CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

The marine environment, which includes the adjacent coastal areas and littoral zones with many wetland features supporting productive and protective habitats such as mangroves, coral reefs and sand dunes (Klemas, 2011). India has a long coastline of more than 7500 km and its marine resources are spread over in the Indian Ocean, Arabian Sea, and Bay of Bengal. The exclusive economic zone (EEZ) of the country has an area of 2.02 million sq km comprising 0.86 million sq km on the west coast, 0.56 million sq km on the east coast and 0.6 million sq km around the Andaman and Nicobar islands. The east coast supports varieties of land use activities such as agriculture and aquaculture whereas a large number of industries are supported on the west coast. Besides these, tourism has also emerged as a major economic activity in the eastern and western coastal tracts.

Presently, the marine environment, especially along the littoral zone and shoreline is facing tremendous pressure, owing to the needs of people, urbanization, industrialization and other infrastructure developmental activities. These pressures contribute inadvertently on the coastal environment and its varied ecosystem found along the coast such as estuaries, lagoons, bays, creeks, tidal flats and so on. It is also known that a comparison of similarities and difference between these ecosystems would throw light on the roles of flora and fauna and their contribution to the environment.

This necessitates devising a method for periodical updating of information on these coastal ecosystems and in turn the change in their spatial extent – both qualitatively and quantitatively. In the present study, such a comparison between two coastal ecosystems - lagoon and fresh /brackish water interface – are carried out using remote
sensing satellite data. This objective was made after a careful literature survey of which a review has been discussed in the following sections.

2.2 Coastal ecosystem

Marine and coastal ecosystems play a vital role in regulating climate and they are a major carbon sink and oxygen source. The industrial development along coast has resulted in degradation of coastal ecosystems and diminishing the living resources in the form of coastal and marine biodiversity and productivity. To protect coastal environment, it is important to study the coastal habitats and their status to formulate a plan for protection. As coastal zone is very dynamic and is changing very fast, it is necessary to study them in a temporal domain for which satellite remote sensing is an excellent tool.

There have been many studies on coastal ecosystem, its function, organisms that comprise coastal ecosystem and human effect on coastal ecosystem (Boesch and Urban Jr., 1995). Coasts are dynamic systems undergoing adjustments of form and process (morphodynamics) at different time and space scales in response to landform such as salt marshes (Adam, 2002) and oceanographical factors (Cowell et al., 2003a,b). Human activity exerts additional pressures that may dominate over natural processes. Often models of coastal behaviour are based on palaeo-environmental reconstructions by studying shore line changes (Bird, 1985) at millennial scales and/or process studies at sub-annual scales (Rodriguez et al., 2001; Storms et al., 2002; Stolper et al., 2005). Adapting to global climate change, however, requires insight into processes at decadal to century scales, at which understanding is least developed (Donnelly et al., 2004). Coastal ecosystem, affected by short-term perturbations such as storms, generally return to their pre-disturbance landforms, implying a simple, coastal land equilibrium. Many coasts undergo continual adjustment towards a dynamic equilibrium, often adopting different ‘states’ in response to varying wave energy and sediment supply (Woodroffe, et al., 2006).

Apart from the influence on coastal ecosystem caused by nature, direct impacts of human activities on the coastal zone have been more significant (Lotze et al., 2006).
Major direct impacts include drainage of coastal wetlands, deforestation and reclamation, and discharge of sewage, fertilizers and contaminants into coastal waters. Extractive activities include sand mining and hydrocarbon production, harvests of fisheries and other living resources, introductions of invasive species and construction of seawalls and other structures. Ecosystem services on the coast are often disrupted by human activities. For example, tropical and subtropical mangrove forests and temperate salt marshes provide goods and services (they accumulate and transform nutrients, attenuate waves and storms, bind sediments and support rich ecological communities), which are reduced by large-scale ecosystem conversion for agriculture, industrial and urban development including aquaculture activities.

The issue of coastal zone vulnerability has received much attention over the last two decades throughout the world with studies being initiated largely due to concerns of rising sea levels (Reed, 2002). Climate change models suggest an increase in global sea-level in the range of 15-95 cm by 2100 (Wigley, 2005). Increased floods due to sea level rise are likely to affect millions of people and densely populated, low-lying areas of Africa and Asia are likely to be severely affected. Driven by these estimates of sea level rise and given the fact that most coastal areas are densely populated there has been an increasing concern to identify and map areas that are vulnerable to such long term changes.

