COASTAL EROSION STUDY OF PONNANI REGION USING MULTISPECTRAL IMAGES

by

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(2013 – 18 – 104)

THESIS

Submitted in partial fulfilment of the

requirement for the degree of

MASTER OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

(Soil and Water Engineering)

Faculty of Agricultural Engineering & Technology

Kerala Agricultural University

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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2015

DECLARATION

I hereby declare that this thesis entitled **"Coastal Erosion Study of Ponnani Region Using Multispectral Images"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title of any other University or Society.

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Certified that this thesis, entitled **"Coastal Erosion Study of Ponnani Region Using Multspectral Images"** is a record of research work done independently by **Miss. Sheeja P.S (2013 – 18 – 104)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ACKNOWLEDGEMENT

With deep sense of gratitude, indebtedness and due respect, I express my heartfelt thanks to my respected advisor **Er. Vishnu, B.,** Assistant Professor, Department of Irrigation and Drainage Engineering, KCAET, Tavanur for his valuable guidance, criticism and immense help throughout the course of work. His critical suggestions and comments was undoubtedly been the key for the successful preparation of this thesis work.

Words seem to be inadequate to express my sincere thanks to **Dr. M. Sivaswami**, Former Dean, KCAET, Tavanur for his professional guidance and constructive suggestions offered during this study. I express my heartfelt thanks to **Dr. Hajilal M.S**, Dean, KCAET, Faculty of Agricultural Engineering and Technology for the unfailing guidance and support that he offered while carrying out the project work.

I engrave my deep sense of gratitude to **Dr. Sasikala, D**., Associate Professor and Head, Department of Irrigation and Drainage Engineering, to **Dr.Rema, K.P.,** Associate Professor, Department of Irrigation and Drainage Engineering, **Er.Sindhu Bhasker**, Assistant Professor, Departmant of Farm Power Machinery and Engineering, KCAET, Tavanur for her valuable suggestions, evaluation and due encouragement during the entire period of the project work.

I sincerely acknowledge the help and suggestions of **Er. Jinu, A.,** Assistant Professor, Department of Land and Water Resources and Conservation Engineering, **Er. Anu Varghese**, Associate Professor, Department of Irrigation and Drainage Engineering, KCAET, Tavanur during my thesis work.

With great pleasure I express my heartfelt thanks to all teachers of KCAET Tavanur for their support during my thesis work.

With great pleasure I express my heartfelt special thanks to my batchmates for their enthusiastic cooperation from time to time for the each step of my thesis work.

I express my thanks to all the **Mr. Sreekumaran, S.**, Assistant Librarian, and all other **staff members of Library**, KCAET, Tavanur for their ever willing help and cooperation. I express my sincere thanks and gratitude to **Kelappaji College of**

Agricultural Engineering & Technology for giving me the opportunity to undergo my post graduation studies and all facilities offered during my thesis work. I engrave my deep sense of gratitude to **Kerala Agricultural University** for providing the opportunity for post graduation, the KAU merit fellowship and for approving my thesis work during my study.

I am greatly indebted to my parents, sister and brother for their blessings, prayers and support without which I could not have completed this work.

My thanks remain with all those who have helped me in the one way or other for the completion of the research work.

Above all, I bow my head to Him who had been constantly present with me during my work and for invigorating, enlightening and making me confident and optimistic throughout my life.

Sheeja, P.S

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SYMBOLS AND ABBREVIATIONS

CAD	Computer-Aided Drafting
CVI	Coastal Vulnerability Index
DN	Digital Number
DSAS	Digital Shoreline Analysis System
E	East
EPR	End Point Rate
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Systems Research Institute
ETM	Enhanced Thematic Mapper
GIS	Geographical Information System
GloVis	Global Visualisation Viewer
GPS	Global Positioning System
GUI	Graphical User Interface
HDDS	Hazards Data Distribution System
HRV	High-Resolution Visible
HTL	High Tide Line
HTTPS	Hypertext Transfer Protocol with Scene
IDE	Irrigation and Drainage Engineering
IRS	Indian Remote Sensing Satellite
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology

km	Kilometer
km^2	Square Kilometer
KML	Keyhole Markup Language
kmph	Kilometer per hour
LCDM	Landsat Data Continuity Mission
LISS	Linear Imaging Self-Scanning
LRR	Linear Regression Rate
m	Meter
m^2	Square meter
m/year	Meter per Year
mips	Maps and Image Processing Software
mm/year	Millimeter per Year
MSS	Multi-Spectral Scanner
N	North
NIR	Near Infrared
NSM	Net Shoreline Movement
PHP	Hypertext Preprocessor
RS	Remote Sensing
RTK	Real Time Kinematics
SCE	Shoreline Change Envelope
SML	Geospatial Scripting Language
SPOT	Satellite Pour l'Observation de la Terre (French)

TIN	Taxpayer Identification Number
TM	Thematic Mapper
USA	United States of America
USGS	United States Geology Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WLR	Weighted Linear Regression

CHAPTER 1

INTRODUCTION

The coastal zone is a complex environment, where the saltwater of the ocean meets the freshwater and/or the land meets the ocean. Carter (1988) defines the coast as "that space in which terrestrial environments influence marine environments and vice versa". However, in practice, the term coastline is frequently used in popular terminology to denote coast. The coast has width, depth as well as length, so the term coastal zone is preferred. The coastal zone represents varied and highly productive ecosystems such as mangroves, coral reefs, sea grasses and sand dunes. The coastal ecosystems harbour a wealth of species and genetic diversity, store and cycle nutrients, filter pollutants and help to protect shorelines from erosion and storms. Moreover, marine ecosystems play a vital role in regulating climate and they are a major carbon sink and oxygen source. The coastal region is of very high biological productivity and thus is an important component of the global life system.

1.1 IMPORTANCE OF THE COASTAL ZONE

The coastal zone contains some of the planet's most productive ecosystems with rich biodiversity reserves and supports a part of the planet's human population. This region is integral to the social and economic life of the region and is the zone in which most of the infrastructure and human activities directly connected with the sea are located. It includes both the area of the sea subjected to land influences and the area of land subjected to marine influences which can be divided into three main components: the sea, the beach, and the land behind the beach. The sea, or offshore area, extends seaward from the low water mark. This area covers the shallow marine habitats of the coast, such as the sea grasses and the coral reefs among others. The beach zone extends from the low water mark to the seaward edge of the coastal vegetation. The last component of the coastal zone is the adjoining coastal land. This zone extends landward for some distance from the end of the beach.

The coastal zone provides a source of income, recreation and a way of life that affects millions of people. It functions as a trade and transportation route. It supplies nurseries for fish stocks, contributes vast quantities of food and supports an economy based on nature. The coasts are also tourist centres and attract people who want to explore these unique environments. The coastal zone represents natural resources such as coral reefs, sea grasses and mangroves. Estuaries, coastal lagoons and other inshore marine waters in the coastal zone are very fertile and productive ecosystems. These ecosystems act as sinks of terrestrial runoff, trapping sediments and toxins, which may damage the fragile coral reefs.

Human civilization is growing rapidly along the coast worldwide due to these abundant natural resources. The coastal areas of the world are of extreme economic importance as approximately, two-thirds of the world's population live along the coastlines. Coast, apart from being rich in minerals, has potential for exploitation of tidal energy and ocean thermal energy for the benefit of development. Ecologically significant, the coastal zone in India is characterized by diversity of habitats, the extensive beaches of silvery sand, spits and dunes, rugged cliffs or slippery domes of rocks, salt marshes, estuaries, lagoons, mangrove swamps, coral reefs, sea grass beds and marshy wetlands.

1.2 COASTAL EROSION- CAUSES AND IMPACTS

The coastal area is a highly dynamic environment with many physical processes such as tidal inundation, sea level rise, land subsidence, erosion, and sedimentation; these processes play an important role in the shoreline change and coastal landscape development (Dey *et al.*, 2002). The coastal zone of world is under increasing stress due to development of industries, trade and commerce, tourism and resultant human population growth and migration, and deteriorating water quality. The shoreline, which is defined as the position of the land-water interface at one instant in time (Genz *et al.*, 2007) is a highly dynamic feature and is an indicator for the coastal erosion and accretion. Shoreline geometry depends on the interactions between and among waves, tides, rivers, storms, tectonic and physical processes. Beach erosion and accretion or shifting shorelines and sea level rise are a chronic problem along most shorelines worldwide since centuries disturbing a dynamic equilibrium.

