian peninsula is situated between the Lakshadweep Sea and the Western Ghats. Due to the abrupt fall in the height from the Western Ghats crest to the midland within a short distance, rivers lose much of their gradient, flow lifeless and emerge into the sea through backwaters (estuaries / lagoons). Coupled with this a series of sea level fluctuations has contributed to evolving various coastal features (Nair.K.M, 1995). There are large extents of coastal features ranging from

the coastal beach, sandy coastal plains, rocky coast, reclaimed mudflats, coastal wetlands, back waters, estuaries and barrier islands.

There are relatively 44 rivers and streams in Kerala (KSLUB, 1989). And 41 out of the 44 rivers in Kerala are west flowing, and originate mainly from the Western Ghats. They merge with the Arabian Sea either directly, or through the medium of the backwaters. Some smaller rivers, like the Kumbala, and Bekal, have separate watersheds, and drain into the sea through the channel of the backwaters. There are a very few fresh water bodies along the Kerala coast. Kerala has many estuaries locally known as 'kayals' all along the Kerala Coast. Estuaries are the lower part of the river that is affected by the mixing of the fresh water and salt water.

The row of barrier islands and backwater systems of the Kerala coast is unique in the country. It has a high biodiversity unparalleled in the country (Nayar, 2002). The mud banks, which are unique to this coast, are one of the largest fish breeding and fishing grounds in the country (Nair.K.M, 1995).

Mangrove vegetation is an important coastal ecosystem associated with tidal /mud flats and back water systems in Kerala. A comprehensive survey on the extent of mangrove vegetation in the State is yet to be undertaken (Gopalan, 2002). However, there are various estimates, for instance it has already been indicated that according to one estimate Kerala had 700 sq.km of mangrove, which had decreased to less than 42 sq.km (Mohanan, 1997). Some other estimates indicate the extent of mangrove vegetation to be 16.71 sq.km at present within a distance of 500 m from the coastline (Nayar.M.P, 2002).

5.1.3 Coastal Zone Management in Kerala

At present ICZM in India is at a fundamental stage though the preferred approach of the country towards coastal area management accepts the application of an integrated coastal management strategy for ensuring sustainable use of the coastal resources at the local level (Chakrabarty, 1987). But Coastal Zone Management (CZM) in India has gained more importance mainly after the Tsunami attack in 2004 for natural disaster management and also for the proper resource management.

The first initiative was by the Central Government through the Ministry of Environment and Forests (MoEF), which issued guidelines for the protection of beaches in India (1984). Then the Environment (Protection) Act was disseminated in 1986, which envisaged drawing up of provisions for protection of the coast. The most important coastal management initiative was the introduction of the Coastal Regulation Zone Notification in 1991 under this Act declaring coastal stretches of seas, bays, estuaries, creek, rivers and backwaters which are influenced by tidal action (in the landward side) as Coastal Regulation Zone (CRZ) and restricting all the developmental activities within this zone.

Considering the importance of the coastal area a 500 metre zone from the high tide line (HTL) had been identified to regulate the activities in the coastal zone. There are four types of zones in India, namely CRZ-I, CRZ-II, CRZ-III and CRZ-IV (Government of India, 2005).

CRZ-I: Areas that are ecologically sensitive and important, such as national parks/marine, parks, sanctuaries, forest reserves, wildlife habitats, mangroves, corals/coral reefs, areas close to breeding and spawning grounds of fish and other marine life, areas of outstanding natural beauty/historically/heritage areas, and areas rich in genetic diversity.

CRZ-II: Areas that are already developed up to or close to the shoreline. For this purpose, "developed area" is referred to as that area within the municipal limits or in other legally designated urban areas, which is already substantially built up and which has been provided with drainage and approach roads as well as other infrastructural facilities, such as water supply and sewerage mains.

CRZ-III: Areas that are relatively undisturbed and do not belong to the areas of either CRZ-I or CRZ-II. These will include the coastal zone in the rural areas (developed and undeveloped) and also areas within municipal limits or in other legally designated urban areas, which are not substantially built up.

CRZ-IV: Coastal stretches in the Andaman & Nicobar, Lakshadweep and small islands, except those designated as CRZ-I, CRZ-II or CRZ-III.

However, there has been serious debate on these regulations as they primarily control construction activities in the coastal zone. A densely populated coastal zone as is seen in Kerala can hardly adhere to the stipulated regulation because there are areas of strong erosion and in some areas, settlements are located right on the coastline. Therefore, serious

concern about the coastal regulations and its applicability has led to considerable rethinking among the policy makers, administrators and other stakeholders about these issues.

Erosion and accretion of the coastline is a natural phenomenon in Kerala, and the vulnerability of the coastline increases due to absence of any coastal vegetation. The high density of population and the associated investments in the coastal region make the impact of erosion all the more significant (Baba, 1995). Therefore, rock walls were the major coastal protection measure adopted in the state. This has been tried for about 360 km out of 590 km of Kerala coast (Nair. M.M, 1987). Unfortunately, it has proved to be an environmental disaster in many locations due to the restrictions it poses for normal beach processes (Chattopadhyay, 1996). In other words, the seawall itself is under erosional threat in certain areas (Baba, 1995). The aesthetics of the coast is also compromised at a time when the State is promoting coastal tourism as a major economic activity.

5.1.4 Land use of coastal areas in Kerala

The Kerala State exhibits a much diversified land use pattern and the coastal belt is no exception to this general trend. Depending upon the variations in topography, soil type and water availability the land use type even in the coastal belt shows high diversity. Activities in the coastal zone of Kerala can be broadly categorized under six land use types, i.e. namely fishing, agriculture, and industry including port, human habitation, tourism and infrastructure (KSLUB, 1989). Land requirements for these activities are always limited and there are competing uses or multi-usability of land. Kerala's marine fish production is the largest in the country. This is in addition to the brackish water fishery. Though under-exploited, the State has a large potential for semi-intensive aquaculture including mussel and pearl culture (Ramachandran .S, 2001). About 300 medium and large scales, and about 2000 small scale industries, ranging from fishing to mining of radio-active minerals, are located in the coastal zone of Kerala (KSLUB, 1989).

Land use within 500 m of coastal zone is dominated by coconut palms in Kerala (KSLUB, 1989). The cropping pattern on the coastal plains of the state shows that other than coconut palms, paddy is the main crop cultivated. Plantation of crops like, rubber, cashews, pepper and tapioca which is the common food in the area, is grown along the fringes of paddy fields throughout the coastal plains (Kannan M.R.2001). Coconut husk rotting is one of the major

coastal activities throughout the state contributing to water quality degradation (Nizimuddin & Basak P, 1997). The husks of the coconuts are separated from the nuts and are rotted in coastal lagoons for up to ten months. The rotted husks are then beaten with wooden mallets manually to produce the golden fibre. Agriculture and coconut rotting continue to sustain livelihoods in major parts of the coastal belt in Kerala.

