Application of Remote Sensing and GIS

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Coastal areas, the place where the waters of the seas meet the land are indeed unique places in our global geography. They are endowed with a very wide range of coastal ecosystems like mangroves, coral reefs, lagoons, sea grass, salt marsh, estuary etc. They are unique in a very real economic sense as sites for port and harbour facilities that capture the large monetary benefits associated with waterborne commerce and are highly valued and greatly attractive as sites for resorts and as vacation destinations. The combination of freshwater and salt water in coastal estuaries creates some of the most productive and richest habitats on earth; the resulting bounty in fishes and other marine life can be of great value to coastal nations. In many locations, the coastal topography formed over the millennia provides significant protection from hurricanes, typhoons, and other ocean related disturbances. But these values could diminish or even be lost, if they are not managed. Pollution of coastal waters can greatly reduce the production of fish, as can degradation of coastal nursery grounds and other valuable wetland habitats. The storm protection afforded by fringing reefs and mangrove forests can be lost if the corals die or the mangroves removed. Inappropriate development and accompanying despoilment can reduce the attractiveness of the coastal environment, greatly affecting tourism potential. Even ports and harbours require active management if they are to remain productive and successful over the long term. Coastal ecosystem management is thus immensely important for the sustainable use, development and protection of the coastal and marine areas and resources.

To achieve this, an understanding of the coastal processes that influence the coastal environments and the ways in which they interact is necessary. It is advantageous to adopt a holistic or systematic approach for solving the coastal problems, since understanding the processes and products of interaction in coastal environments is very complicated. A careful assessment of changes that occur in the coastal

environments and in coastal ecosystems forms a major milestone for effective coastal ecosystem management and leads to sustainable utilization of coastal resources. All these can be achieved only through the collection of accurate, reliable and comprehensive set of scientific data. Remote sensing technology in recent years has proved to be of great importance in acquiring data for effective resources management and hence could also be applied to coastal environment monitoring and management (Ramachandran, 1993, Ramachandran *et.al.*, 1997, 1998). Further, the application of GIS (Geographical Information System) in analyzing the trends and estimating the changes that have occurred in different themes helps in management decision making process.

Remote Sensing Technology

Remote sensing is the technique of deriving information about objects on the surface of the earth without physically coming into contact with them. This process involves making observations using sensors (cameras, scanners, radiometer, radar etc.) mounted on platforms (aircraft and satellites), which are at a considerable height from the earth surface and recording the observations on a suitable medium (images on photographic films and videotapes or digital data on magnetic tapes).

When electromagnetic radiation falls upon a surface, some of its energy is absorbed, some is transmitted through the surface, and the rest is reflected. Surfaces also naturally emit radiation, mostly in the form of heat. It is that reflected and emitted radiation which is recorded either on the photographic film or digital sensor. Since the intensity and wavelengths of this radiation are a function of the surface in question, each surface is described as processing a characteristic "Spectral Signature". If an instrument can identify and distinguish between different spectral signatures, then it will be possible to map the extent of surfaces using remote sensing. Satellite remote sensing is widely used as a tool in many parts of the world for the management of the resources and activities within the continental shelf containing reefs, islands, mangroves, shoals and nutrient rich waters associated with major estuaries.

Satellites & Sensors

The mode can be geostationary, permitting continuous sensing of a portion of the earth or sun-synchronous with polar orbit covering the entire earth at the same equator crossing time. The Landsat series of satellites have a repeat period ranging from 16 – 18 days, whereas in the case of IRS, it is 22 days. Satellites cover the same area and provide

continuous coverage of a fixed area. The sun-synchronous satellites have a synoptic coverage. The ground area covered by the satellite's passes can be obtained by referring to its path and row.

Sensors are devices used for making observations. They consist of mechanisms usually sophisticated lenses with filter coatings to focus the area observed onto a plane in which detectors are placed. These detectors are sensitive to a particular region in which the sensor is designed to operate and produce outputs, which are either representative of the observed area as in the case of the camera or produce electrical signals proportionate to radiation intensity.

Spatial resolution: It is a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor. The greater the sensor's resolution, the greater the data volume and smaller the area covered. In fact, the area coverage and resolution are inter-dependant and these factors determine the scale of the imagery.

Spectral resolution: It refers to the dimension and number of specific wavelength intervals in the electromagnetic spectrum to which a sensor is sensitive. Narrow bandwidths in certain regions of the electromagnetic spectrum allow the discrimination of various features more easily.