The wearing down of the top surface of the land is called erosion, while accretion denote the building up of the loose materials at a place. The processes of erosion and accretion affect human life, cultivation and natural resources along the coast. The rapid changes in shoreline can create catastrophic social and economic problems along the populated strands. Design of viable landuse and protection strategies to reduce potential loss is necessary and this requires comprehension of regional shoreline dynamics (Blodget *et al*., 1991 and Chu *et al*., 2006).

Coastal erosion has different spatial and temporal forms. There are three major spatial forms of coastal erosion:

(1) Coastline retreat, which occurs dominantly for soft coast (comprising quaternary sediment and eluvial sediments of red soil weathering crust and barrier-lagoons) without protection measures like seawall engineering,

(2) Landward movement of the zero meter depth contour, which is caused by beach surface incision, usually occurring on a coast with a seawall, and

(3) Downward erosion of the lower beach in the sub-tidal zone by tidal current with the upper flat maintaining its original shape.

Erosion can also be divided into two types in terms of time scale:

(1) Long-term erosion (invisible) is the permanent change in the shoreline position due to events such as a sea level rise, river diversion or decrease in sediment discharge, which reduce the original sediment budget. The erosion process takes a long time and moves slowly under the circumstances of new coastal dynamics and sediment budget.

(2) Short-term erosion (visible) can be caused by storm tides and storm surges without causing a permanent change in the shoreline position, but it brings enormous destruction (Feng *et al.*, 2009).

The coastal erosion is prevalent in over 70% of the world's beaches and it is a serious hazard to many coastal regions (Addo *et al*., 2011). The loss of land mass due to the backward movement of sand towards the ocean as a result of the actions of natural forces like wind, tides, waves, and the ocean currents etc. changes the shoreline. Ministry of Earth Sciences, Hyderabad (2009) reported that In India about 40% of 7517 km long shoreline is affected by various degree of erosion varying from minor, moderate to severe. As much as 1248 km of the shoreline is getting eroded all along the coast. As per the report of the Environment and Forests Ministry of Government of India the long-term shoreline change was assessed for a period of 38 years from 1972-2010 and accordingly, 480 km of the 569 km shoreline of Kerala is subjected to coastal erosion ranging from low, mediam to high. Thus around 63% of Kerala coast (sum of high, medium, low and artificial coast) is being affected by the phenomenon.

In order to ensure sustainable development, it is necessary to develop accurate, up-to-date and comprehensive scientific databases on habitats, protected areas, water quality, and environmental indicators and carry out periodic assessment of the health of the system. Coastal zone monitoring and mapping can be accomplished with the aid of remote sensing, GIS and GPS and the results can be used for sustainable management of coastal areas.

1.3 MONITORING AND ASSESSMENT OF COASTAL EROSION

The modern scientific tools of remote sensing, GIS and GPS are extremely valuable in the development of databases and to analyse coastal area in an integrated manner and to derive management action plans. The availability of repetitive, synoptic and multispectral data from various satellite platforms, viz. IRS, LANDSAT, SPOT, etc. has helped to generate information on varied aspects of the coastal and marine environment.

Remote sensing technology is useful for assessing the coastal environment and monitoring the changes that have occurred over time in the coastal zone (Nayak, 2000). This technology had been used commonly to map the shoreline and it offers the potential of updating maps frequently (Frihy and Lofty, 1997). These remotely sensed data can be used to evaluate the coastal processes like erosion or accretion and shoreline changes. Remote sensing satellite images have been effectively used for monitoring shoreline changes of different locations (Rao *et al*., 1984; Alesheikh *et al.*, 2007).

Remote Sensing imageries use different wavebands to record the reflected energy from the earth. Different wavebands of light penetrate water to varying degrees; red light attenuates rapidly in water and does not penetrate deeper than 5 m or so, whereas blue light penetrates much further (15 m), the green light penetrates as far as 15 m in clear waters, near infrared (NIR) (0.7- 0.88μm) penetrates to a maximum depth of 0.5 m and infrared (IR) (0.8- 1.1μm) is fully absorbed by the water and no reflection occur (Mumby and Edwards, 2000).

Geographic Information System (GIS) is designed to work with data referenced by spatial or geographical coordinates. The major advantage of GIS is that it allows identifying the spatial relationships between features and the temporal changes that have occurred within an area over time. For measuring and monitoring coastal erosion and accretion, satellite imagery is useful in extracting the shorelines, and GIS has been used extensively to overlay multitemporal shoreline maps to detect and visualize the changes over time.

Sea coast of Ponnani area in Malappuram district, Kerala has been facing erosion. There are several houses of especially fisher men near to the coastal area, which are facing threat of destruction due to sea erosion. This region is considered for this particular study to understand the extent and magnitude of the erosion problem and to suggest steps to prevent erosion. It is very important to study the erosion and accretion processes along the coast in order to develop proper erosion control measures. The present study was undertaken with the following objectives:

1. To apply remote sensing to assess the temporal changes along the coastal areas of Ponnani.
2. To determine the shoreline changes using digital change detection techniques.
3. To study the extent and magnitude of the coastal erosion.
4. To evaluate the impact of coastal processes on erosion.
5. Identification of priority areas and suggestion of suitable preventive measures.

CHAPTER 2

REVIEW OF LITERATURE

The previous studies about coastal erosion assessment using remote sensing and GIS techniques are being reviewed in this section.

2.1 ROLE OF REMOTE SENSING AND GIS

Remote sensing technology is useful for assessing the coastal environment and monitoring the changes over time in the coastal zone (Nayak, 2000). This technology had been used commonly to map the shoreline and offers the potential of updating maps frequently. These remotely sensed data can be used to evaluate the coastal processes like erosion or accretion and shoreline changes. Remote Sensing is used to address a wide variety of management and scientific issues in the coastal zone. Due to its repetitive, multispectral and synoptic nature, remote sensing data has proved to be extremely useful in providing multispectral information on various components of the coastal environment. It plays an important role for spatial data acquisition from economical perspective (Alesheikh *et al.,* 2003). The modern scientific tools of remote sensing, Geographic Information System (GIS) and Global Positioning System (GPS) are extremely valuable in development of databases and to analyse coastal area in the integrated manner and derive management action plans. Availability of repetitive, synoptic and multispectral data from various satellite platforms, viz. IRS, SPOT, LANDSAT have helped to generate information on varied aspects of the coastal and marine environment.

A variety of data sources are available for examining shoreline position however, the availability of historical data is limited at many coastal sites and so the choice of data source is largely limited to what is available for the site at a given time (Boak and Turner, 2005). The different features over the earth's surface can be classified based on spectral properties of the satellite image. Shoreline mapping techniques applied to data sources have moved towards automation in association with technological advances and the need to reduce uncertainty. Although these changes have resulted in improvement in coastal data processing and storage capabilities, the frequent change in technology has prevented the emergence of one standard method of shoreline mapping. This has occurred because each data source and associated method has their own unique capabilities and shortcomings.

GIS is designed to work with data referenced by spatial or geographical coordinates. The major advantage of GIS is that it allows identifying the spatial relationships between features and temporal changes within an area over time. For measuring and monitoring coastal erosion and accretion satellite imagery is useful in extracting the shorelines, and GIS has been used extensively to overlay multitemporal shoreline maps to detect and visualize changes over time.

Mani *et al*. (2009) conducted a study on monitoring shoreline environment of Paradip, east coast of India using remote sensing. Imageries of Indian Remote Sensing Satellites (IRS1D and IRS P6 – Resourcesat) from 1998 to 2005 were to monitor the coastal environment of Paradip. The resultant coastal vector maps were used to estimate the geomorphological changes and shifting of the shoreline position. This integrated study is found useful for exploring accretion and erosion processes in the region. The shoreline maps were compared with the 1973 Survey of India toposheet to estimate the changes which have occurred in the region. Results indicate an increase of 7.72 km in shoreline length and a net loss of 18.73 km^2 of beach area between the years1973 and 1998, and 0.46 km reduction in shoreline length and 3.11 km^2 increase in beach area between1998 and 2005. An overall net increase of 7.26 km length shoreline and a net loss of 15.6 km^2 were observed between 1973 and 2005. The years 2001, 2002 and 2003 exhibited loss in length of shoreline as well as area of the beach.