5.2 Major issues concerning the coastal zone of Kerala

Coastal erosion, water logging, saline water intrusion, degradation of surface and sub surface water quality, loss of biodiversity, loss of agricultural biodiversity, degradation of wetlands, siltation of canals and traditional water harvesting structures, lime shell mining, sand mining, clay mining, land diversion from food crop to non food crop and/or other use are some of the environmental problems encountered in Kerala. As a preface, some of the main coastal issues in Kerala have been described.

5.2.1 Coastal erosion

One of the coastal problems to be considered in Kerala is mainly coastal erosion. When the landward displacement of the shoreline results in the loss of sub-aerial landmass into a sea or lake due to the forces of waves, wave currents, winds and tides, or even due to the human interference it is termed as coastal erosion (Baba, 1995). Natural factors that cause erosion in Kerala are heavy rainfall, loose sandy sea shore, sub-terrain pressure from low inland areas, increase of water level in the sea due to melting of ice in the polar region, destruction of mud deposits in the sea, and heavy discharge of water devoid of alluvium (silt and clay). From the human interference point of view, the main factors that influence coastal erosion are overexploitation of coastal resources like beach sand mining, vegetation, destructive land use practices, sea walls and inadequate coastal management (Baba, 1995).

The coast of Kerala is severely affected by coastal erosion. About 80% of the entire coastline of Kerala is affected by long term coastal erosion and part of the coastline of Kerala is affected by erosion and accretion in monsoon months (Baba, 1995). Accretion is a process of increase in land along the shores of a body of water, as by sand deposit. And it is evident that some of the early eroding sites are either stabilized or in the processes of

accretion. Similarly, parts of accreting beaches are now subject to erosion(Chattopadhyay, 1996).

5.2.2 Habitat destruction

Kerala is well blessed with wetlands and the coastal wetlands accounts for 24 % of the total geographical area of the State (Gopalan, 2002). This major coastal ecosystem is facing severe environmental degradation due to several reasons. The size of wetlands is decreasing, the depth is reducing due to siltation and there is a serious water quality problem. The mangrove vegetation has decreased and the critical habitat, like turtle breeding grounds, is also under threat. For example, the nesting sites of Olive Ridley turtle (*Lepidochelys olivacca*), one of the endangered turtle species, at the Kolavipalam beach on the northern coast of Kerala, is currently facing threat of degradation due to human intervention in the form of habitat destruction and physical disturbance (Ramachandran, 2001).

5.2.3 Coastal flooding and saline water interference

Flooding due to heavy rainfall during monsoons is one of the major problems faced by the people living in the coastal belt of Kerala. In addition to this, urbanization, settlement expansion, construction activities, reclamation of wetlands also contribute to this. Salt water intrusion into the agricultural lands due to flooding creates problem to those depending on the coastal agriculture (Baba, 1995). Due to river sand mining and the regulation of river water flow in the coastal area, as a result of dam construction in the upper region, saline water and fresh water interface has been pushed landward which results in the degradation of ground water quality (Nizimuddin & Basak P, 1997).

5.3 Case study area- Mararikulam Panchayats

Erosion of coastal areas is a common feature that occurs in Kerala and the coastline of Kerala is a typical example of an area that is vulnerable to erosion. The coastal erosion affects badly even the structures that are intended to protect the coast. Among all the districts of Kerala, Allappuzha, a coastal district, has a unique ecological habitat that

includes canals, backwaters, lagoons, mud-banks and beaches. Mararikulam South and Maraikulam North are the two Coastal Grama Panchayat areas selected for the study from the Alappuzha district.

Fig 2. Allapuzha district map
http://www.spiderkerala.net

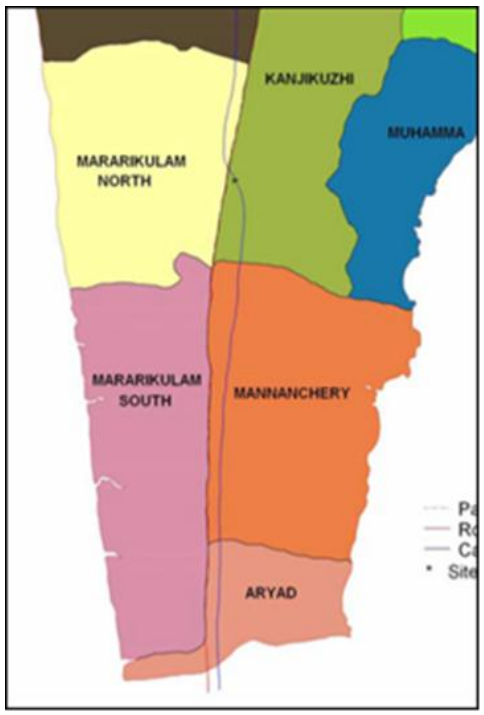


Fig 3. Mararikulam North & South Panchayat
GIS Lab, Centre for Earth Science studies

Physiographically, the major part of the both panchayat areas is classified as coastal plains. The general elevation of the area is less than 6 m above mean sea level with some of the areas below the mean sea level. Since the population density is very high (1,415 persons per sq km) in the district compared to the State's average (749 persons per sq km), the land is intensively used both for cultivation and for human habitation. Coastal alluvial sand covers the entire Mararikulam South and it has about 3.4 km^2 area falling under the 500 m regulation zone. Mararikulam North has about 2.37 km^2 areas falling within the 500 m Coastal Regulation Zone and 0.02 km^2 areas in the 100 m regulation zone. Altogether the coastline runs for 20 km along the west of both panchayat areas. Beach sands occur along the coast with an average width ranging from 0.5 to 1 km, and are essentially made up of fine to medium quartz sands.

Mararikulam receives two monsoons in a year. The highest rainfall in both panchayats is recorded during the month of June in Alappuzha climate station of the Indian Meteorological Department. There is a rainfall in every month except January. mean monthly temperature varies between 27º and 32ºC.

Mararikulam North comprises small villages like Perunormangalam, Kanichukulangara Beach, Poklasheri and Chennaveli. And the South Panchayat comprises Kattoor, Pollathai, Valavanadu, Preethikulangara, Omanapuzha, Kalavoor, Pathirapally, and Chettikadu.
The main livelihood of the people in these two panchayats is fishing and coir yarn spinning. Various social groups belonging to all major religions inhabit the coastal zone. The major single coastal community is the fishing population, who are considered socially and economically back-ward due to various reasons. The vast majority of the fishing community takes part in fishing and allied activities, like small-scale fish distributors, fish curers, and peeling shed workers, etc. Marine fishing dominates and backwater fishing is limited in both panchayats. The other social communities pursue the vocation of agriculture, industry and other services.

The main actors involved in coastal resources comprise fishermen, other neighborhoods, and market operators, owners of the industries, tourism promoters, government and local people. The various social groups operating in the coastal zone are the fishing population, cultivators, agricultural workers, people engaged in traditional industries like coir, modern industrial workers and other communities. M. South and M. North has a relatively long coast protected by a seawall due to major problems like coastal erosion, encroachment, coastal flooding, etc.