Temporal resolution: It refers to how often a given sensor obtains imagery of a particular area. Ideally, the sensor obtains data repetitively to capture unique discriminating characteristics of the phenomena of interest.

Radiometric sensitivity: It is the capability to differentiate the spectral reflectance/ emittance from various targets. This depends on the number of quantisation levels within the spectral band. In other words, the number of bits of digital data in the spectral band will decide the sensitivity of the sensor.

Geographical Information Systems

A Geographical Information System (GIS) is a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modeling, representation and display of geo-referenced data to solve complex problems regarding planning and management of resources. Functions of GIS include data entry, data display, data management, information retrieval and analysis. The applications of GIS include mapping locations, quantities and densities, finding distances and mapping and monitoring change.

Function of an Information system is to improve one's ability to make decisions. An Information system is a chain of operations starting from planning the observation and collection of data, to store and analysis of the data, to the use of the derived information in some decision making process. A GIS is an information system that is designed to work with data referenced to spatial or geographic coordinates. GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operation for working with data. There are three basic types of GIS applications which might also represent stages of development of a single GIS application

Inventory Application

Many times the first step in developing a GIS application is making an inventory of the features for a given geographic area. These features are represented in GIS as layers or themes of data. The emphasis at this stage of application development consists of updating and simple data retrieval.

Analysis Application

Upon completion of the inventory stage, complex queries on multiple layers can be performed using spatial and aspatial analysis techniques.

Management Application

More advanced spatial and modelling techniques are required to support the decisions of managers and policy makers. This involves shifting of emphasis from basic geographic data handling to manipulation, analysis and modelling in order to solve real world problems.

Uses Of Coastal GIS Packages

1.Retrieval of information of any specific site.

2. Provision of summary data for planning purpose.

3. Graphical display for educational and public relation exercise.

4. Classification of coasts and management zone.

5. Predicting modelling to determine.

      A. Projections of coastal changes.

      B. Impacts of individual schemes.

      C. Impacts from changes of use.

      D. Impacts from natural calamities.

Application of Remote Sensing and GIS in Coastal Ecosystem Management

Based on remote sensing a variety of data pertaining to the coastal zone like, identification of plant community, biomass estimation, shoreline changes, delineation of coastal landforms and tidal boundary, qualitative estimation of suspended sediment concentration, chlorophyll mapping, bathymetry of shallow waters, etc. can be collected and all these data will help in effective coastal ecosystem management.

The latest Indian satellites IRS – 1C, 1D, P4 and P6 with their improved spatial resolution (PAN – 5.8 m, LISS III – 23.6 m, LISS IV – 5.8 m, WiFS – 188 m and AWiFS – 56 m), extended spectral range (inclusion of middle infrared band in LISS – III) and increased repetivity (5 days for WiFS data) have opened up new applications in coastal zone. Preliminary analysis of IRS – 1C, 1D data indicates that coral reef zonation, identification of tree and shrub mangroves, mudflats, beach, dune vegetation, saline areas, etc as well as better understanding of suspended sediment patterns are now possible. The PAN data combined with the LISS – III and LISS - IV data are extremely useful in providing detailed spatial information about reclamation, construction activity and ecologically sensitive areas, which are vital for the coastal zone regulatory activities. The information available from merged PAN and LISS III, IV data about coral reef zonation, especially for atolls, patch reef and coral pinnacles, is valuable for coral reef conservation plans. The distinction between tree and shrub mangroves in FCC (middle infrared, infrared and red bands) of LISS III provides vital information on biodiversity studies (Ramachandran et. al., 2000a). The high temporal resolution provided by the WiFS data is found to be a major improvement in studying the behavior of suspended sediments in the coastal waters, which would help in understanding the movement of sediments and pollutants (Nayak *et.al.*, 1996).

Mangroves

Satellite remote sensing has been found to be a very valuable application tool in forest management including mangroves, not only in monitoring, but also carrying out relevant observations, which can bring out the impact of deforestation on global climate. Remote sensing of change-detection is a process of determining and evaluating differences in a variety of surface phenomena over time. For detection of land cover change, multi temporal data of Landsat TM were found to be more suitable for identification of deforestation areas, mapping the

regeneration/ regrowth of forest area and tracing major changes in land cover.