Absornsuda (2010) did a study to detect the coastline changes in Thailand by remote sensing. LANDSAT imageries have been used to detect the coastline change both from natural and man-made causes in various parts of Thailand. The images in 1988, 1994 and 2000 before and after the constructions of the reclaimed lands were used to study the coastline changes by image difference method. The accretion and erosion of the western coastline during this period were estimated as 5,250 and 6,975 m^2/year, while the eastern coastline was 4,650 and 11,400 m^2/ year. LANDSAT images were analysed by colour density slicing method to detect the effect of monsoon wind on sediment distribution which can cause accretion and deposition of the coast here. With environmental data such as wind, river discharge and human activities the causes of coastline changes are also discussed.

Pritam and Prasenjit (2010) made a project on Shoreline change and sea level rise along coast of Bhitarkanika wildlife sanctuary, Orissa: An analytical approach of remote sensing and statistical techniques. This study has used Multi-resolution satellite data of series such as Multispectral Scanner (MSS), Thematic Mapper (TM), and Enhanced Thematic Mapper (ETM+). The study was carried out to analyse and interpret optical remote sensing data for shoreline change mapping and statistical techniques for shoreline change rate over the four decades and to trace out where there are any the interactive relationship between sea level changes and shoreline change. Initially, the shorelines have been identified and delineated using the processed NIR bands of LANDSAT imageries. Shoreline changes and change rate were measured by quantifying the amount of shoreline shift along transects perpendicular to baseline in the desired spacing. Several statistical methods were used to calculate the shoreline change rates with the most commonly used being endpoint rate (EPR) calculations or linear regression (LRR). End point rate calculations are simply the rates determined based on the changes in position between the oldest and most recent shorelines in a given dataset. Linear regression rates are the result of estimating the average rate of changes using a number of shoreline positions over time. The zone based analysis of shoreline changes shows that an extensive part of the shoreline is affected by the shore zone erosion during last 36 year. Based on the present study, it can be concluded that accurate prediction of shoreline changes can be done cost effectively using satellite data of higher resolution at smaller intervals and selecting short spaced transects.

2.2 REMOTE SENSING AND GIS BASED ANALYSIS OF COASTAL EROSION

Vedast *et al.* (2004) conducted a case study for monitoring shoreline change at Kunduchi area, Tanzania by using remote sensing and GIS. Aerial photographs of the study area from 1981, 1990 and 2002 were used for quantification of shoreline change. The scanned photographs were georefenced with the aid of GPS. A suitable map projection, the Universal Transverse Mercator (UTM) projection (UTM zone 37) was used, along with the World Geodetic System 1984 (WGS 1984) datum. The digital aerial photograph files were displayed as background in ArcView 3.1 software. The shoreline was therefore identified and digitised on the screen along the high water mark. These shapefiles are overlaid together. A new line theme was created and four lines were digitised perpendicular to the shoreline in selected areas of overlaid lines of the shoreline. It has been observed that shoreline change in the study area results from both erosional and accretional processes. The study has revealed that during 1981-2002, more erosion took place in the northern part of the creek while deposition took place in the southern part.

Detection of shoreline changes at Kuala Terengganu, Malaysia from multitemporal satellite sensor imagery was done by Muslim *et al*. (2010). This research utilizes multitemporal satellite imageries of study area Seberang Takir, Terengganu, Malaysia from 1992 to 2009 to monitor shoreline changes through image processing techniques and statistical analysis. SPOT HRV, IKONOS and RazakSat are the three different satellite sensor from which imageries were aquired. Geometric correction was done inorder to improve the spatial features of the imageries and it influence the accuracy of shoreline changes. For producing shoreline two classification techniques were adopted. The hard classification were adopted for IKONOS sensor images where image is classified into two classes.

For RazakSat and SPOT imageries were classified using a soft classifier which predicts the per class composition of a pixel. Determination of erosion and accretion along selected shoreline positions were carried out.

Vinayaraj *et al.* (2011) used remote sensing and GIS for quantitative estimation of coastal changes along selected locations of Karnataka, India. The study has been carried out using toposheets of Survey of India and satellite imageries (IRS-P6 and IRS-1D). Changes during 30 years period are studied at each station. Topomaps were scanned and opened in ERADAS IMAGINE 8.5 environment. IRS (LISS-III) imageries of 1998 and 2008 were Geo-registered with the base map using more than 25 corresponding Ground Control Points. The geocorrected data is entered to the ArcGIS environment for digitization of shoreline. Quantification of erosion or accretion rate is done by digitization as polygon features using ArcGIS. For minimizing the error, the data during similar tidal phase is considered in this study. The erosion observed is not continuous all along the coast but in isolated stretches along the coast. Comparatively large erosion have been observed at the river mouths. The coastline at Malpe is almost stable with negligible erosion and deposition. Significant amount of loss of land is observed mainly at the river mouth due to the sediment erosion from the banks because of complex interactions between river flow, waves and the tides.

Klemas (2011) made a study on Remote sensing techniques for studying coastal ecosystems. To map longterm changes of the shoreline due to beach erosion, time series of historical aerial photographs and topographic maps have been used. Aerial photographs are available dating back to the 1930s, and topographic maps exist to extend the record of shoreline change to the middle to late 1800s. Such data are held by local, state, and federal agencies, including the U.S. Geological Survey (USGS) and the U.S. Department of Agriculture Soil Conservation Service. They also have various maps, including planimetric, topographic, quadrangle, thematic, orthophoto, satellite, and digital maps. To performe shoreline position analysis, the shoreline can be divided into segments that are uniformly eroding or accreting. Then the change in the distance of the waterline can be measured in reference to some stable feature like a coastal highway. The instantaneous water line in the image is not a temporally representative shoreline. The high water line, also referred to as the wet or dry line, is a commonly used indicator because it is visible in most images.

Anil *et al.* (2012) focusd on coastal erosion assessment along the Southern Tamilnadu coast, India. This paper mainly focuses on coastal erosion hazard assessment estimated along the coastal precinct between Kanyakumari and Mandapam, southern Tamilnadu coast over a length of about 360 km. The total number of types of coastal erosion indicators found along the coastal zone and general spatial distribution (percentage of surface area) of coastal erosion indicators along the coastal zone were the two main components considered for coastal erosion assesment. The results show that effect of anthropogenic activities have played a major role for negative sedimentary budget identified.

Padmakumari *et al.* (2012) made an attempt to study the shoreline changes, using remote sensing and GIS techniques in the coastal part of East Godavari District, Andhra Pradesh, India. 1990 Survey of India toposheet and 2006 and 2007 IRS 1C LISS IV satellite data were used for this study. The available shorelines were subdivided into smaller segments by creating transects at right angles to a master shoreline for analysing shoreline geometry. Shoreline changes along these transects were computed and these can be further used to predict future shoreline changes positions based on the perceived historical trends. According to the temporal changes occurred during the past seventeen years i.e. from 1990 to 2007, the increase in measurements of shoreline from 163.08 km to 200.26 km and 194.31 km is attributed to inclusion of smaller spits, offshore bars and shoals and decrease of the same is linked to the resolution of the satellite images of 2006 and 2007 wherein LISS-IV and LISS-III images have been used respectively made by using ArcMap 9.3.

A study on quantitative estimation of shoreline changes using remote sensing and GIS in the parts of Cuddalore district, East coast of Tamil Nadu, India by Kumaravel *et al.* (2012) made an attempt to elucidate the effect of shoreline changes ersion and accretion along the study area. IRS imageries and Survey of India toposheets were used as the data sources. The kind and extent of shoreline changes were investigated by using GPS during ground truth verification. Erosion during the period 1971 to 1991 was 0.81 km^2, 1991 to 2001 was 4.91 km^2, 2001 to 2006 was 0.39 km^2 and 2006 to 2012 was 1.27 km^2 respectively. The accretion during the period 1971 to 1991 was 4.07 km^2, 1991 to 2001 was No change, 2001 to 2006 was 1.13 km^2 and 2006 to 2012 was 0.21 km^2 respectively. Erosion and accretion were also observed in specific geographical areas such as beach, plantation, land with scrub, river, mangrove forest, villages and urban coast. In overall these areas the erosion dominates, suggesting that many of the natural disasters occurred in the study period. The results are analyzed and presented in this paper. The study results revealed that 3.21 km^2 area erosion of the shoreline occurred in the past 41 years.