6 Methodology

6.1 Map preparation

Producing a cadastral map of the study area using Geographic Information Systems (GIS) helps to pasteurize and estimate the current trends and status of land use and coastal erosion of the study area. Therefore, a land use map of the study area was produced from topographic maps and satellite image using Arc GIS to see the trend and the nature of changes in the land use of Mararikulam North and South for the last 40 years. A detailed study of the erosion and accretion trends, land use changes through socio-economic survey helped to come up with the alternate ideas as a result of an appropriate Coastal Zone Management Plan for Mararikulam Panchayat (South and North).

The two satellite images dated 2005 of Alappuzha district were rectified with the help of ERDAS software with reference to a Survey of India topographic map no 58 C/6 (Scale 1:50 000). An area of interest, Mararikulam South and North Panchayat was selected as a subset from rectified images. An analysis and interpretation of the land use map was done with the rectified 2005 satellite image and the geo-rectified topographic map of 1967 by digital image processing. The land use map developed using 2005 satellite data and the geo-rectified topographic map of 1967 revealed the erosion rate of the Mararikulam North and South Panchayat.

6.2 Socio-economic survey

As a major part of data collection, socio-economic field survey was conducted along the coast of Mararikulam South and North Panchayat. The field survey was carried out in the form of questionnaires and interviews in October and November 2011 on the study area. The field survey was conducted with the local people, shop keepers, fishermen as well as the tourists of Mararikulam South and North. Undoubtedly, the fishermen population becomes the dominant segment of the population in the coastal zone of Mararikulam South and North panchayat so the number of field surveys of the fishermen is higher than the other category of people.

Table 2. Number of people interviewed in the socio-economic survey

Name of the Panchayat	No of Fishermen	No of Shop keepers	No of Local people	No of Tourists	Total No of Samples
Mararikulam South	15	8	11	3	**37**
Mararikulam North	15	17	14	7	**53**

Shops along the coast in Mararikulam South were very few when compared to Mararikulam North, where the shops and tourism activities are more. Though tourism is one of the major activities in Mararikulam South and North, the number of foreign visitors and the domestic visitors, who visit often, is very few so the survey conducted with the tourists was not effective.

Coastal area data, i.e. namely the current status and the trends of the coastal changes, types and nature of land use practices of Mararikulam South and North have been demarcated on the basis of field survey. The type, condition and the existence level of coastal vegetation and the current status of the erosion and accretion beaches were noted on the basis of field observations and the information gathered from the local people.

7 Result

7.1 Land use in Mararikulam South

Use of land along the coast of Mararikulam South is mainly settlement with coconut palm vegetation and fishing activities. But it was observed that since 2004 there is a vast change in the land use after the beach started to erode in Mararikulam South. The available land is undergoing rapid changes in its use and cover. Coastal areas that were used for settlements before the tsunami attack (2004) in Mararikulam South have sold for resorts and used for recreational activities. Due to severe erosion, strong wave currents and the coastal flooding, the beach vegetation is sharply decreasing and almost not existing in Mararikulam South. As the resorts mainly occupy most of the coastal area and beaches, the fishing activities are decreasing and there is not enough space for drying fish, so the local people and the fishermen cut the coconut trees, remove the climbers that grow on the beach and pluck up all the Common Ironwood trees planted by the government in 2010 for the protection of the coast against coastal erosion.

Flooding is one of the natural hazards that affect M. South during the monsoons. Some coastal parts of M. South are protected with seawalls. According to the local people and fishermen, there is no benefit of seawalls and thus do not protect the coast from erosion due to the poor maintenance.

Additionally all the fishermen of M. South agreed that there is a change in the composition of fish in M. South and there is a decrease in the annual fish catch also. The main livelihood of people in both panchayats is fishing, and a decrease in the quantity of fish catch is a major concern expressed by the local people.

Fig 4. Fishing activities in Mararikulam North Panchayat
Photographer: Gayathri Pandurangan (2011)

7.2 Land use in Mararikulam North

The use of land along the coast of Mararikulam North is mainly settlement with coconut palm vegetation and for fishing activities. As there is an evidence of coastal accretion, the fishermen get enough space for themselves and gradually the fishing activities are increasing in Mararikulam North. People living in the critical areas near the shore-line are often threatened by the changes in the coastal ecosystem. The major coastal issues observed in Mararikulam South are coastal erosion, coastal flooding, and degradation of beach vegetation. On the other hand, Mararikulam North is not facing such coastal issues due to the accretion of the beach.

