CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The coastal zone is an integration of two large natural systems - the coastal lands and coastal waters. It is a complex ecosystem under the influence of physical, chemical, and biological processes which interact under natural conditions. Physiographic and ecological processes in this zone are interlocked in a narrow expanse of land and water, to give birth to geomorphological and biogeographical units such as rivers, lakes, plains, wetlands, coastal lagoons, beaches, bays, estuaries, and littoral zones. These units form habitats for many biological communities. However, these units are often affected by various natural and anthropogenic factors leading to degradation of the habitats (Lundin et al 1993 and Viles 1988).

Coastal wetlands are the most important ecosystems with a highly dynamic environment, being affected both, seasonally and annually by variable climatic conditions. They are highly diverse in nature and depend on a system of natural or artificial waters, of a permanent or temporary nature, stagnant or running. Fresh or salt water or a combination thereof may form them. The major types of wetlands are: coasts (including coral reefs, marshes, and sea grasses), estuaries, floodplains, swamps, peatland, lakes and lagoons, flooded forests of fresh or salt water (mangroves), and the rivers.

The spatial configuration of the coastal ecosystem seems to be highly mixed and complex in nature, and no sharp boundary exits among certain coastal features. Mapping and monitoring of such a ecosystem with conventional techniques
and surveys are time consuming processes. The cost is very high and some of the areas not accessible.

Remote sensing technology, in recent years, has proved its potential in mapping and monitoring such a complex ecosystem of the coastal zone. In addition, remotely sensed data can also be used to determine the wetland conditions, amount of vegetation biomass and the degree of water inundation and conditions. The spatial complexity in certain coastal features makes it difficult for accurate mapping using conventional image processing techniques. This is because the remotely sensed data tend to represent the non-homogeneous coastal features in the form of pixels in an image. To overcome this problem and the limitations, the recent image processing techniques are necessary for accurate coastal mapping.

This study addresses a few of the problems of coastal mapping using remotely sensed images, and attempts to use certain recent image processing techniques for extraction of information about coastal features with improved accuracy.

1.1.1 Principles of Remote Sensing

Remote sensing is essentially an earth observation technique. It is the science and art of obtaining information about an object through the analysis of data acquired by a device that is not in contact with the object (Lillesand and Kiefer 1994). Since the launch of Landsat-1 in 1972, remote sensing has become an important tool in many resource management areas such as land-cover classification, resource inventory, pollution detection, environmental impact assessment, and environmental modeling. Generally, a remote sensing system consists of five components. They are the energy source, the sensor, ground objects, the data-handling system, and the multiple data users. According to the source of energy used, two types of remote sensing systems – active and passive – are distinguished. "Active" refers to a sensor
that supplies its own source of energy or illumination. Imaging radar sensors are active sensors, which emit a burst of microwave radiation and receive the back-scattered radiation. Most commercial satellite sensors are passive solar imaging sensors. In this case, the sun is the source of electromagnetic radiation (ERDAS Field Guide 1997).

Remote sensing systems operate on the principle of electromagnetic radiation. As different types of earth surface features have their own distinctive electromagnetic energy signals, they can be detected, recorded and interpreted on the basis of their electromagnetic reflections. In remote sensing, it is most common to characterize electromagnetic waves by their wavelength location within the electromagnetic spectrum. The wavelength ranges in which the atmosphere is particularly transmissive of energy are referred to as atmospheric windows. Remote sensing data acquisition is limited to the atmospheric windows. Sensors form the heart of remote sensing systems. They are used to record variations in the way earth surface features reflect and emit electromagnetic energy. Wavelength range and spatial resolution are two major indications of a sensor’s technical capabilities. No single sensor is sensitive to all wavelengths. All real sensors are designed to be sensitive to a fixed range within the electromagnetic spectrum. Sensors also have a limit on how small an object on the earth’s surface can be and still be “seen” by a sensor as being separate from its surroundings. This limit is called the spatial resolution of a sensor. Spatial resolution is an indication of how well a sensor can record spatial details.