Alshaikh (2013) used remote sensing and GIS to detect environmental degradation in the Jeddah coastal zone, Saudi Arabia.The main objectives of the work were to identify the environmental degradation factors and their role in the destruction and creation of environmental problems of Jeddah marine coast. LANDSAT TM and ETM images acquired in 1986 and 2003 of the study area were used. Manuscripts and topographic maps of scale of 1: 4000,000 for Jeddah governorate, in addition to data and information obtained from different institutions were also employed. ERDAS IMAGINE 8.5 software was used for image processing (i.e. Export function, layers tacking, geometric correction etc.). Results showed that the negative changes in the coast exhibit 84 km as it record a length of 111 km compared to 195 km in 2003. This change leads to the depletion of natural environmental marine resources and erosion of the recreational areas at the coast line. Absence of a proper sustainable planning strategy and management of coastal natural resources cause improper human pressures and disorders in the natural balance of the marine environment. The study has suggested a strategy for sustainable touristic development, represented in building systems and developing laws with continuous work to revise procedures and update the standard limits.

A research conducted by Chandrasekar *et al*. (2013) aimed to classify the vulnerable risk zones of the Southern tip of India using shoreline change analysis and coastal vulnerability index (CVI). The shoreline change analysis has been done by automatic image analysis techniques using multitemporal LANDSAT data (1973, 1992, 2000 and 2006). The results have shown remarkable erosion in Cape Camoron (4.21 m/year), Idindakarai (4.56 m/year) and Vijayapathi (4.66 m/year). In contrast, the station between Chinna muttam and Visvanarayanapuram has predominant deposition. The CVI index were established based on following six variables: Geomorphology, Shoreline change rate (m/yr), Coastal slope (degree), Relative Sea level change (mm/year), Mean wave height (m), Mean Tide range (m). According to the CVI value, Cape Camoron (Left), Idindakarai and Vijayapathi sites were identified as highly vulnerable zones. In the study, remarkable coastal landform dynamics was observed in chinna muttam. The vulnerable map prepared for the southern tip ofIndian coast can be useful to prevent the coastline erosion and future disaster mitigation.

Kumaravel *et al.* (2013) made a case study on the application of remote sensing and GIS based shoreline change studies in the Cuddalore district, East Coast of Tamilnadu, South India. The study deals with the investigation of the spatial as well as quantifying the shoreline changes along the coast in the parts of Cuddalore district, east coast of Tamil Nadu by using geospatial techniques. The Survey of India topographic map, multitemporal Indian Remote Sensing satellite data were used to extract the shorelines. The data is processed and analysed by software like ERDAS image processing, ArcGIS respectively. The rates of shoreline changes are estimated by overlay analysis by using GIS environment. Due to length of the shoreline, the study area was divided into five segments namely A, B, C, D and E. The study reveals that most of the study area has been undergoing erosion around 3.21km^2 for the past four decades except Segment D.

Both natural and anthropogenic processes along the coast modify the shoreline configuration and control the erosion, accretion activities of the coastal zones.

Muthukumarasamy *et al.* (2013) made a case study to find out the shoreline changes using remotesensing and GIS environment along Valinokkam and Thoothukudi coast, Tamilnadu, India. The base map was prepared by Topo sheet. The quantification data on the shoreline changes in the study area was exported using image from 1992, 2000, 2005, 2010 and 2012. Erosion and deposition environment data is prepared from the for multiple years. The collected information was interpreted and incorporated with GIS analytical findings. The present shoreline changes were captured, which shows stunning examples of shoreline erosion and deposition. It is estimated that erosion during the period 1992 to 2000 was 369 m, 2000 to 2005 was 573 m, 2005 to 2010 was 172 m and 2010 to 2012 with 305 m respectively. The accretion during the period 1992 to 2000 was 1258 m, 2000 to 2005 was 120 m. 2005 to 2010 were 531 m, and 2010 to 2012 were 366 m correspondingly. Simultaneous erosion and accretion were also observed in specific geographical areas in Hare Island as sand spits below southern harbour breaker water and urban coast. In these areas the accretion dominates, suggesting the coast as a pro-grading coast.

Manik *et al.* (2013) had done shoreline change monitoring along the south Gujarat coast using remote sensing and GIS techniques. Data used for this study are multitemporal satellite images of LANDSAT MSS (1972), TM (1990), ETM (2001) and IRS P6, LISS-IV (2011). The shoreline consider as the high tide line (HTL) as it is easily photo interpreted and field located. Visual interpretation of satellite imageries has been carried out to demarcate the HTL based on various geomorphology and land use & land cover features. The satellite data has been process in ERDAS IMAGINE and HTL is demarcated in ArcMap. The study found that the coastal erosion is a major problem in the area. The period between 2001 and 2011 about 83.06 percentage of the South Gujarat coast is eroding, about 10.15 percentage of coast is stable and about 6.78 percentage of the coast is accreting in nature. The highly eroding areas occur along the southern portion of the study area particularly Valsad district. The main causes of coastal erosion of the study area were the strong tidal currents accompanied by wave action and reduced the sediment of the river. Various protection measures are observed such as sea wall and rubble dumping etc. The severity of erosion is alarming and draws immediate attention.

Poornima (2014) conducted a study on detection and future prediction of coastal changes in Chennai using remote sensing and GIS techniques. This study deals with the coastal change detection of the Chennai coast few years before and after occurrence of the Tsunami using satellite imagery for effective study area monitoring and assessment. Data between 2000 and 2012 were used as primary data sources in this study and change detection was performed by using image processing techniques and classification algorithms. The images were classified into two classes according to the spectral signatures of land and water. These classified images were imported into IDRISI GIS through which the changes in the coastal area for various years were found out and analysed.

2.3 COASTAL EROSION ASSESSMENT USING DIGITAL SHORELINE ANALYSIS SYSTEM

Thieler *et al.* (2007) used GPS data and ArcGIS software to produce a shoreline analysis on the coast of Rincon, USA. The analysis was done through the USGS extension tool called Digital Shoreline Analysis System better known as DSAS for its acronym. DSAS is free software used to calculate shoreline change statistics through vector data. This software is intended for use on coastal environments but it is useful in other environments that display boundaries like snowlines, land cover and vegetation lines.

Benjamin *et al.* (2008) carried out a project on modern erosion rates and loss of coastal features and sites, Beaufort Sea coastline, Alaska. Rates of erosion were determined for the three time periods with DSAS version 3.2, extension for ESRI’s ArcMap. This study presents modern erosion rate measurements based upon vertical aerial photography captured in 1955, 1979, and 2002 for a 100 km segment of the Beaufort Sea coastline. The required inputs for DSAS consist of a sequential time series of vector shoreline positions and a user created reference baseline to serve as the starting point for generating transects. The baseline was created manually, and transects were created using the simple cast function with a spacing of 100 m. This method effectively calculated erosion rates for 992 points along this 100 km stretch of coastline for 1955-1979, 1979-2002, and 1955-2002. Annual erosion rates from 1955 to 2002 averaged 5.6 m. However, mean erosion rates increased from 5.0 m/year in 1955-79 to 6.2 m/year in 1979-2002.

Addo (2009) conducted a project on detection of coastal erosion hotspots in Accra, Ghana. Previous studies have cited different erosion rates in Accra’s coastline, which ranges from 2 m to10 m/year. In this study Accra’s coastline historic rate of erosion terms was statistically calculated using DSAS. Available geospatial data, which includes a bathymetric map from Ghana Ports and Harbour Authority produced in 1904, topographic maps produced by the Survey Department of Ghana in 1974 and 1996, and a map of Ghana 2002, were used to create a database in ArcGIS. Orthogonal transects were generated along which historic recession rates were calculated using linear regression. The extracted coastline positions of 1904, 1974, 1996, and 2002 were overlaid in ArcGIS. This enabled linear changes in the coastline positions over the 98 years period to be detected and the locations experiencing significant recession identified. The computed historic rates of change at the transect points facilitated erosion ‘hotspots’ in the Accra coastline to be determined.

Tuncay (2010) conducted a study on Quantitative analysis of shoreline changes at the Mediterranean Coast in Turkey by remote sensing techniques. In this study, coastline changes were researched by using radiometrically and geometrically corrected multitemporal and multispectral data from MSS dated 1972, TM dated 1987, and ETM dated 2002. In the image processing steps, mosaicing, subset, Iterative Self-Organizing Data Analysis Technique classification, band ratioing, edge detection, and overlay techniques were used to carry out coastline extraction and the DSAS was used to calculate rate of coastline changes. DSAS program generated 741 transects that are oriented perpendicular to the baseline at a 100 m spacing along shore. The measured distance between the fixed baseline point and the shoreline positions generated by the program provides a reliable record monitoring the changes of shoreline positions over the 30 year time frame of the generated vectors. As a result of the analysis, in some parts of the research area, remarkable coastline changes (more than 2,900 m withdrawal and −24.50 m/year erosion) were observed for a 30 year period.