7.3 GIS Analysis of the change in the land use

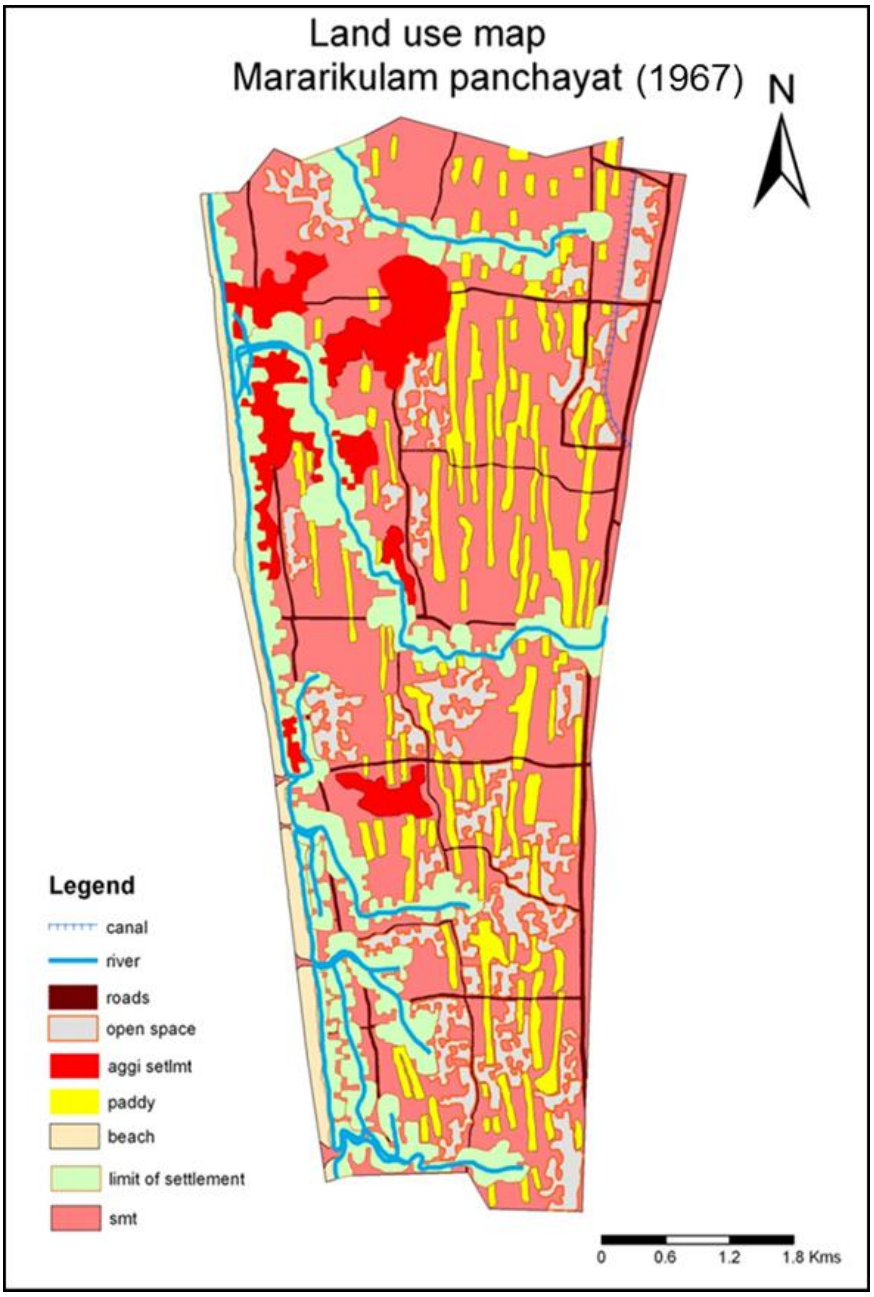


Fig 5. Land Use Map of Mararikulam South and North in 1967

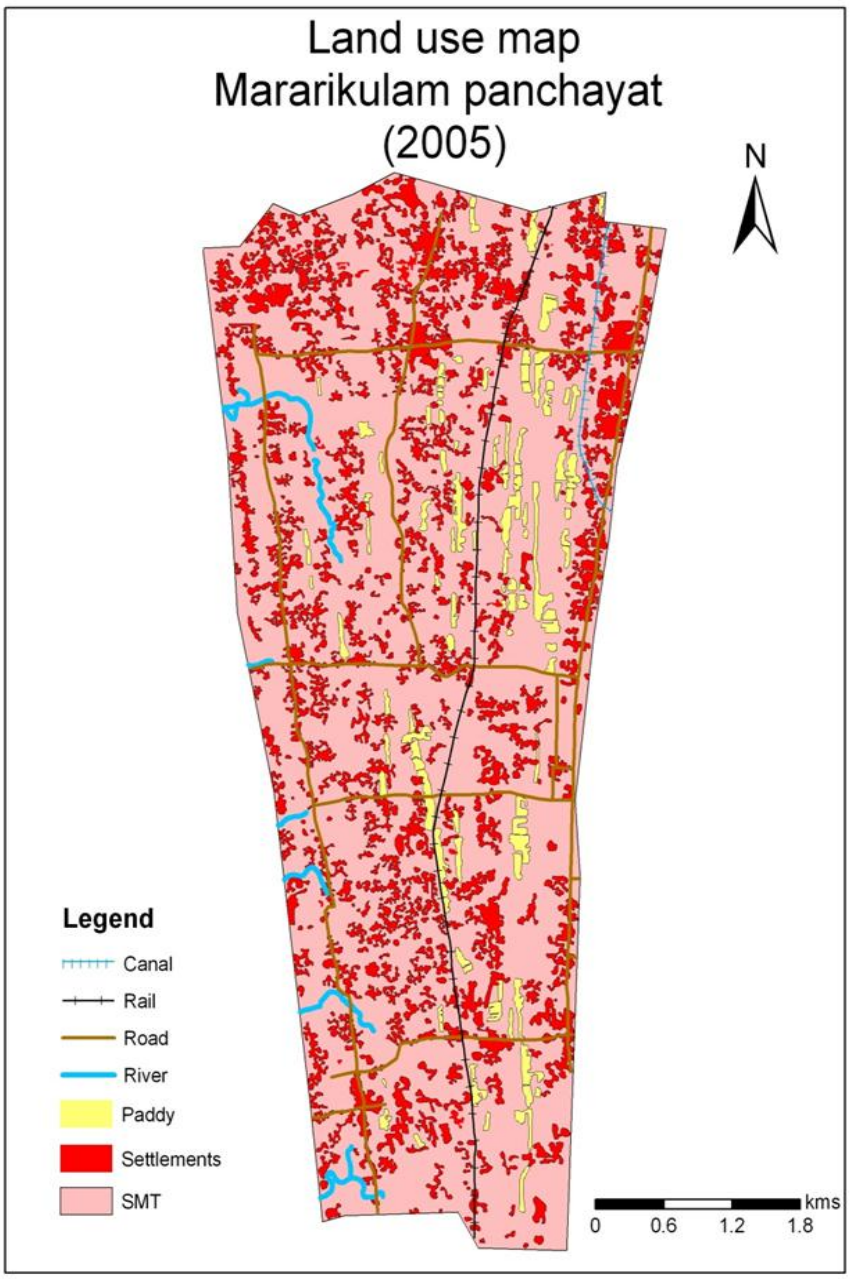


Fig 6. Land Use Map of Mararikulam South and North in 2005

Two sample maps showing Mararikulam South and North panchayats land use are provided here (Fig.no. 5 & 6). Mararikulam South panchayat in Allapuzha district show severe erosion since 1967 whereas Mararikulam North panchayat show considerable acrretion since 1967, the year for which cadastral maps are available. Both maps show land forms, land use and resources, runnel and ridge topography characterise the area. However, there is a huge variation in land use practices in both panchayats since 1967.

It was traditional to cultivate paddy in the runnels in early days but now these lands have been diverted for tree crops like coconut and mixed trees.

It is clear from this map (Fig. 6) that there are more than a 150 m accretion in Mararikulam North Panchayat and the people are living very near to the coast in the newly emerged lands. In the case of Mararikulam South, the coastline is dominated by severe erosion since 1967 till the survey date (2011), and the local people, who were living in the coastline, have migrated to some other places.

7.4 Coastal erosion

A major portion of the coastline of Mararikulam South is subjected to severe erosion when compared to Mararikulam North during the monsoons, when the sea becomes rough due to the consistent attack of waves. The coastline is sometimes subjected to tidal overflow as well, when adjoining low lying lands are submerged. Erosion is very severe in the coastal area during the south-west monsoon (April to October) period. Coastal erosion is controlled by various parameters e.g. like the nature of beach sediment, beach morphology, tidal currents, wave activities, etc. In addition, it is observed from the field that, in most of the eroding sites, the nature of the sand is coarser when compared to the accreting beach, where the sand is finer. It was also noticed that there are deposits of some black silt and clay in the eroding sites.