Remote sensing data derived from different satellite such as Landsat MSS data can provide us information about the areal extent, conditions and boundary of coastal wetlands. Further, multidated satellite data can be used effectively to find out the changes in the aereal extent of mangroves. Sequential nature of IRS data provide opportunity to monitor changes in the landuse activities in the mangroves. IRS has been quite extensively used for Mangrove landuse pattern both the visual as well as the digital analysis of IRS data provide useful information.

Data acquired by both passive and active remote sensing systems can be used in the study of mangroves. The research involves two main steps. In the first step, a broad classification of the general land cover, including mangroves is made (Figure1). This indicates the best approach to dealing with the various types of imagery in order to detect the mangrove deforestation. The second step concentrates on the specific problem of detecting changes in the mangrove areas (Figure2). It examines different approaches for monitoring the nature of the changes in order to produce maps showing the current and former conditions in an area. SAR data, which is independent of cloud, cover and weather interference can be used for mapping mangrove and estimation of mangrove biomass.

One of the sub tasks of Land Ocean Interactions in the Coastal Zone (LOICZ) of IGBP project is to develop a methodology for mangrove zonation, succession and regeneration (IGBP, 1994). The important tasks for the study of mangroves are mapping and change detection, identification of species/ plant communities and biomass estimation. To prepare a management plan for mangroves, a comprehensive database should be available, including the information on distribution and extent of mangrove areas and species composition. As a first step towards this, the Space Applications Centre has carried out national level wetlands mapping to prepare shoreline change maps and wetland maps on 1: 250,000 scale (SAC, 1992). This work presented the status of wetlands, primarily the level-I and level-II categories and the total area of mangroves has been estimated to be about 4000 sq. km.

Although the methodology for visual interpretation of satellite data for vegetation/ land cover classification and mapping has been standardized and made operational in India, the potential of high resolution data such as IRS LISS-II and LISS-III for extracting vegetation-

related information through visual interpretation yet requires separate classification system for mangrove mapping. High-resolution data provides more information on the health and distribution of mangroves. In addition, it could also be used to derive qualitative information about turbidity conditions in wetlands and studying turbidity is important for the health of the mangroves as it supplies nutrients to the system.

In Tamil Nadu coastal zone, well-developed mangroves occur mainly in two places, one in Pichavaram and the other in Muthupet in the Cauvery delta. The mapping of wetlands in the Cauvery delta using remote sensing data showed that about 40% of the mangrove area has been degraded i.e. 32 sq. km. In 1976 has been reduced to 19 sq. km. in 1989 (IRS, 1991). But the estimates using 1994 data showed that the area of mangroves is only 260 ha. and nearly 63% has become barren between 1897 and 1994 (Krishnamoorthy and Ramachandran, 2000).

The fast clearing of healthy mangrove areas in Mahanadhi coast has been clearly demarcated using LISS-III data. This imagery shows the human impact on mangrove forests in **Mahanadhi coast (dark tone indicates healthy** mangroves and the adjacent light tone are the areas converted for agriculture).

Mangroves and coral reef mapping along the coastal zone of Andaman Islands were attempted using SPOT and airborne SAR X-band imagery (Krishnamoorthy et al., 1993). The availability of single polarization SAR data from aircraft and spacecraft platforms are not used effectively for mangrove mapping in India because of the difficulties in separating mangroves from other vegetation, influence of understory parameters, effect of soil moisture and the speckle effect (Krishnamoorthy and Ramachandran, 2000).

The area covered by mangroves in the islands of Andaman were calculated using SPOT 1993 and IRS-1D LISS III 2003 imageries. The change in mangrove area within a span of ten years has presented in the form of a table (IOM report, 2003b).

IRS 1D LISS III Image of Coringa Mangroves (Andhra Pradesh)