Khalid and Omran (2010) conducted a research on automated techniques for quantification of beach change rates using series along the North-eastern Nile Delta, Egypt. Ten scenes of sensors (MSS, TM and ETM+) at unequal intervals spanning 35 year period between 1972 and 2007 were analysed to quantify erosion and accretion pattern along the north-eastern coastline of Nile Delta, from Gamasa to Port Said. Rates of shoreline changes were calculated from automated waterline positions generated at 852 locations using a DSAS version 3.2 program. To assess impacts of coastal structures on the beach morphology the shoreline positions are divided into two groups. The first group (1972-1990) is designated to calculate rates of shoreline retreat approximately before protecting the coastline and the second one (1995-2007) after construction of protection works. Rates of shoreline changes estimated from three statistical approaches of DSAS (the end point rate, the Jackknife and a weighted linear regression) are validated with ground observations of beach profile survey data at the same corresponding positions. Comparison of shoreline rates of beach change obtained from LANDSAT data with that previously estimated from beach profiles shows that the method used is reasonably accurate with a correlation coefficient value of 0.76. Results indicate that the general alongshore erosion/accretion pattern is locally disrupted by the construction of protective engineering structures. The erosion at the tip of the Damietta promontory is terminated due to the construction of the 6 km seawall built in the year 2000; erosion was originally -43 m/year. before construction of this wall. Further west and prior to protection of Ras El Bar resort, erosion (-10 m/year.) is spatially replaced by a formation of salient accretion (15 m/year.) following emplacement of the detached breakwaters between 1991 and 2002. However, local adverse erosion has been resulted in at the western end of the breakwater system, averaging -5 m/year.

Cossu *et al.* (2010) conducted a study on contribution to understanding the erosion processes in Alghero coast. The sandy shore comprised between Alghero and Fertilia (Alghero Gulf, NW-Sardinia) has been monitored through satellite and aerial images from 1977 to 2009 and uploaded in ArcGIS system. Satellite images, air photos and maps of several years, from 1977 to 2009, have been uploaded in ArcGIS 9.3 - ESRI. Coastal lines analyses have been performed using DSAS, version 3.2 -USGS. DSAS can automatically generate orthogonal transects to the coastal line and define the coastal variation occurred between two times. The base line has been created using the “cast” function with 100 m interval (Jones *et al*., 2008). The erosion rate has been calculated in 48 places, along a 4.5 km of sandy shore in 1977, 1989 and 2009.

2.3.1 Application of Digital Shoreline Analysis System

The Digital Shoreline Analysis System (DSAS) is computer software that computes rate of change statistics from multiple historic shoreline positions residing in a GIS. It is also useful for computing rates of change for just about any other boundary change problem that incorporates a clearly-identified feature position at discrete times. The DSAS was developed to determine historical shoreline rates of change using a time series of shoreline data residing in a GIS. The DSAS employs a measurement baseline approach to calculate shoreline rates of change statistics reviewed by Dolan *et al*. (1991) (end point rate, average series of rates, linear regression and jackknifing) at a user specified interval along the shoreline.

DSAS is an extension that enhances the normal functionality of ESRI ArcGIS software, and enables users to calculate shoreline rate-of-change statistics from a time series of multiple shoreline positions. The extension was designed to aid in historic shoreline change analysis. DSAS is also useful for datasets that use polylines as a representation of a feature’s position at a specific point in time, such as the forward limit of a glacier; river channel boundaries, land use and land cover maps. DSAS works by generating orthogonal transects at a user-defined separation and then calculates rates-of-change and associated statistics that are reported in an attribute table. The DSAS tool requires user data to meet specific field requirements.

More broadly, DSAS in Historical Trend Analysis can be used to undertake:

i. The mapping of historic configurations of shoreline position over the period covered by available spatial data (e.g. maps, aerial photographs);

ii. The evaluation of historic changes and trends of individual or selected transects (discrete alongshore positions). Within DSAS, shoreline change is calculated at specific transects, and the time-series of change at specific locations can be evaluated using the DSAS output;

iii. The analysis of shoreline geometry, including foreshore steepening using the distance between mean high and low water marks and orientation for example, to examine rotational tendencies;

iv. To predict patterns of shoreline behaviour using the derivation of historical rate of change trends as an indicator of future trends assuming continuity in the physical, natural or anthropogenic forcing which have forced the historical change observed at the site (Addo *et al.* 2011)

The purpose of this extension is to extend the normal functionality of the ArcView Geographic Information System to include historic shoreline change analysis. The application extension is designed to efficiently lead a user through all the major steps of change analysis in a clearly organized and attractive user interface. This extension to ArcGIS contains three main components to assist a user to define a landward baseline, generate orthogonal transects at a user defined separation and to calculate rates of change. The baseline vector is added which may be the shoreline vector of oldest image available. The transects were formed from baseline which must be long enough then only most of the transects cross the shoreline vectors from all dates. Different shoreline vectors obtained are overlaid together so that the geodatabase is formed for further analysis. Shoreline change is calculated along these transects. The extension utilizes Avenue code to develop transects and rates and uses the Avenue programming environment to automate and customize the user interface. Landward movement of the shoreline (erosion) is expressed as a negative number and accretion is expressed as positive in this system.

DSAS computes shoreline rates of change using four different methods: (1) endpoint rate, (2) simple linear regression, (3) weighted linear regression, and (4) least median of squares. The standard error, correlation coefficient, and confidence interval are also computed for the simple and weighted linear-regression methods. The results of all rate calculations are output to a table that can be linked to the transect file by a common attribute field. DSAS is intended to facilitate the shoreline change calculation process and to provide rate of change information and the statistical data necessary to establish the reliability of the calculated results. The software is also suitable for any generic application that calculates positional change over time, such as assessing rates of change of glacier limits in sequential aerial photos, river edge boundaries, landcover changes, and so on.

Khalid (2011) made a case study on changes in the shoreline position caused by natural processes for coastline of Marsa Alam and Hamata, Red Sea, Egypt. This paper presents shoreline maps illustrating the shoreline erosion accretion pattern in the coastal area between Marsa Alam and Hamata of Red Sea coastline by using different sources of remote sensing data. In the present study, MSS (1972), TM (1990), ETM+ (1998, 2000) and Terra Aster (2007) satellite images were used. In this study, two techniques were used to estimate rate of shoreline retreat. The first technique is corresponding to the formation of automated shoreline positions and the second one is for estimating rate of shoreline change based on data of remote sensing applying DSAS software. In this study, the EPR was calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements at each transect. Alongshore rate changes shows that there are changes of erosion and accretion pattern due to coastal processes and climate changes.

Sajid and Chris (2012) carried out a GIS based analysis and modeling of coastline advance and retreat along the coast of Guyanaand modeling of coastline advance and retreat along the coast of Guyana. A time series (1941-1987) of empirical advance and retreat data from the coast of Guyana was used. Coastlines were also extracted from 1987, 1990 and 1992 LANDSAT TM images, and 1999, 2002, 2004 and 2006 ETM+ images. The historical data were used to calculate advance and retreat rates and sediment volume changes. Distinct periods of advance and retreat matched corresponding periods of sediment gains and losses. DSAS was used to predict rates of coastline change. Graphical plots of DSAS results identified spatial and temporal phase shifts of the coastline. Recurring episodes of accretion and erosion could be associated with the presence or absence of mudbanks along the coast.

Assessment of shoreline changes along the Lithuanian Baltic Sea coast during the period 1947–2010 done by Ingrida *et al.* (2012) used DSAS as a tool to determine coastal erosion and accretion. Shoreline position measurements at various time instants can be used to derive quantitative estimates of the rate of shoreline change and help to understand the magnitude and timing of erosion or accretion processes. Aerial photographs and topographic maps from 1947 to 2010 have been used to derive instantaneous shoreline positions, from which shoreline change rates have been estimated using statistical parameters: shoreline change envelope (SCE), net shoreline movement (NSM), and end point rate (EPR). Calculation of the shoreline position changes over the time was performed for all derived shorelines of 1946-2010. In order to determine the pattern of shift, the relative distance to the historical shorelines was measured from an onshore baseline along shore and 179 perpendicular 1 km long transects spaced 500 m apart. Among them 77 transects were located at the mainland coast and 102 transects at the western coast of the Curonian Spit This study was carried out along 90.6 km of Lithuanian Baltic Sea coast over the time span 1947 to 2010. The study demonstrated that combined use of cartographic data and statistical methods could be a reliable method for shoreline related studies. Application of such data seems to be trustworthy in qualitative monitoring of shoreline changes, while it is the only available method for long term studies.