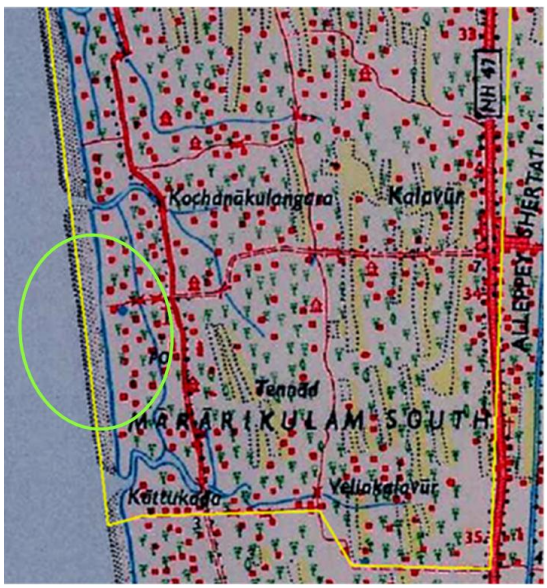


Fig 7: Cadastral Map of M.South dated 1967
GIS Lab, Centre for Earth Science Studies

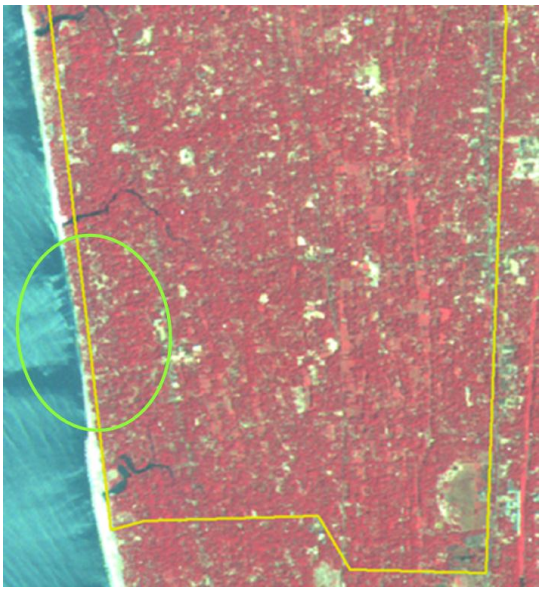


Fig 8: Satellite image of M.South dated 2005
GIS Lab, Centre for Earth Science Studies

When comparing the land use map of M. South dated 1967 (Fig. 7) with the satellite image of M. South dated 2005 (Fig. 8) it is evidence that coastal erosion is increasing at a faster rate almost 10 km since 1967, especially along the coast of Kattur village (the area that is

highlighted in the Fig. 7 and Fig. 8) when compared to other coastal areas of both panchayats. On the other hand, the land has accreted about 5 km in Mararikulam North since 1967.

Fig 9. Coastal Erosion in Mararikulam South
Photographer: Gayathri Pandurangan (2011)

Fig 10. Coastal Accretion in Mararikulam North
Photographer: Gayathri Pandurangan (2011)

7.5 Decrease in beach vegetation

Another major coastal issue of Mararikulam South is decrease in coastal vegetation which is a sign of severe coastal erosion, and which is directly related to the socio-economic status of the coastal community. At some of the places in Mararikulam South, where coastal erosion is severe, the condition of coastal vegetation, especially coconut palms are critical. Plantation of Common Ironwood trees by the government, in order to prevent the coastal erosion, are also noticed in a few places. According to the local people from M. South, the beach vegetation is decreasing because the fishermen do not have enough space for drying fish and therefore sometimes cut the trees and remove the climbers that grow on the beach.

Fig 11. Local people removing the climbers that grows on the beach
Photographer: Gayathri Pandurangan (2011)

Through intensive field work, the current condition and the existence level of the coastal vegetation is as follows:

Table 3. Existence level of Coastal vegetation in the study area

Name of the Panchayat	**Beach vegetation**			
	Not existing %	**Very little %**	**Moderate %**	**Dense %**
Mararikulam South	**11.7**	**55.8**	**32.3**	**-**
Mararikulam North	**-**	**17.3**	**60.8**	**19.5**

7.6 Coastal problems in Mararikulam Panchayats

The analysis of available data has brought out the main problems and prospects in the coastal zone of Kerala. Coastal problems, driving forces and possible impacts in Mararikulam North and South panchayats are as follows:

Table 4. Coastal problems, driving forces and the possible impacts in Mararikulam North and South

Coastal problems	Driving forces	Possible impacts
Coastal erosion	Natural process Decreasing coastal vegetation End erosion associated with seawalls	Loss of beach Loss of potential tourism Restricted fishing activities Restricted beach activities of local people
Coastal flooding	Sea level rise	Destroy coastal habitat Saltwater intrusion
Loss of coastal vegetation	Change in habitat condition Population pressure Increasing tourism activities	Loss of habitat Loss of natural protection against erosion

8 Discussion

Of these two panchayats, Mararikulam South is undergoing erosion and Mararikulam North is undergoing accretion. Some parts of the coast are eroding, apparently, without any human intervention; hence it is believed that the phenomenon is natural, precisely due to wave action. And some parts of the coast started to erode mainly after the human activity started in that area. Hence the question that comes into our mind is, is there a connection between the land use changes and the changes that occur in the coastal ecosystem?

Wherever the coast is experiencing the coastal erosion, the seawalls are constructed and why are the seawalls not holding out? Is it because of poor construction or due to unsuitability of the solution? And is there is any possibility of finding a lasting solution to this problem, because huge sums are spent year after year in Kerala to mitigate the coastal erosion but without a long term resolution.

When rain falls on land, the following runoff carries eroded sediments from land all the way through the natural drainage pattern to the sea. This process is set to go until the land is eroded to the level of the sea, or till a next tectonic disruption pushes the land higher or sea into the dry land. Therefore, from this rainfall-runoff-erosion-drainage cycle it is

obvious that land will go on eroding with sediments being transported to the sea, across the coast. As a result, two things will happen, progressively. The coast will grow seaward, and the sea off this extending coast becomes shallower. The sea becoming shallower is actually due to the undersea extension of land precisely the growth of the continental shelf. All dormant coasts or what the geologists term as 'passive continental margins' are subjected to depositions of land sediments and extension of the continental shelf.

The coast of both Mararikulam South and Mararikulam North coasts are 'passive continental margins' with practically no tectonic activity. Obviously, both coasts must extend seaward, naturally. With the monsoons still going strong as ever, then the erosion and the subsequent accretion along the coast must continue and it should extend seaward. But then, why is the coast eroding and why only sections of the coast?

Actually, human activity plays an important role in this process and every section of eroding coast can be connected to a human activity. For example, the long sections of the coast started to erode immediately after the highway was laid very close to the coast, in Kerala and Karnataka. Then in Fort Kochi(in Kerala) beach started eroding when the Navy built a caisson jetty from Wellington Island, just North of Thevara Bridge in Kerala (Kumaran, 1994).