In the recent past, the need to identify coastal vulnerability zones has further gained momentum and interest due to the increased damage caused by storms and tropical cyclones. Although the increase in the periodicity of such severe storms and cyclone may not be to climate changes, the severity and impacts of such events are being witnessed world over re-emphasizes the need for coastal vulnerability studies.

In the Indian context the need to carry out such studies has been recognized and gained impetus after the 2004 tsunami and have become more important with the proposed draft Coastal Management Zone (CMZ) notification by the Ministry of Environment and Forests (MoEF) in 2008. Such assessments not only identify the most vulnerable settlements and communities but also pinpoints linked vulnerable industries which are likely to be affected by these extreme weather events. Results
from such studies help in making more realistic predictions for future storm and sea level rises, and additionally have implications on insurance premiums, urban infrastructural design and emergency planning especially in regions where rapid urbanization is occurring.

However, there are very few studies that have assessed the coastal vulnerability of Indian coasts. While the urgency for vulnerability mapping has been acknowledged there are no standard methods or guidelines that are being followed (Thieler and Hammar-Klose, 2000). The different approaches to estimating coastal vulnerability can broadly be classified into two categories namely, physical and socio-economic. The physical models classify coastal stretches into different vulnerability zones based on physical attributes of the coast (for example flood plain analysis). The socio-economic models assess coastal vulnerability based on factors concerning people, land use, or the economy (Shankar, 2000). A few studies have focused on developing techniques which incorporate both approaches of integrating physical as well as economical models (Boruff et al., 2005).

### 2.3 Remote sensing in coastal ecosystem studies

Aerial and space borne photographs have been used to detect submerged features since 1970s to retrieve the seabed composition, and to map bathymetry (Ackleson, 2003). The first remote sensing satellite Landsat MSS (Multi-spectral satellite sensors) data became available in the mid 1970s, numerous attempts (Hammack, 1977) have been made to explore the possibilities of remote sensing in coral reef science and management (Mumby et al., 1997; Ackleson, 2003). Many studies ever since have shown the usefulness of remote sensing to provide baseline information on coral reefs (Green et al., 1996; Bryant et al., 1998; Lunetta and Balogh, 1999; Mumby and Edwards, 2000). According to Phinn et al., (2000), four categories of information can be extracted from remote sensing data regarding coastal reefs. These categories include information about the configuration and the composition of the reef structures; the biophysical parameters of the seas and oceans in which the coral reefs occur; and changes over time of these elements. Information about the configuration of a coral reef encompasses its localization planimetric and bathymetric- as well as a
classification of the reef’s geomorphological structure. On the ecological level, remote sensing provides information about the dominant reef communities, benthic habitats or bottom-types, which compose the reef system. (Vanderatraete, et al., 2005).

Remote sensing data can be used in environmental monitoring programs where the objective is to monitor changes in surface phenomena over time (Howarth and Wickware, 1981). It was well demonstrated in a more recent study in monitoring shore line changes, in turn changes in the profile of the local ecosystem (Makota et al., 2004). The continued monitoring of shoreline changes helped them to understand the changes taking place at the Kunduchi–Manyema creek of Tanzanian coast and thereby the change in the ecosystem.

More importantly, the sustainable use and management of important tropical coastal ecosystems (mangrove forests, sea grass beds and coral reefs) cannot be done without understanding the direct and indirect impacts of man. The ecosystem’s resilience and recovery capacity following such impacts must be determined. This could be well studied by the spatial changes in the coastal ecosystem and the dependencies of human for their livelihood on this ecosystem (Goetz et al., 2004). This could be well studied by using remote sensing satellite data and GIS (Farid, 2002). The study illustrated various tropical coastal zones, their land cover patterns, population structure and dynamics. It further showed that integration of remote sensing technology and other scientific tools can be integrated in long-term studies, including predictive models and mitigation studies. Since, coastal ecosystem involves many parameters such as landform, flora, fauna, land cover and land use patterns, localized human pressure, it is necessary to involve all these parameters to have a holistic concept and the use of spatial techniques such as remote sensing and GIS are very important. These are essential in the spirit of sustainable development and management, particularly in developing countries, which are often more vulnerable to environmental degradation.

In another paper, Blasco et al., (1998) reiterated the ability to map mangrove ecosystem through remote sensing satellite data. The authors have used image
processing method for the identification and delineation of coastal ecosystems. From a spectral point of view, it is practically impossible to characterize each of the sixty species of trees and shrubs that constitute the mangroves of the world (Blasco et al., 1996). Nevertheless, some possibilities exist to map at global and at local scales mangrove areas from satellite products supported by ground truth verification and field knowledge. Similar studies using remote sensing data have been carried out in Sunderbans of India and mangroves in Burma for mapping the spatial extent of mangrove species (Blasco et al., 1994; Imhoff et al., 1990).