Changes in Mangrove Area in Andaman Islands

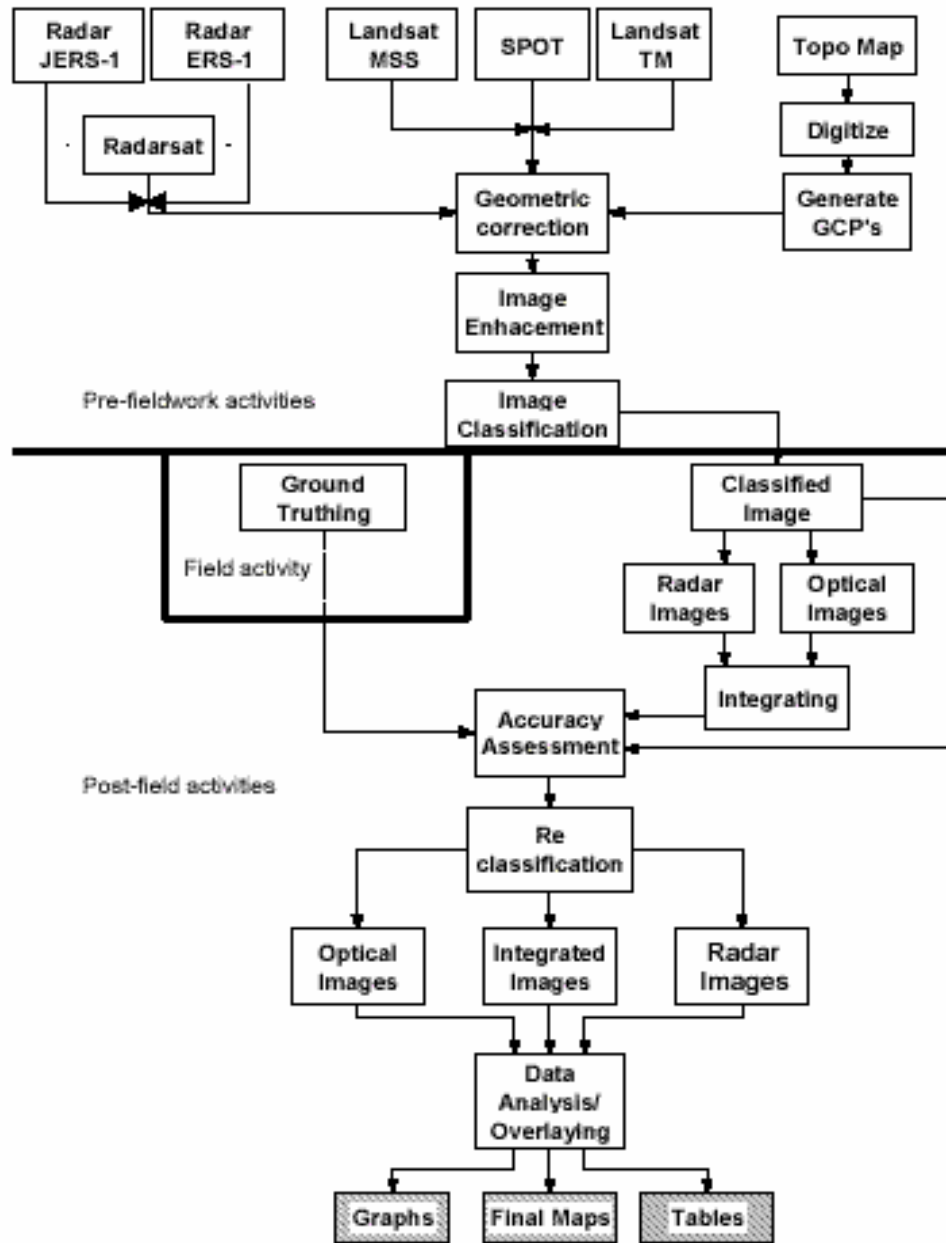| S. No.	Island	Area in ha. (1993)	Area in ha. (2003)	Change in area (ha.)	% Change
1.	Havelock	1468.51	895.37	-573.14	(-) 39
2.	Neil	22.30	9.12	-13.18	(-) 59
3.	North Passage	242.14	275.45	+33.31	(+) 14
4.	Interview	1302.46	1116.26	-186.2	(-) 14
5.	East	3.60	16.82	+13.22	(+) 367
6.	Strait	18.28	19.33	+1.05	(+) 6
7.	Ross & Smith	358.68	236.76	-121.92	(-) 34
8.	Long	78.07	40.11	-37.96	(-) 49