From this study it can be seen that the linkage between land use changes and its impacts on the coastal ecosystem is not a direct one. But the changes in the land use are also one of the driving forces for coastal erosion in Mararikulam South. For example, removing the coastal vegetation and using that land for fishing activities does create a great impact on the coastal ecosystem. According to the local people of both panchayats, the climbers that grow on the beaches are not planted by anyone and they grow naturally on the beaches, which in turn keeps the beach sand tight and prevents coastal erosion. But due to the lack of land for fishing activities the fishermen are forced to remove the coastal vegetation in Mararikulam South.

According to the local people of Mararikulam South, it is evident that leaving such climbers undisturbed helps in creating a new coastal habitat. Likewise in Mararikulam North, when the climbers started to grow, the land was left undisturbed and it helped in preventing the coastal erosion in the coast where erosion took place for almost 15 years.

After the Tsunami attack in 2004, the local people of Mararikulam South realized that the beach vegetation prevents erosion and planted coconut palms all over the coast of Mararikulam South. But it is well known that coconut trees due to its shallow fibrous root system, it do not have the capability of holding the beach sand tight and thus it does not help in preventing the erosion. Then in the late 2010, the government planted ironwood trees all over the Kerala coast and it was an effective barrier to prevent coastal erosion. But in the case of Mararikulam South, the locals removed most of the ironwood trees from the coast, whereas these barrier trees resulted in creating many social and cultural problems. The tourists and the youngsters use the advantages of the bushy tree to hide themselves and perform illegal activities that created public nuisance. When the people remove the ironwood trees from a coast that is vulnerable to erosion, it does have a great impact on the coastal ecosystem. Furthermore, after the plantation of the barrier trees in 2010, the government officials did not visit or monitor the condition of the coast and the barrier trees, which clearly shows the mismanagement of the coast.

Of these two panchayats, one in the erosional stretch and another in the accreting stretch indicate two different problems to be handled by institutional intervention. In case of an accreting area conflict arises about the land use among the landowners about the ownership aspect. And the point to note is that, can anyone claim ownership right of a land that emerged as a part of natural processes?

And the second issue is where a land is eroded, how can the owner of the eroded land be compensated?

A comprehensive coastal zone management plan cannot be effective without paying attention to these issues. Though the erosion and deposition is happening every year in both panchayats, the necessity of constructing seawall in similar circumstances is needed and the plan to construct such seawalls should not be stopped. Again, rehabilitation of displaced persons in risk zones along the coast should be avoided, even though the coast in Mararikulam North shows the accreting trend. While the seawall gives temporary protection, threats due to coastal flooding cannot be ruled out.

Plantation of effective vegetative barriers along the beach should be reestablished to ensure a better protection for the shoreline from erosion. Current knowledge about selecting the suitable species of trees that can prevent erosion is inadequate. However, more research is

still needed for determining the effectiveness of the tree species that can protect the coast from erosion. In some cases, re-vegetation fails because environmental conditions do not favour the growth of species at that particular site or it is also possible that anthropogenic influences have completely altered the natural processes in that area. Hence, the most obvious indicator of site suitability is the presence of vegetation already growing. This can be extended by other factors such as the slope, elevation, tidal range, salinity, substrate and hydrology. Planting vegetation species relative to their correct elevation in coastal environments is important (French, 2001).

The resource base in both panchayats is subject to severe stress, which can be attributed to mismanagement of the coastal zone. People depending on the local resource are pressed hard to sustain their living as the changes in the coast impose restrictions on resource availability or access to the resources. A mutual re-enforcement trend is observed between land use changes and its impact on the coastal ecosystem. Policy regulations and interventions have a strong link to the changes in land use and cover. Therefore, a proper coastal management plan with due attention to conservation measurements can mitigate the situation and provide necessary support to address the issue of coastal problems.

Generation of detailed data covering all aspects including biophysical, biodiversity, resource use, socio-economic characteristics, environmental degradation, etc. will be the first step in the direction of addressing improved management. This will be followed by interaction among various stakeholders on definite issues emerged from the data analysis. The future course of action, priority fixation, program execution and similar other intervention measures can be worked out subsequently. The level of biodiversity, loss of species, both endemic and endangered, and the scope of halting further degradation are emerging issues warranting further surveys and mitigation action to arrest these trends. Impacts of on-site as well as off-site human activities are yet to be assessed in detail. Global Positioning System (GPS), is able to measure and quantify erosion and accretion at a high temporal and spatial resolution. This provides an important contribution to the understanding of local coastal erosion and sediment deposition patterns. And this is significant in decision making for coastal management.

9 Conclusion

Each nation's strategy for good governance is different, and is characterized by their respective culture, geography, political and administrative traditions, economic conditions and other factors. However, from the coastal sector point of view, governments share many challenges and features in terms of how they respond to these challenges.

A continuous balance normally exists between uses and resources in the coastal zone. However, human activities and natural forces affect this balance. Hence, long term modeling of land use and land cover changes in the coastal zone is highly essential. Developing an Integrated Coastal Zone Management is very much essential to sustain users and resources under possible scenarios of natural and socio-economic changes. ICZM could not be a remedy for all coastal problems, but it could address most of the issues and support sustainable development.

Coastal zone management primarily aims to create a contributive environment of economic development with conservation. A development with the least impact on the coast might be the appropriate choice. In order to devise a comprehensive, CZM plan the approach should be based on ecosystem analysis, so that the interrelationships among the various environmental elements are properly understood. To initiate the intervention plans effectively, participation of local people in the planning process need to be ensured. The CZM will be effective only when responsibility will be given to the local people, i.e., traditional users of the coastal zone. It may be pointed out here that the traditional users of the coastal zone follow and react to the order of the natural processes of the coastal zone to a larger extent, and it is the recent development activities that have resulted in various problems.

Based on the study of the coast of Mararikulam North and South as well as observations made during field visits, the following concluding remarks can be made:

- Coastal Management issues are complex in nature and highly interdependent.
- There are limited engineering solutions to control coastal erosion.
- There is a need to emphasize the importance of public participation in the social mitigation process.
- The need to avoid the use of risk zones for development purposes should be highlighted.

- Classification of coast based on erosion vulnerability at cadastral level could help to control the land use and development activities in the coastal zone.
- The ICZM should be periodically reviewed and updated at least every five years in order to take into account the short term requirement of the local population and development schemes of the area.
- Apart from the anthropogenic activities, natural causes also play an important role in coastal environmental changes. Hence, there is an inevitable need to monitor and manage the coastal zones regularly, properly, and optimally.

References

AGENDA 21, (1992). *The United Nations Programme of Action from Rio.* Rio Declaration on Environment and Development.

An evaluation of non-sustainable land use practices using GIS- a case study in parts of Vamanapuram river basin. Dept. of Geology, University College, Trivandrum, India. http://www.scribd.com/doc/3756198/Landuse-practices-in-Kerala (retrieved: 22.04.2012)

Allapuzha district map. CPM candidates in Alappuzha district for Kerala Assembly Elections 2011 http://www.spiderkerala.net/resources/6041-CPM-candidates-their-pofiles-Alappuzha.aspx (retrieved: 03.05.2012)

Allapuzha. New Allied Tour. http://www.newalliedtour.com/travel-map.html (retrieved: 16.04.2012)

Baba, M. (1995). *A new approach to coastal erosion problem.* Paper presented in the first meeting of the "Coastal protection and development advisory committee", Thiruvananthapuram.