In the same way, satellite data combined with GIS techniques are very useful in mapping coastal wetlands in arid environment too (Althausen Jr, et al., 2003). In this study, digital image processing algorithms (Jensen, 1996) and techniques (Sabins, 1997) have been applied on the remote sensing satellite data to enhance the imagery in such a way that features nearly undetectable in visual examination are discernible after classification, i.e., oolitic ridges and black mangroves. The functionality of combining raw TM bands with principal components and band ratios in a hybrid spectral analysis has also been demonstrated in this study. Also, the arid climate of the study area makes it ideal to use in this case because of the low levels of atmospheric constituents and water vapor, associated with the region and hence limiting the degradation of the signal (Khan et al., 1992; Murali and Lulla, 1992; Narumalani et al., 1993).

In another study, coastal and marine environment has been studied MODIS sensor multispectral imagery and the study showed that MODIS could be used as an alternative for anomaly detection especially to study oil spills in the sea and coast (Dessia, et al., 2008). In this study, a simple spectral index is applied on the image to detect fluorescence anomalies due to oil spills and standard sea temperature elaborations have been used to verify the methodology.

2.4 Remote sensing in coastal landform studies

The utility of remote sensing satellite data in delineating lithological units and landforms to study groundwater environment of a terrain has gained enormous
momentum (White, 1993) and extended to other areas apart from hard rock terrain, especially coastal area. A remote sensing based understanding of the subtidal habitats (Lysenga, 1978), turbidity condition of water bodies (Lindell et al., 1985) stress the significance of using remote sensing techniques in understanding the various coastal environmental parameters. Coastal evolution studies by delineating various landforms such as spits, bars, beach ridges, tidal flats, mangroves, marshy areas and beaches (Weerakody, 1988) including studies related to recent and near-future coastal changes to understand the significance of coastal environment of the terrain (Raj, 1985). Many interesting studies using remote sensing satellite data have reiterated its advantage in monitoring coastal ecosystem and shoreline configuration.

Delineation of sub-tidal coastal habitats in the western Arabian Gulf (Khan, 1992), analysis of satellite data to understand the relationships among hydrology, geomorphology and vegetation (Gomarsca et al. 1992) to extract information on the coastal landforms such as ancient beach ridges, old dunes to infer lineaments and relating the present shoreline with the lineaments of the area (Kunte and Wagle, 1994) are some of the earlier studies on coastal environment using remote sensing satellite data.

Many studies have been conducted amplifying the capability and significance of remote sensing satellite data in understanding the coastal ecosystem and environment such as monitoring beach erosion by Frihy et al in 1994, mapping of saline lake environment (Radhakrishnan et al.,1994; Radhakrishnan and Elango, 1996), mapping landuse types and monitoring landuse changes especially in coastal zone management by Huang and Fu (2002) and Alphan (2003) including identification and mapping of wetland vegetation along the coast (Adam, et al., 2010).

Similarly, construction of port and artificial jetties could also play a role in stability of shore line and near shore features influencing the coastal ecosystem. Such changes in coastal ecosystem due to infrastructure development could be studied using remote sensing satellite data (Nayak et al., 1997; Sanil kumar et al., 2006). Accretion and erosion along the shoreline over a period of time (Mani Murali, et al., 2009) and in turn their influence on the ecosystem could be studied using multi-temporal remote
sensing satellite data apart from natural changes in vegetative pattern due to tidal action near an estuary (Field and Philipp, 2000).

Quantitative information about shoreline position is fundamental for coastal resource management and environmental monitoring because it has a direct influence on the ecosystem and littoral zone marine resources. It is also necessary to have clear dynamic coastline information so that it could be continuously monitored not only for human activities (settlements and roads) but for inventorying natural resources, delineating areas exposed to coastal hazards (Zeidler, 2007; White et al., 1999; Liu et al., 2007) and so on. Recent technique such as image processing combined with field knowledge and field verification really helps to monitor such changes at frequent intervals (Puissant, et al., 2008).