Figure 1. Flow chart for studying the ecosystem changes using satellite data
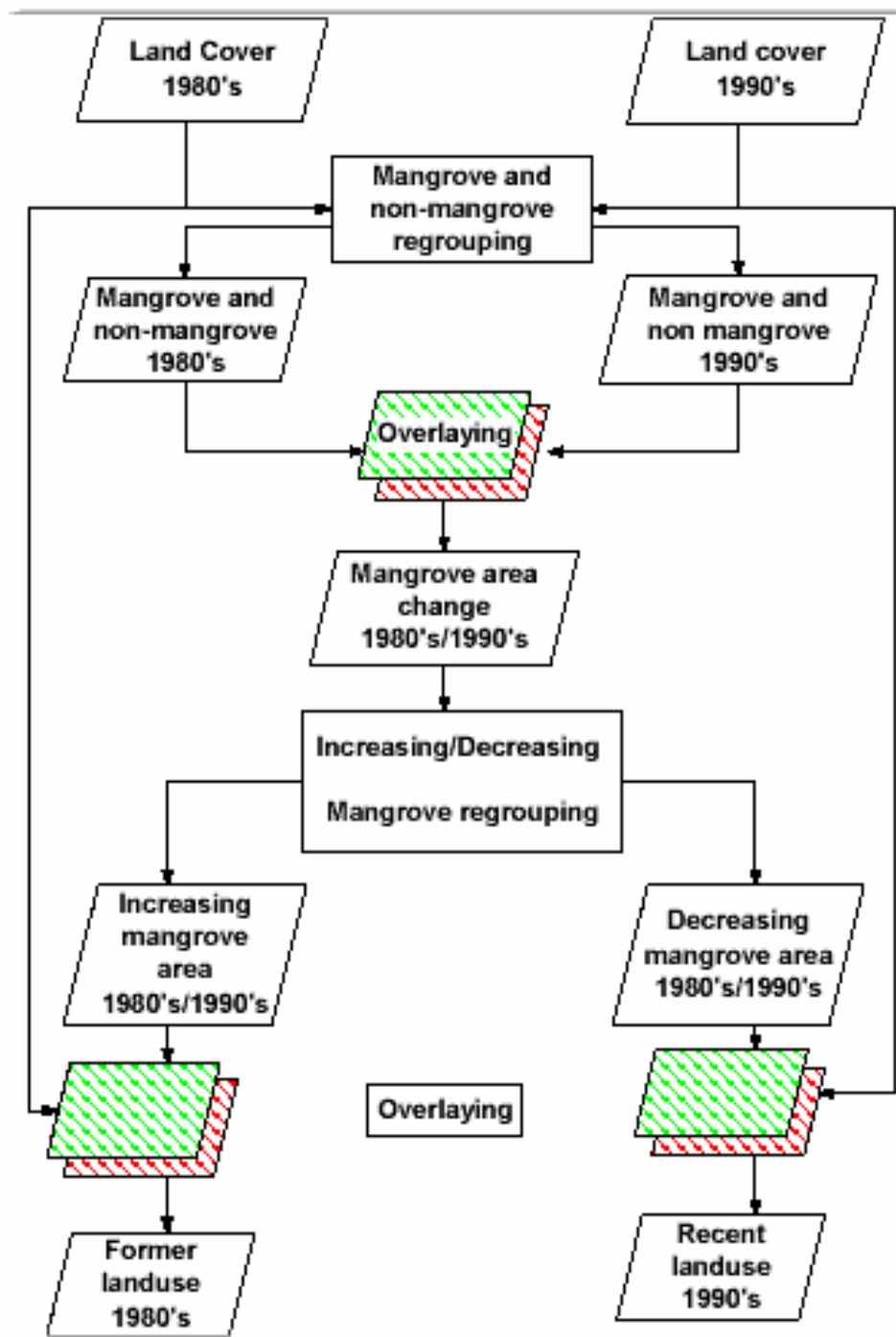(Hussin *et. al.*, 1999)

Figure 2. Mangrove forest area change detection procedure (Hussin *et. al.*, 1999)

Coral Reef Ecosystem

The coral reefs characterize an ecosystem of high biological diversity, having the greatest number of species of any marine ecosystem. Coral reefs are considered as one of the most important critical resources for various ecological, environmental and socio-economic reasons. They play an important role in global biochemical processes and in the reproduction of food resources in the tropical regions. They act as a barrier against wave action along coastal areas thus preventing coastal erosion. In addition, coral reefs protect mangroves and sea grass beds in certain areas, which are the breeding and nursing grounds of various economically important fauna. Because of the increasing human population along the coastal area, anthropogenic impacts on the coastal zone have become severe over the past few decades. Coral ecosystem also face many threats, of which some are of natural origin like storms and waves particularly tropical storms and cyclones that cause major intermittent damage to reefs. The majority of damage to coral reefs around the world has been through direct anthropogenic stress.