Brommer, M.B. & Burgh, L.M.B. (2009), *Sustainable coastal zone management: A concept for forecasting long term and large scale coastal evolution, J. Coastal Res*., 25 181-188.

Brahtz J.F, (1972). *Coastal Zone Management-Multiple use with conservation*. *An approach paper, A model for micro level resource survey with people's participation*. pp. 32.

Cadastral plans and maps. Fundamentals of Mapping http://www.icsm.gov.au/mapping/maps_cadastral.html (retrieved: 22.04.2012)

Centre for Earth Science Studies, CESS, (1998). *Coastal Zone Management Plan of Kerala: Coastal Land Use and Resource Maps of Kerala, final Report*. Vol.3, Submitted to the Department of Science, Technology and Environment, government of Kerala, Thiruvananthapuram.

Chakrabarty S.C. (1987). *An approach to managing coastal environment.* The Indian Geographical Journal, Vol. 62, No.1 pp 1-10.

Chattopadhyay, S (1995). *Environmental impact on urbanization: a case of Kerala, India.* Institute of Indian Geographers. Vol.17. pp.15-27.

Chattopadhyay, S (1996). *Coastal zone management: a methodological approach with examples from Kerala*. Special Issue on Coastal Environmental management. Vol.4. pp. 14- 22.

Clark J.R. (1991). *Coastal Zone Management. In A.Kreimer and M. Munasinghe (eds)* Managing Natural Disasters and the Environment, The World Bank, Washington D.C. pp. 115-119.

Coastal Erosion and Catastrophic Storms, A Case Study on Risk Analysis and Risk Management. Woodrow.
http://www.woodrow.org/teachers/esi/1997/53/ (retrieved: 22.04.2012)

Coastal erosion. Cochin Overseas
http://cochinoverseasfundsociety.blogspot.com/ (retrieved: 24.04.2012)

Coastal Erosion. Our Ocean Planet.
http://oceanworld.tamu.edu/resources/oceanography-book/coastalerosion.htm (retrieved: 22.04.2012)

Coastal Zone Management. Kerala State Council for Science, Technology & Environment
http://www.kscste.kerala.gov.in/pgm_czm.htm (retrieved: 22.03.2012)

Devoy, R.J.N., (2000). Implications of Sea Level Rise for Ireland. In R. J. Nichol and A de la Vega(eds), *Vulnerability and Adaptation to Impacts of Accelerated Sea Level Rise*, pp33-46.

EPA (Environmental Protection Agency), (2000). *Ireland's Environment: A Millennium Report*, edited by Stapleton, L., Lehane, M and Toner, T. EPA, Wexford.

Falconer K H Robin (1990). *Experience with Geographic Information System (GIS) in the marine world*. Hydrographic Journal No. 58.

FAO (2001). *The State of World Fisheries and Aquaculture 2000*. Rome: FAO.

Flint R.W. and Kalke R.D (1985).Coastal resource management. *The ecosystem perspectives In Coastal Zone* 85.pp. 1201-1214.

French, P.W. 2001. *Coastal defences: processes, problems & solutions.* Florence, KY, USA, Routledge. http://site.ebrary.com/ (retrieved: 01.05.2012)

GESAMP (2001). *Protecting the Ocean from Land-Based Activities*. Reports and Studies 66. London: GESAMP.

Gopalan, U.K. (2002): *Backwaters of Kerala-an endangered wetland ecosystem. In Wetland Conservation and Management in Kerala*- A Compendium on the Focal Theme of Fourteenth Kerala Science Congress, STEC, Thiruvananthapuram

Gopinath, G., & Seralathan, P. (2005). *Rapid coastal erosion of the Sagar Island, West Bengal. Environmental Geology*, 48(8), 1058–1067.

I*CZM Action Plan of Mararikulam Area: A discussion note.* Montclair State University. http://chss.montclair.edu/anthro/coastal.htm (retrieved: 22.03.2012)

IPCC (2001). *The Regional Impacts of Climate Change: An Assessment of Vulnerability*, edited by Watson, R.T., Zinyowera, M.C., Moss, R.H. and Dokken, D.J. Geneva: IPCC.

Kannan M.R (2001). Geology and non-sustainable land use practices in parts of Vaamanapuram river basin in and around Koliyakkod, Thiruvananthapuran, Kerala,India – a GIS-based analysis., University of Kerala, India. pp 56-59.

Kerala State Land use Board (KSLUB) (1989). *Land Resources and Land use in Kerala*, Thiruvananthapuram.

Kumaran, P. (1994). *Urban pollution in Kerala with specific reference to Kochi*. International Congress on Kerala Studies, AKG Centre for Research and Studies, Thiruvananthapuram , Vol 5. pp. 175 -176.

Location map of Kerala. Thekkotil.
http://www.thekkottil.com/pradeep/aboutkerala.html (retrieved: 21.04.2012)

Mahamaya Chattopadhyay. (2004), Geomorphology Map of Kerala Coast, in *RETA project for Coastal and Marine Resources management and Poverty Reduction in South Asia, India (Kerala) component*, (CESS Project Report no. 872004, Trivandrum).

Mararikulam. Wikipedia.
http://en.wikipedia.org/wiki/Mararikulam (retrieved: 05.01.2012)

Maragos J.E., Soegiarto A, Gomez E.D. and Dow M.A (1983). *Development planning for tropical coastal ecosystem.* In R.A. Carpenter ed. Natural systems for development, pp. 229-298.

Map of Kerala. Culture holidays.
http://www.cultureholidays.com/kerala/india-kerala-map.htm (retrieved: 16.04.2012)

Nair, M.M. (1987), *Coastal geomorphology of Kerala*, *J.Geol.Soc. of India*., 29, pp.450-458.

Nair K.M. (1995), *Geological history and natural resources of lowland of Kerala*. In Science and Technology for Development STED, Government of Kerala, pp.1-15.

Nandakumar D and M.Muralikrishna, (1998), *Mapping the Extent of Coastal Regulation Zone.* Violations of the Indian Coast, NFF, Trivandrum.

Nayak, S. R. (2002). *Application of remote sensing to coastal zone management in India.* Paper presented in ISPRS Technical Commission VII Symposium on Remote Sensing and Environment Monitoring and ISRS Annual Convention held at Hyderabad, India.

Nayar, M.P., (2002). *Biodiversity of the coastal stretch of Kerala.* A State-Of-Art Report. Local consultant's report, Asian Development Bank.

Nizimuddin and Basak P. (1997). *Ground Water Resources, In The Natural Resources of Kerala,*(Eds.) K.Balachandran Thampi, N.M.Nayar and C.S.Nair, World Wide Fund for Nature-India, Kerala State Office, Thiruvananthapuram pp. 59-64.