Satellite imaging systems designed for earth resource observation purposes use multi-spectral scanners. The multi-spectral scanner (MSS) is a sensor that acquires data from multiple spectral bands simultaneously. Multi-spectral scanners sense simultaneously through multiple, narrow wavelength ranges that can be located in the visible through the thermal spectral region. Multi-spectral imagery provides more information than data collected in any single spectral band. When the signals recorded in the multiple bands are analyzed in conjunction with each other, more information becomes available. A multi-spectral scanner operates on the same principle of
selective sensing in multiple spectral bands. But multi-spectral scanners have some inherent advantages over their photographic counterparts (Lillesand and Kiefer 1994).

- Using electronic detectors, multi-spectral scanners can extend the range of sensing from 0.3 to approximately 14 μm. This range includes the ultraviolet (UV), visible, near infra red, middle infra red, and thermal spectral regions. MSS systems can also sense in very narrow spectral bands.

- MSS systems use the same optical system to collect data in all spectral bands simultaneously. This ensures that data in separate bands are comparable to one another spatially and radiometrically.

- MSS data are generated electronically and are therefore more amenable to calibration. The electronic format of the scanner output also permits recording over a greater range of values in a digital format.

A main thrust in the recent development of sensor technology has been the increasing spatial and spectral resolution. In addition to existing imaging systems such as Landsat TM and SPOT HRV, a number of new remote sensing sensors with significantly improved geometric resolution are already in operation (Dragger et al 1997). For example, the French SPOT-4, launched in 1997, has incorporated 5-m spatial resolution and along-track stereo imaging capability. The German MOMS-02 sensor system has a designed ground resolution of 4.5m and has adopted the latest three-track technology combined with a stereo- and multi-spectral module.

The Indian Remote Sensing Satellite (IRS)1C and 1D have an advanced imaging system. This system has a panchromatic camera that captures data with a spatial resolution of 5.8m and a ground swath of 70km. In addition to that, the IRS-1C/1D imaging system is equipped with a linear imaging and self scanning (LISS)
sensor that provides multi-spectral data collected in visible, near infra red (NIR) and short wave infra red (SWIR) regions.

A number of high-resolution imaging systems with up to 1-m ground resolution are already in operation. Among these high-resolution satellites are EarlyBird (3-m resolution). The latest development is the launch of IKONOS of Space Imaging, Inc. on 24 September 1999. The IKONOS imaging system provides image with a ground resolution of 1m. In the pipeline are QuickBird (1-m resolution) of Earth Watch and OrbView-1 (1-, 2-, and 4- m resolution) of the Orbital Sciences Corporation (Li 1998).

In microwave image data, Several different wavelengths (spectral range between 1cm and 100cm) can be used to identify land cover types based on the different scattering cross section with wavelength. However, further information can be obtained using microwave imaging, from this specific characteristic of the microwave band; that is the polarization of the transmitted and scattered radiation. The polarization of an electromagnetic wave refers to the orientation of the propagated electric field. During scattering by surface materials some polarization changes occur and energy can be received as horizontally and/or vertically polarized. The degree of polarization rotation that occurs can also be useful indicator of surface materials.

The launching of European Remote Sensing (ERS-1&2 SAR) series of satellites 1991 and 1995 is a significant achievement of the earth resources scientific community in its efforts to improve operational monitoring of land cover changes in the coastal regions frequently affected by cloud coverage and atmospheric problems. Both carry several sensors which are useful for landscape monitoring: Active Microwave Instrument (AMI), Along Track Scanning Radiometer (ATSR), and a radar altimeter. The satellites have a polar, circular, sun-synchronous 782-km orbit with a 35-day repeat cycle orbit. The SAR incidence angle is 23° with a swath width
of 100km, while the wind scatterometer points fore and aft 25-59° with a swath width of 500km. ATSR also has a swath width of 100km (Henderson and Lewis 1998).

1.1.1.1 Advantages of Mapping Coastal Features using Satellite Imagery

Using satellite imagery to extract and represent coastal land-cover information is a key application of remote sensing technology. Compared to more traditional mapping approaches such as basic aerial photo-interpretation, coastal mapping using satellite imagery has four advantages.