Sayedur and Nitin (2013) conducted a study on Coastal erosion and accretion in Pak Phanang, Thailand by GIS analysis of maps and satellite imagery. The study carried out between 1973 and 2003 was measured using multitemporal topographic maps and satellite imageries.Within a GIS environment landward and seaward movements of shoreline was estimated by a transect-based analysis using DSAS, and amounts of land accretion and erosion were estimated by geosaptial analysis. The whole longitudinal extent of the 58 kilometer coast was classified into six kinds based onhistorical trends of erosion and accretion using agglomerative hierarchical clustering approach. Erosion and accretion werefound variable over time and space ranging from 18.4 mm per year to 33.65 mm/year, and periodic reversal of status was also noticed in many places. Land loss due to erosion as high as about 3 ha per km of shoreline, and land gain as high as about 1.8 hectare per km of shoreline was estimated in different tambons. As high as 1% of total land of a tambon was lost due toerosion, whereas the largest gain was estimated to be slightly over half-percent of the total area in another tambon. In general, southern tambons were more affected by erosion. Estimates of erosion were evaluated against field survey based data, and found reasonably accurate where the rates were relatively great.

Shanmugam and Nayak (2013) carried out a study on remote sensing and field studies to evaluate the performance of groynes in protecting an eroding stretch of the coastal city of Chennai. This study is concerned with remote sensing, GIS and field based studies to evaluate the performance of these groynes along the north Chennai coast and quantify the rate of accretion. Digitally processed multitemporal (1972-2011) satellite images were interpreted and the shorelines for 7 different years were digitised in a GIS environment. The digitised shorelines, imported into the DSAS were analysed and final maps were generated depicting erosion in before 2004 and accretion in after 2004 periods.

These maps showed that the shoreline has eroded about 220 meters in the last 32 years up to 2004, while it is accreting at a rate of about 8 m/year from 2004 up to 2011. Finally a shoreline change prediction model was prepared in the DSAS environment. The positions of the future shorelines were determined using a component of DSAS called LRR and the position of predicted shorelines was obtained. This study has shown that due to the construction of groynes, erosion has reduced and deposition is in progress to regain the lost beaches in Chennai City, thus indicating that the groynes are performing well.

William (2013) made a protocol for high resolution geospatial analysis of coastal change in the Arctic Network of Parks. Coastal zones for Bering Land Bridge National Preserve and Cape Krusenstern National Monument extend for over 450 km. Where erosion has occurred, rates have averaged -0.5 m/year, reaching more than -3 5 m/year with shoreline retreat of tens to hundreds of meters. This study provides background, a summary of historic coastal change, methodological rationale, data and operational guidelines, and stepwise procedures for geospatial analysis of coastal change specifically, erosion and accretion of the shoreline. DSAS was usedd as a tool for spatial analysis og erosion and accretion along the coast.

Cenci *et al.* (2013) made a research on geomatics for Integrated Coastal Zone Mannagement: multitemporal shoreline analysis and future regional perspective for the Portuguese Central region. This research utilized previous studies that combined both Remote Sensing and GIS techniques to assess, map and forecast shoreline evolution from short-term perspectives. The study area is located in the central region of Portugal, between the counties of Ovar and Marinha Grande (140 km) and the time period assessed was from 1984 to 2011.

Historical data were used to calculate advance and retreat rates in order to support environmental scenarios for the Portuguese Central Region’s Coastal Management Plan. To ensure accuracy, a repeatable procedure was validated using TM and ETM+ satellite images, which were subsequently enhanced and elaborated by Remote Sensing analyses to detect and extract shorelines. They were subsequently integrated within an Esri ArcGIS software application DSAS to determine and predict rates of coastline change. Graphical DSAS plots identified coastline phases and shifts and were used to simulate the 2022 coastline scenario. These results will be integrated into the Coastal Zone Management Plan.

Cristina *et al.*(2014) used DSAS for characterising shoreline change and coastal vulnerability with imagery in the outer Hebrides, Scotland. Historic and periodic (6-8 year intervals) imagery from the archive was used to investigate transformations in the Atlantic coast of two Scottish islands over the period 1989-2011. Supervised classification of spectrally normalized images followed by change detection and spatialanalysis reveals the patterns of change and the location of the most dynamic coastal areas. Quantitative measures of recent shifts and movement rates of relevant coastal lines, such as thelower limit of land-based vegetation, are assessed with the DSAS.While very low rates are indicated for horizontal changes in the position of the lower limit ofland-based vegetation (0.35 m/year), specific areas have been subjected to high rates of coastal accretion as well as erosion (e.g. 2.5 5 m/year at Stilligarry). Information derived from satellite data supports the characterization of geomorphologically dynamic coasts at regional scales.

Kaliraj *et al.* (2014) conducted a study on evaluation of coastal erosion and accretion processes along the southwest coast of Kanyakumari, Tamil Nadu using geospatial techniques. Multitemporal satellite images of the study area from 1999 to 2011 were used for the analysis. Short-term coastal erosion and accretion rates changes have been performed during 1999–2000, 2005–2006, and 2010–2011 and the subsequent The long-term shoreline changes were calculated for the periodsbetween 1999 and 2011. Based on this principle, the enhanced images were classified into two classes namely sea and water, and the discrete line between these two classes were extracted. These multidated shorelines were overlaid together for the identification of shoreline shift towards either offshore or onshore. Then,the intersection of shoreline line geometry was converted into polygon geometry using the feature to polygon conversiontool in ArcGIS 9.3 for the estimation of erosion and accretion along the study area using DSAS.The areas of erosion and accretion was categorized based on land loss and land gain along the 16 coastal zones of the study area.

Emmanuel and Kyriaki (2014) used DSAS for quantification of deltaic coastal zone change based on multitemporal high resolution earth observation techniques. The coastline of Istiaia (North Evia, Greece) has been chosen for this study as several areas of accretion and erosion have been identified during the past few decades. We combined different types of datasets, extracted from high resolution panchromatic aerial photographs and traced the contemporary shoreline by high accuracy surveying with Real Time Kinematics (RTK) GPS equipment. The interpretation of all shorelines required geo-statistical analysis in a Geographical Information System. Retreating and extension rates were calculated for each section reaching the values of 0.98 m/year and 1.36 m/year, respectively. The results proved to be very accurate, allowing to expand the developed methodology by using more complete time-series of remote sensing datasets along with more frequent RTK-GPS surveying.

Kankara *et al.* (2014) carried out a case study along Chennai coast to monitor the shoreline changes in Integrated Coastal Zone Management (ICZM) framework. The study was conducted for 25 km long stretch of Chennai coast. TM (1990), ETM+ (2000), cartosat-1 (2006), resourcesat-1 (2008) and resourcesat-2 (2012,2013) satellite images were used as input dataset. Field survey was also carried out using GPS instrument for 2011. Three methods i.e. EPR, LRR and Weighted Linear Regression (WLR) were employed to calculate shoreline change rate for 1990-2013. While, EPR method is used to calculate short term analysis for 1990-1998 and 1990-2012. Study area was divided into four distinct zones. Totally 412 transects were generated with 50 m spacing and the length of each transect was 200 m. from the long term analysis, the high erosion was noticed on the northern side of Thiruvottiyur region with a rate of more than 5 m/year. Accretion of 2 to 4 m/year was seen along Marina beach. The analysis showed that the northern portion of the Chennai port is eroding and the southern portion of the port is accreting.

Tran *et al.* (2014) studied Application of remote sensing and GIS for detection of long-term mangrove shoreline changes in Mui Ca Mau, Vietnam. In this study, remotely sensed aerial (1953), (1979, 1988 and 2000) and SPOT (1992, 1995, 2004, 2008, 2009 and 2011) images used and the DSAS to quantify the rate of mangrove shoreline change for a 58 year period. There were 1129 transects sampled at 100 m interval salong the mangrove shoreline and two statistical methods, namely EPR and LRR, were used to calculate the rate of change of mangrove shorelines and distance from 1953 to 2011. The study confirms that erosion and accretion, respectively, are significantat the East Sea and Gulf of Thailand sides of Mui Ca Mau.The East Sea side had a mean erosion LRR of 33.24 m/year.The accretion trend at the Gulf of Thailand side had an average rate of 40.65m/year.