IRS LISS -II data has been used to map the coral reefs in the Gulf of mannar on an much larger scale (upto 1:25000) under the DOD programme on Critical habitate Information system. Supervised classification of LISS -III digital data is used to identify the different species of coral reefs apart from the classification odd patch reef, fringing reef and atolls. Due to high spectral resolution (23m) LISS-III data were found to be more useful for coral reef mapping and monitoring. digital image processing is widely used for coral reef mapping. IRS -LISS III data was processed using ERDAS IMAGINE software for coral reef classification and 50 classes were identified using the unsupervised cluster model of ERDAS. All the four bands of the image were used in the classification.

In Gulf of Mannar, the coral reefs have been used as a source of calcium carbonate and building blocks. In general, coral reefs in Gulf of Mannar can be categorised as "degrading", and hence, monitoring and management of these valuable marine resources are of prime importance. IRS LISS-II (1988), IRS LISS-III (1998) satellite data and ARC-INFO and ARC-VIEW GIS software have been used for coastal geomorphology, seafloor, shoreline, coastal land use/land cover and coral reef mapping of Gulf of Mannar.
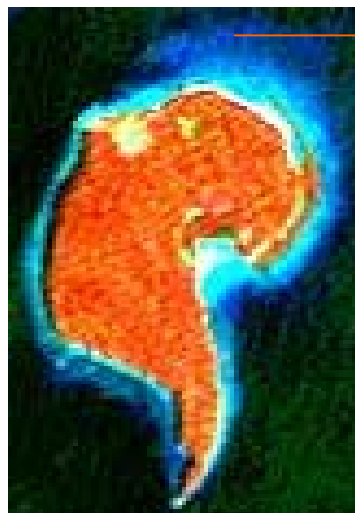
The remote sensing data of SPOT, Landstat, IRS LISS -II and IRS LISS-III are used for the mapping of coral reef mapping. Using these data the coral reefs can be identified and mapped. The living and non-

living corals appear in turquoise- blue and greenish-blue tone on SPOT FCC of band combination 2,3, & 4 (Krishnamoorthy, 1995). In LISS -III the band combination 3,2, &1 are also found to be useful. At the time of validation of mapping, it is also observed that the tonal variations in coral reefs are not only due to the living and non-living corals, but also due to the depth of occurrence.
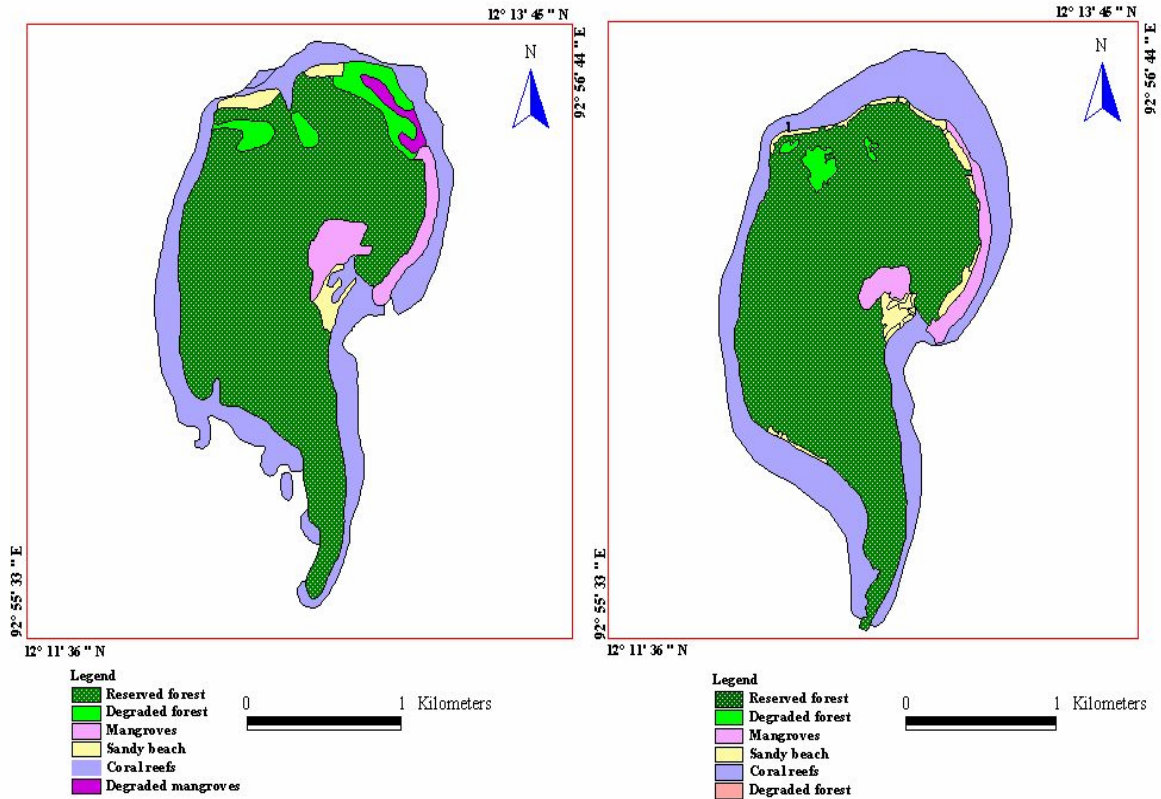
The coral reef area for the islands of Andaman were calculated using SPOT 1993 and IRS-1D LISS III 2003 imageries. The change in coral reef are within a span of ten years has presented in the form of a table (IOM report, 2003b). Remote Sensing data (IRS IC LISS-III 1998) was used for mapping the coral reefs of the Kadmat Island in the Lakshdweep islands and digital classification was performed for the identification of corals around the island.