- First, coastal cover types can be mapped from digital satellite imagery faster and often with lower costs.
- Second, fast and inexpensive updating of coastal map products is possible. This is because satellite images are captured for the same geographic area at a high revisit rate.
- Third, satellite imagery data are captured in digital forms. They can therefore easily be integrated with other types of ground object information through such techniques as GIS.
- Fourth, satellite images cover large geographic areas. The great economies of scale provided by digital image processing make it relatively inexpensive to map large expanses of land, making it easier and more cost effective to generate large amounts of map products.

1.2 NEED FOR THE STUDY

Traditional field sampling and surveying approaches for ecological studies of the coastal zone can only cover small areas in detail, can be time consuming, and are often invasive and destructive. Spatially extensive and non-invasive remote sensing data due to its synoptic, repetitive and multi-spectral nature provide a wide range of information over inaccessible and larger areas in frequent intervals has made remote
sensing technology a useful tool in coastal mapping and management. Coastal zone refers to broad geographic area in which terrestrial and marine factors are mixed to produce unique landforms and ecological systems. It is highly dynamic area surrounding the interface between the land and sea. The coastal zone is extremely important to country’s society and economy and includes a unique collection of the available natural resources such as beaches, mangroves, forests, corals, mudflats, salt marsh, lagoons, water, gas, sand dunes, dune vegetation etc. Wetland in the coastal zone is highly dynamic, complex and fragile ecosystem and is often affected by various physical and anthropogenic factors. The coastal line of Tamil Nadu, extending over 1000 kms in length, is ecologically complex and sensitive, is susceptible to natural hazard and human interference. Hence, there is a need to map and monitor the ecologically important areas along the Tamil Nadu coast. Thus remote sensing technology, in recent years, proved its potential for mapping and monitoring coastal features in an accurate manner. This study attempt multi-sensor approach and use recent and improved image processing techniques for better information extraction about the coastal fractures of Tamil Nadu.

1.3 AIM AND OBJECTIVES

This study aims to realise the potential of certain recent and emerging image processing techniques applied to multi-sensor satellite image data for mapping coastal features of Tamil Nadu State with greater accuracy.

The objectives of this study are:

- to develop a remote sensing based approach that can efficiently identify various components of the coastal ecosystem and map them in a more accurate fashion.

- to evaluate the potential use of the conventional and recent image enhancement techniques for better information extraction about the coastal features.
• to evaluate the certain conventional classification techniques for mapping the coastal features, and
• to quantify certain biophysical parameters of the coastal ecosystem using recent image processing (Spectral Unmixing) techniques.

1.4 STRUCTURE OF THE THESIS

The thesis is organised into eight chapters.

Chapter 1 gives the introduction, principles of remote sensing, advantages of mapping coastal features using satellite imagery, need for the study, lists the aim and objectives, and previews of all other chapters.

Chapter 2 reviews the available literature with respect to coastal studies, remote sensing applications to coastal zone, various conventional and recent image enhancement and classification techniques.

Chapter 3 describes the three coastal sites selected for the study, the satellite image data products used and lists their characteristics.

Chapter 4 attempts certain digital image enhancement techniques (both conventional and recent) for enhanced coastal mapping. Though image enhancement techniques gave satisfactory results with respect to coastal feature identification and delineation, the ultimate aim of producing coastal maps could be done only by classification of satellite image data. Hence, there is a need to perform image classification.

Conventional classification techniques such as unsupervised and supervised classification techniques were attempted in Chapter 5 and the results were analysed by comparing the coastal maps with existing maps and ground survey.
The results of the conventional classification systems were not satisfactory for coastal mapping in terms of accuracy. Hence, the recent image processing technique Spectral Unmixing was attempted in Chapter 6. This chapter describes the concepts of sub-pixel classification (Spectral Unmixing) and the methods of validating the results.

The results of the study and a discussion about the same are given in Chapter 7.

Chapter 8 summarizes the work done and lists the conclusion of the results obtained from this study and it also lists the scope for further work.