Presently, implementation of semi-automated techniques using image processing methods is applied on the images to monitor wetland restoration and quantifying vegetation change (Tuxen, et al., 2008). Normalized Difference Vegetation Index (NDVI) is used to monitor vegetation change in a restoring salt marsh. Change in vegetation over a period of 10 years was analyzed using a post-classification comparison technique where yearly information obtained from image was classified individually into vegetated and non-vegetated areas using NDVI thresholds. The difference between years was used to identify areas of vegetation change. The study further demonstrated that high-resolution remotely sensed data could be analyzed with common geospatial software to monitor change in a rapidly vegetating wetland and remote sensing is useful for post-restoration monitoring of tidal marsh ecosystems.

Analysis of Remote Sensing Image (RSI) is a major application domain used for various feature extraction and pattern recognition involved in natural resources assessment, hazards and environmental monitoring activities such as coastal area, sea grass and mangrove ecosystem (Farid, 2002), beach morphology (Teodoro, et al., 2008) and coastal hazards (Garcin et al, 2008; Roemaer et al., 2010). The process of information extraction from RSI (Yu et al., 2000) exploit the interaction of objects on the earth with electromagnetic spectrum (ems) such as reflection, refraction and absorption, which in turn gives rise to the term spectral behavior. This spectral
behavior is well exploited to identify and categorize each objects and to generate information database of any specific theme (Chen and Wang, 2004). Hence, it requires an understanding on the inherent characteristics of different objects in different spectral region, attenuation or noise of signals involved due to atmospheric particles, capability of sensors and various measures of pre-processing of satellite data and at last types of image processing for information extraction procedures especially for coastal environment (Bhuvaneswari, et al., 2011a). In another study by the same authors illustrated the utility of image processing of remote sensing satellite data to depicts coastal wetland features such as beach, tidal flats, saltpan, coastal dune, marsh, lagoon ecosystem apart from saline area and other terrestrial vegetation such as plantation and crop and scrub. The study showed that with some simple unsupervised classification, sensitive wetland features contributing to the preservation of ecosystem could be delineated. The result may be verified on field and the sensitivity of individual wetland features with respect to prevailing coastal ecosystem could be studied (Bhuvaneswari, et al., 2011b).

To use the spatial techniques to the advantage of ecosystem monitoring, integrated approach using both remote sensing and Geographic Information System (GIS) could be more powerful and could include huge volume of qualitative and quantitative data such as collateral data and other related field data for analysis and monitoring.

### 2.5 GIS in coastal ecosystem studies

To monitor shore line changes and change in ecosystem, integration of data in GIS would be much easier and more significant. Derived shorelines from satellite data may be brought into a GIS system periodically and any changes in the form of deposition and erosion could be monitored (Li et al., 1998). Studies integrating remote sensing and GIS in deriving information on coastal hazards have been explained by Garcin et al., in 2008. GIS is also helpful in modeling and mitigating ecological damage. An efficient instrument for conducting surveys and inventories of coral reefs to assess those ecosystems at higher risk and develop mitigation strategies is through the use of a Geographic Information System (GIS) is well explained by Snow and Snow (2008). The study involved generation of coastal data baseline such
as changes in coastal land use, wetlands, shoreline configuration and coral reef structure and their extent. The study also demonstrated the significance of GIS in modeling the mitigation of coral reef damages from climate change and other threats.

Such studies highly compliment the capability and the utility of remote sensing and GIS in monitoring ecosystem, assessing them either directly or indirectly through coastline and shore landform studies.

2.6 Summary

All these above studies under various sections explained the significance of coastal environment, coastal ecosystem and parameters influencing them. Studies on coastal wetland features such as tidal flats, marsh, lagoons etc., explained the intricate webbing of coastal ecosystem and the importance of these features in maintaining the balance of ecosystem. Moreover, changes in shoreline, erosion and accretion, and its impact of coastal area are also reviewed. The impact of infrastructure development such as port, artificial jetties and roads on shore landform, in turn, changes in the shoreline and ultimately their combined effect on the existing ecosystem is well brought out through the literature review. At this point, the significant role of remote sensing as an effective tool to monitor and assess coastal environment is highly appreciated. Its synoptic view and repetitive coverage under illumination makes it a highly desirable source of information on the studies of coastal ecosystem. Furthermore, the significance of image processing techniques of the remote sensing satellite image in bringing out required information on the coastal system is reviewed in detail. With this knowledge, a suitable methodology has been adopted after careful review of literature to study the coastal ecosystems of a lagoon and an interactive ecosystem of lagoon and freshwater lake at two different selected sites along the northern coast of Tamil Nadu, India, has been discussed in the following chapter.