Very little information on maps showing the distribution of various benthic habitats in the coral reef is available. Remote sensing technologies have great potential in overcoming this information void. Space Technology Application and Research Program (STAR) evaluated the suitability of latest satellite in Landsat series: Landsat 7 ETM+ for investigating coral reef habitat in several small islands in Riau Archipelagos in Indonesia.

Coral Reef

LANDUSE MAPS OF STRAIT ISLAND USING SPOT 1993 AND IRS- 1D LISS III 2001 IMAGERIES

Legend

Reserved forest
Degraded forest
Mangroves
Sandy beach
Coral reefs
Degraded mangroves

Legend

Reserved forest
Degraded forest
Mangroves
Sandy beach
Coral reefs
Degraded forest

Changes in Coral Reef Area in Andaman Islands

S. No.	Island	Area in ha. (1993)	Area in ha. (2003)	Change in area (ha.)	% Change
1.	Havelock	2062.30	1846.00	-216.30	(-) 10
2.	Neil	270.47	459.01	+188.54	(+) 70
3.	North Passage	384.73	435.84	+51.11	(+) 13
4.	Interview	1818.63	2764.51	+945.88	(+) 52
5.	East	197.36	177.46	-19.9	(-) 10
6.	Strait	90.80	127.28	+36.48	(+) 40
7.	Ross & Smith	272.76	459.81	+187.07	(+) 68
8.	Long	232.45	179.43	-53.02	(-) 23

Lagoonal Ecosystem

Coastal lagoon is defined as an inland water body, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets and having depths which seldom exceed a couple of meters. Lagoons are formed due to the rise in sea level during Holocene or Pleistocene period. They constitute a very fragile ecosystem in the coastal zone. They are important indicators of environmental degradation. The coastal lagoon systems exhibit very high primary and secondary production rates; provide nursery and breeding ground for many species of marine fauna. Recently the lagoons of these types are experiencing an accelerated decline in the water quality, an increase in siltation, environmental problems such as pollution of sediments and increased turbidity.

With the advent of satellite-based remote sensing platforms, the availability of geo-referenced information and the potential for use of such information has increased dramatically. There is a major information gap in the mapping and broad-scale investigation of the shallow-water coastal areas from which the majority of Pacific rural people derive their sustenance and income. Cartographers have concentrated on terrestrial areas (for land use planning) and on areas outside the lagoons (for navigation), and most maps and charts draw a complete blank over the maze of coral reefs where tropical fisheries are most accessible and most productive. This shallow-water area is also most amenable to investigation through the multispectral imaging capabilities of RS satellites such as SPOT, where classification of digital images can yield extremely cost-effective, even priceless information to assist in the definition of living marine resource potential, and subsequent management.

Pulicat lake is the second largest brackishwater lake in India and it is located between 13°26′ and 13°43′ N latitude and 80°03′ and 80°18′ E longitude lying almost parallel to the Bay of Bengal. It extends over the Ponneri and Gummidipundi taluk of Thiruvallur district in Tamil Nadu and Sulurpet and Tada taluk of Nellore district in Andhra pradesh and covers an area of about 461 sq. km. A study was undertaken at the Institute for Ocean Management, Anna University to delineate the water spread area, lagoonal configuration in conjunction with shoreline, water quality viz. salinity, suspended sediment concentration, saline water intrusion, bathymetry etc. of Pulicat lake using IRS- LISS I, LISS II and LISS III data of 1989, 1990 and 1998. in this study all radiometric and atmospheric corrections were carried out

using the VIPS32 functions in the pre-processing stage and a particular scan line of cloud free IRS-1A LISS-1 (non monsoonal season) and Landsat MSS (monsoon) covering the entire stretch of Pulicat has been selected to study the spectral reflectance of the water body. Digital analysis of IRS and Landsat MSS data was carried out using VAX 11/780 image analysis system to find out suitable enhancement techniques for various parameters of water quality (Ramachandran et. al., 2000b).