Panchayat system in India, India net zone.

http://www.indianetzone.com/40/panchayat_system_india.htm (retrieved: 22.04.2012)

Pirazzoli P.A (1985), *Sea level change, Nature and Resources*, vol.21, No.4, pp.2-9.

Ramachandran, S.,(2001). *Coastal and marine protected areas in India.* In Coastal Environment and Management, Ed. S Ramachandran, Institute of Ocean Management, Anna University, Chennai pp. 138-145.

Soman K (1997). *Geology of Kerala* (Geological Society of India. Bangalore). pp.280.

Thanikachalam, M., & Ramachandran, S. (2002). *Conservation of coral reefs in Gulf of Mannar: A remote sensing and GIS approach.* Indian Society of Geomatics (ISG) Newsletter, Special Issue on Coastal & Marine Environment, 8(2 & 3), pp.65–71.

UN (2002). United Nations Atlas of the Oceans.
http://www.oceansatlas.org (retrieved: 24.04.2012)

Vallega, A (1993). A conceptual approach to integrated coastal management. Ocean and Coastal Management, V.20, pp. 149-162

What is coastal erosion. Coast in crisis.
http://library.thinkquest.org/J0110230/what_is_coastal_erosion%20page%20two.htm
(retrieved: 22.04.2012)

Appendices

Appendix 1: Questionnaire to the local people

1) Name of the respondent
2) Occupation of the respondent
3) For how many years are you in Mararikulam?
4) What are the changes in the coastal area?
   Beach erosion Beach deposition/ accretion
   Change in beach gradient Yes / No (Increased / Decreased)
   No change
5) Is there any change in material composition (Sand size) of the beach especially after the Tsunami?
   Yes No
6) What are the changes in land use?
   Nature of change:
7) Beach vegetation- existing / not existing
   If existing what type of vegetation?
8) What are the causes of the coastal change?
   Natural Beach sand mining Removal of trees Land use change
   New building construction Others, specify
9) How often does the erosion/deposition pattern change?
   Every 5 years 5- 10 years >10 years
10) Are you affected by the coastal change due to the above mentioned causes?
    Yes No
    If yes, how are you affected?
11) What has the government done so far to prevent the coastal change?
    Sea wall construction Regulation policies No action

    If regulation policies, what are those?

12) What are the actions you expect from the government to prevent the coastal change?
13) If no action taken what will be the changes in the future on the coast?
    Coastal erosion / deposition
    Depth of the sea near the coast increases / decreases
    Others, specify
14) Is there a development gap in Mararikulam?
    Yes No
    If yes, what are those gaps?
    Reason for the gap:
15) Is there any migration due to the changes in the coast?
    Yes No
16) Are you satisfied with the on-going management of the coast?
17) How do you respond to CRZ regulations?
18) Is there any conflict of interest as far as uses of coastal areas are concerned?

Appendix 2: Questionnaire to the Shop keepers

1) Name of the respondent
2) Occupation of the respondent
3) For how many years have you been in Mararikulam?
4) Why did you choose to put the shop in Mararikulam?
   More tourists Developing area Others, specify
5) Number of tourists visiting this area has
   Decreased Increased
6) What are the changes in the coastal area?

   Beach erosion Beach deposition
   Change in beach gradient Yes / No (Increased / Decreased)
   No change
7) Is there any change in material composition (sand size) of the beach especially after the tsunami?
   Yes No
8) What are the changes in land use?
   Nature of change
9) Beach vegetation- existing / not existing
   If existing what type of vegetation?
10) What are the causes of the change?
    Natural Beach sand mining Removal of trees Land use change
    New building construction Others, Specify
11) How often does the erosion/ deposition pattern change?
    Every 5 years 5 – 10 years > 10 years
12) Are you affected by coastal change due to the above mentioned cause?
    Yes No
    If yes, how are you affected?
13) What did the government do so far to prevent the coastal change?
    Sea wall construction Regulation policies No action
    If regulation policies, what are those?
14) What are the actions you expect from the government to prevent the change?
15) If no action taken what will be the changes in the future on the coast?
    Coastal erosion / deposition
    Depth of the sea near the coast increases / decreases
    Others, specify
16) Is there a development gap in Mararikulam?
    Yes No
    If yes, what are those gaps?
    Reason for the gap:
17) Is there any migration due to the changes in the coast?
    Yes No
18) Are you satisfied with the ongoing management of the coast?
19) How do you respond to CRZ regulations?
20) Is there any conflict of interest as far as uses of coastal areas are concerned?

Appendix 3: Questionnaire to the fishermen

1) Name of the respondent
2) Family profile

Sl No	Name	Age	Sex	Education	Occupation

3) For how many years have you been in Mararikulam?
4) How long have you been engaged in fishing activities?
5) Are you engaged in other jobs, apart from fishing?
   Yes No
   If yes, specify job
6) Where do you go fishing?
7) How often in a week do you go fishing?
8) Are you a member of **'Karanila'**?
   Yes No
9) Is there any change in the type of fishing people?
10) Is there any change in fish species composition?
11) Is there any change in the annual fish catch?
12) Is there any migration due to drop in fish catch?
13) What are the changes in the coastal area?
   Beach erosion Beach deposition/ accretion
   Change in beach gradient Yes / No (Increased / Decreased)
   No change
14) Is there any change in material composition (sand size) of the beach especially after the tsunami?
   Yes No
15) What are the changes in the land use?
   Nature of change:
16) Beach vegetation- existing / not existing
   If existing what type of vegetation?
17) What are the causes of the change?
   Natural Beach sand mining Removal of trees Land use change
   New building construction Others, Specify
18) How often does the coastal erosion/deposition pattern change?
   Every 5 years 5-10 years > 10 years
19) How are you affected due to coastal changes?
20) What has the government done so far to prevent the coastal change?
   Sea wall construction Regulation policies No action
   If Regulation policies, what are those?
21) What are the actions you expect from the government to prevent the coastal change?
22) If no actions taken what will be the changes in the future on the coast?
   Coastal erosion / deposition
   Depth of the sea near the coast increases / decreases
   Others, specify
23) Is there a development gap in Mararikulam?
   Yes No

If yes, what are those gaps?
Reason for the gap:

24) Is there any migration due to the changes in the coast?

25) Are you satisfied with the on-going management of the coast?
Yes No

26) How do you respond to CRZ regulations?

27) Is there any conflict of interest as far as uses of coastal areas are concerned?

Appendix 4: Questionnaire to the tourists

1) Name of the respondent
2) Nationality and occupation of the respondent
3) How often do you visit the beach?
4) How did you come to know about this place?
5) How are the facilities on this beach?
6) What are the changes in the coastal area you can notice?
Beach erosion Beach deposition/ accretion
Change in beach gradient Yes / No (Increased / Decreased)
No change
7) What do you think are the causes of the change?
Natural
Beach sand mining Removal of trees Land use change
New building construction Others, specify

List of Tables

List of figures