Temitope (2014) used DSAS as a tool for determining shoreline morphodynamics at Crantock Beach, southwest England. The investigation of changes in shoreline positions in the vicinity of the sandy, macrotidal Crantock Beach and Gannel estuary is carried out using the Ordnance Survey historical mapping archive, available for the period between 1888 and 2012. The historical mapping is available as georeferenced GeoTiffs. Shorelines were digitised from each map, and the standard DSAS shoreline change measures - NSM, EPR were calculated. The distance between the oldest (1888) and the youngest (2012) shorelines, which presents the overall change in shoreline position for the 124 year period was repotred by Net Shoreline Movement. The EPR converts this NSM into an annual rate of shoreline change. The case study revealed that DSAS can yield valuable information on the morphodynamic behaviour of shorelines in terms of shifting shoreline position and changes in foreshore geometry, in the identification of areas of erosion and deposition, and in the variation of planimetric properties of the coastal environment.

Uwem *et al.*(2014) carried out a study on shoreline change detection in Niger delta, Ibeno, Nigeria. Satellite imageries of 1986, 2006 and 2008 were used to extract the shoreline through heads-up digitization. Different analogue maps collected were captured through scanning, georeferencing, headsup digitizing and database creation in ArcGIS 9.2 software. For easy data handling, the three images were spatially re-projected to Universal Transverse Mercator (UTM 1984). After the shorelines were extracted, a base-line was created parallel to these extracted shorelines in order to cast perpendicular lines to the shorelines and also to serve as the origin for measuring distances of the shorelines in relation to the established baseline. The baseline and shoreline data were imported into a geodatabase in order for DSAS to recognize the data. The rate of shoreline change was assessed using LRR, EPR methods. The shoreline change detection was conducted using the DSAS. The result however indicated that the rate of erosion is found out to be very high with maximum value of -7.8m/year recorded at Itak Abasi community. On the other hand, some portions of the shoreline are accreting at an average rate of 2m/year. Areas mostly affected by accretion processes are identified near eastuary where sand filling is usually done for settlement purposes.

2.4 ESTIMATION OF SHORELINE CHANGE USING TNTmips

Darlene *et al.*(2003) carried out estimation of coastal erosion middle coastal bays, Maryland using TNTmips. Based on geomorphologic variability and differing rates of shoreline erosion, the study area shoreline was divided into 23 reaches, ranging in length from about 1,000 m to 67,000 m; most were less than 8,000 m long. A template of irregular polygons was constructed to demarcate the reaches, and total land loss (m^2) during the 47 year period was determined for each polygon. Image processing was done with TNT mips. Eroison rates were computed along the transect cast with equal spacing. Erosion estimates for this area could be calculated for a duration of 47 years.

Hariklia *et al.* (2006) studied spatio-temporal changes to the coastal zone of Vari (Greece), using remote sensing and GIS techniques.The aim of this paper was to examine the spatio-temporal, qualitative and quantitative changes in the natural environment and morphology of the coastal area of Vari, a suburb of Athens, Greece. The changes were studied using maps, aerial photographs and GIS techniques. Qualitative changes including man-made alterations that took place in the area of Vari bay during the last hundred years were detected by comparing the geomorphologic characteristics portrayed by recent topographic maps with those visible on old maps (edition 1885). Comparisons were made and the changes documented using GIS software (ArcGIS and TNTmips) capabilities. Quantitative changes, in the same area, were noted, registered and assessed in terms of surface changes by interpreting aerial photographs taken between 1945 and 1987.

Subhasish *et al.* (2013) carried out a study on monitoring shoreline and Inland changes by using multitemporal satellite data and risk assessment: A case study ofGhoramara Island, West Bengal. In this study, multi-resolution and multi temporal satellite images of and ASTER have been utilized to understand the erosion accretionpattern of the island over past four decades (1972-2010). The time series analysis has been carried out using TNT mips professional version. The rate of change in shoreline positions have been estimated using statistical linear regression, NSM and EPR method and cross validated with regression coefficient method. Land use land cover map has been prepared for all these years to understand how the erosion-accretion affected the island and the vulnerability map indicates the maximum and minimum vulnerable zones on the basis of individual polder area, shoreline changes of the particular polder area and the population density of the unit. It hasbeen shown that the island is constantly shrinking over time and lost almost 50% of its area.

2.5 COASTAL EROSION MANAGEMENT

According to Clark (1995) options for combating coastal erosion are traditionally two types, namely hard structural/engineering options and soft structural/engineering options. These solutions have at least two hydraulic functions to control waves and sediment transport. Hard structural/engineering options use structures constructed on the beach (seawalls, groynes, breakwaters/artificial headlands) or further offshore (offshore breakwaters). These options influence coastal processes to stop or reduce the rate of coastal erosion.

i) Groyne: A coastal structure constructed perpendicular to the coastline from the shore into the sea to trap longshore sediment transport or control longshore currents. This type of structure is easy to construct from a variety of materials such as wood, rock or bamboo and is normally used on sandy coasts.

ii) Seawall: A seawall is a structure constructed parallel to the coastline that shelters the shore from wave action. This structure has many different designs; it can be used to protect a cliff from wave attack and improve slope stability and it can also dissipate wave different designs; it can be used to protect a cliff from wave attack and improve slope stability and it can also dissipate wave energy on sandy coasts.

iii) Offshore breakwater: An offshore breakwater is a structure that parallels the shore (in the nearshore zone) and serves as a wave absorber. It reduces wave energy in its lee and creates a salient or tombolo behind the structure that influences longshore transport of sediment. More recently, most offshore breakwaters have been of the submerged type; they become multipurpose artificial reefs where fish habitats develop and enhance surf breaking for water sport activities. These structures are appropriate for all coastlines.

Soft structural/engineering options aim to dissipate wave energy by mirroring natural forces and maintaining the natural topography of the coast. They include beach nourishment/feeding, dune building, revegetation and other non-structural management options.

Kunhimammu *et al*. (2008) studied the influence of estuarine breakwater constructions on Kerala coast in India. At seven coastal inlets in Kerala, the breakwaters are already constructed/being constructed for the development of fishery harbours and minor ports. In this study, an attempt has been made to analyze the impact of the breakwater construction at seven estuaries on the adjoining coasts. The collected data on shoreline changes and hydrographic survey data available for the inlets were analyzed to infer the impact of breakwater constructions on the coastal geomorphology. There are net accretion on the north of most of the north breakwaters constructed in the estuaries of Kerala.

Frost (2011) determined the changes in the morphology of Lady Robinsons Beach, were using historical aerial photographs. Eleven rock rubble groynes were constructed in two separate stages (1997 and 2005) in an attempt to widen and stabilise the beach. The effectiveness of these groynes at maintaining a wide beachfront was determined by observing changes in the morphology of the beach since their construction, using aerial photographs. It was found that while, in many areas, the groynes have been successful at creating a wider beachfront, there are several areas where erosion and accretion is still taking place. The study reveals that groynes are not entirely effective at solving the erosion problems experienced on Lady Robinsons Beach. There was found to be a significant difference in particle size of sediments on the southern point of the beach where there is a large accumulation of sediment. Analysis suggests that since the construction of the groynes this area has developed into a dune feature. This highlights the significant effects the groynes have had on Lady Robinsons Beach.