False Fourier Transformation using IRS and MSS data enhances bathymetry (low and high depths) and these areas also show good correlation with DN values of the raw data. Higher DN (reflectance) values in lower depths have also been contributed by the occurrence of sea grass beds, which has been verified by ground truth studies. Since IRS bands 4 and 2 have narrow spectral width when compared to MSS, the density slicing ratio for the output of bands 4/2 provides qualitative information on suspended sediments concentrations. The colour variations derived from local optimization functions is expected to be due to chlorophyll concentrations. Resampling supervised classification based on field data provides information on salinity variations. The intrusion of sea water into the lagoon has been clearly shown using Principal Component analysis.

The Principle Component analysis of IRS LISS-I band 2 shows the lake configuration and the areas of submergence and erosion during monsoon (17-12-1990). At the end of the monsoon, the lagoon bar mouth will be completely exposed and it will be closed by the deposition of longshore drifted sediments during summer season. Hence the mixing between the lake water and ocean is restricted, influencing increase in salinity, which will disturb the ecological health of the lake. As a result of increase in salinity in the central part of the lake, the density of the water mass increases which does not allow the suspended particles to settle at the bottom.

Imagery of Pulicat Lake

Land Use map - 1998
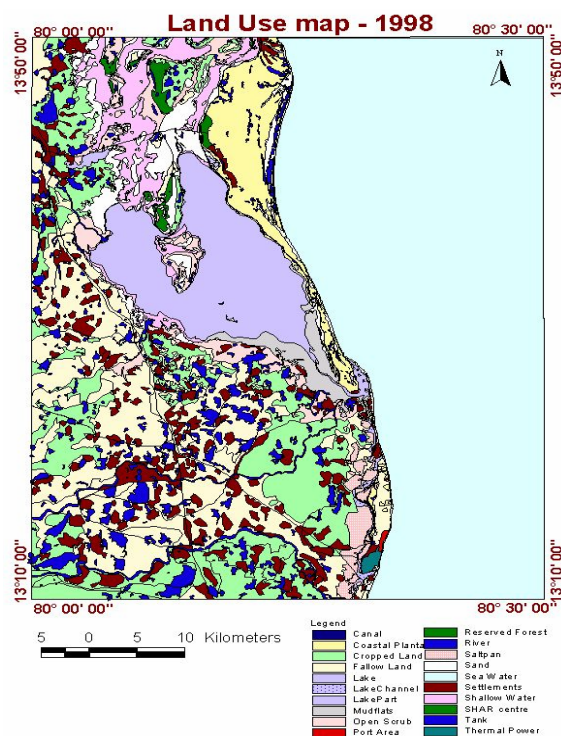
Changes in Landuse between 1990 and 1998 (Pulicat Lake)

S. No.	Class	1990	1998	Changes
1.	Canal	5.77	5.97	+0.2
2.	Coastal plantation	144.49	122.20	-22.29
3.	Lake	261.81	251.62	-10.19
4.	Lake channel	16.13	16.84	+0.71
5.	Lake part	2.10	2.96	+0.86
6.	Cropland	544.62	411.36	-133.26
7.	Sand	149.79	147.12	-2.67
8.	Settlement	201.24	334.45	+133.21
9.	Tank	135.62	149.90	+14.28

Source: IOM report, 2001

Conclusion

Coastal ecosystems are of great importance and of immense value to mankind in the present and in the future. They are being degraded at an alarming rate by various preventable activities including that of human interference. The coastal ecosystems are to be monitored periodically for better management plans. The satellite based sensors provide valuable information useful in assessment, monitoring and management of coastal ecosystems. Optical remote sensing data is very useful for mapping the coral reef, mangrove and lagoon ecosystems. The information, which is thus derived, can be very useful in the coastal ecosystem management, which is greatly required for the sustainable use, development, and protection of the coastal and marine areas and resources. Thus remote sensing and GIS technologies are widely used today in coastal ecosystem management.

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