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

The study area selected was the coastline near Ponnani in Malappuram district, along the central coastline of Kerala extending from Kuttayi (10°51’31” N, 75°53’44” E) in the North to Chavakkad (10°33’21” N, 76°0’57” E) in the South. Ponnani is a sea shore town situated at the mouth of Bharathapuzha (Nila River), bounded by the Arabian Sea on the west and estuaries and backwaters on the northern side. This ancient scenic coastal town is located at around 10° 46' 3" N Latitude and 75° 55' 30 " E Longitude. It has an average elevation of five metres above MSL and it is also the smallest taluk of the district. The major source of income for the people in the coastline is fishing. The additional source of income is agriculture involving rice, coconut and arecanut as the main

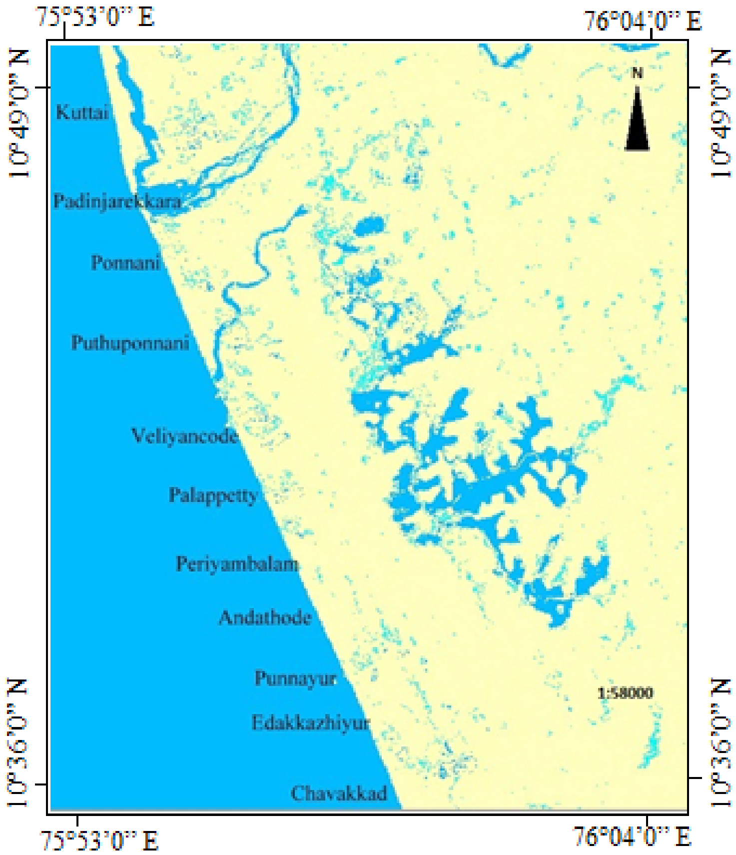


Figure 3.1 Study area

cultivars. The tidal port at Ponnani is an important fishing harbour and houses the office of the Malappuram district fisheries board.

The Bharathapuzha river is the second longest river of Kerala, originating from the Anamalai Hills (1964 m above mean sea level) in the Western Ghats. The river below the confluence of Bharathapuzha and Gayathripuzha is also called the Ponnani river. Bharathapuzha flows through the districts of Palakkad, Malappuram and Thrissur and drains into the Lakshadweep Sea near Ponnani town in Malappuram district.

There are several beaches along the Ponnani coastline. Padinjarekkara beach is the tidal mouth of Bharathapuzha where Bharathapuzha and Tirur river join and drains into the Arabian Sea. The major fishing harbour of Ponnani is situated on the southern side of the mouth of the Bharathapuzha river. Padinjarekkara beach is a beautiful, clean and unpolluted beach which forms the habitat of several migratory birds during the months of February and March. Veliyamcode beach is situated towards the south of the mouth of one of the tributaries of Bharathapuzha river. The whole beach is protected by sea wall, with some frontal beach left. Perumbadappu beach is situated just south of the Veliyamcode beach. Here the coast is considerably wider than that at Veliyamcode. The sea wall is 20-25 m away from the sea. The coastal area between Kuttayi and Chavakkad was considered for the study and the coastal area in between these two places was divided into 10 coastal zones like:

1) Kuttayi,
2) Padinjarekkara Azhimukham
3) Ponnani
4) Puthuponnani
5) Veliyamcode
6) Palappetty
7) Andathode
8) Punnayur
9) Edakkazhiyur and
10) Chavakkad

The Ponnani coast that extends over a length of 35 km between Kuttayi and Chavakkad which is interspersed with rivers, unprotected coast and coast with man-made sea erosion protection structures was considered for assessment of erosion. The Malabar Coast is generally rocky and lateritic on crystalline and tertiary formations with alluvial patches, but the Ponnani stretch is composed of purely alluvium. Alluvial soils are soils of the low lands and are mainly seen along the coastal plains and valleys. The texture of these soils range from exclusively drained to moderately well drained sand to sandy clay in nature.

The most potential aquifer in Malappuram district is alluvial aquifer. The coastal alluvium is essentially composed of sand, silt and clay. The ground water in these aquifers occurs under water table conditions. The domestic and agricultural needs of water are met by a large number of dug wells and filter point wells tapping this aquifer. The coastal alluvium aquifer can sustain medium to heavy duty pumping. Wherever the saturated sand thickness exceeds 5 m along the coast, filter point wells are feasible. Such potential areas for filter point wells are seen around Ponnani, Chamravattom, Mangalam, B.P Angadi, and Tirur. Open dug wells and shallow tube wells are feasible in the stretch of riverine alluvium with considerable thickness seen along the northern side of the Bharathapuzha River.

3.2 DATA COLLECTION

Landsat Thematic Mapper (TM) imageries of the coast of Ponnani region acquired for different time periods from 1999 up to June 2014 were used for the long-term erosion and accretion assessment. The short-term changes in erosion and accretion were analysed using multi-temporal images for periods of 1999-2000, 2002-2003, 2005-2006, 2008-2009, and 2013-2014. Landsat Thematic Mapper (TM) imageries have 30 m spatial resolution and are composed of seven spectral bands, namely blue, green, red, near IR, mid IR, SWIR and thermal IR. The Landsat imageries were downloaded using the geospatial search engine of United States Geological Survey (USGS) called “Earth Explorer”.

3.2.1 Earth Explorer

Earth Explorer provides online search, display browsing, metadata export, and data download of earth science data from the archives of the USGS.

Key features in Earth Explorer include:

- Fast, geospatial search engine
- Map viewer for viewing overlay footprints and browse overlays
- Simple, fast Graphical User Interface (GUI)
- Data access tool to search and discover data
- Textual query capability
- Keyhole Markup Language (KML) export capability to interface with Google Earth
- Save or export queries, results, and map overlay for reuse
- Request on-demand products
- Access to browse images from standard products
- User authentication service for access to specialized datasets and tools
- Access to Landsat Data Continuity Mission (LDCM) quality band data
- Standard product downloads
- User notifications of new acquisitions and available products through subscription services
- Updated software code base supporting JavaScript and PHP

The Earth Explorer user interface provides the overall capability for users to interact with the Earth Explorer components and services. The body of Earth Explorer is composed of the Data Search Functions and the Google Map components. The Data Search components are parted among four tabs and allow users to enter search criteria, advanced search, select datasets to query, and examine results in a tabular window. Google Map is a useful tool for determining a search area and for verifying whether that results fall in the area of interest. All of Earth Explorer’s features, including saving search criteria, downloading data, and accessing subscription services can be used by registered users, as the USGS Earth Explorer system requires users/customers to register to download the data.

The information gathered from the registration process is not distributed to other organizations and is only used to determine trends in data usage and for certain orders. The same login can be used for the USGS Global Visualization Viewer (GloVis) and USGS Hazards Data Distribution System (HDDS) systems.

The majority of the datasets are available for download from the USGS at no cost. A few datasets have a minimal fee to cover the cost of increasing the priority in production. Each criteria page is different and is based on the unique dataset attributes defined for that dataset. The specific search criteria include:

- WRS Path
- WRS Row
- Cloud Cover
- Data Category
- Day Night
- Landsat Scene Identifier

3.3 IMAGE DATA PRE-PROCESSING

False colour composites with different bands were tested for visualisation of the shoreline. Band 4 was found to be most effective for mapping shoreline and this was used for the coastline extraction. Image pre-processing and coastal erosion assessment were carried out using the TNTmips software.

3.3.1 TNTmips

TNTmips is a robust, full-featured GIS and image processing system. TNTmips has exactly the same features for Windows and Mac OS X and is available for both 32- and 64-bit systems. TNTmips professional version contains so many features for a wide variety of applications; many users may not require the full TNTmips package. MicroImages provides lower cost, derivative products that use the same code as TNTmips but do not allow access to all its features: TNTedit and TNTview. TNTview supports the advanced display features of TNTmips, onscreen image interpretation, the use of MicroImages' scripting language (SML), import and export of the hundreds of formats supported by TNTmips, and a variety of utility programs, such as the map calculator and tools for managing Project File contents.

TNTedit adds the spatial data editing and georeferencing capability to the features available with TNTview. The family of TNT products is rounded out by two free products, TNTmips Free and TNTatlas, and one very low cost product, TNTmips Basic.TNT products use a single data structure, the project file that can hold all of project materials. A project file appears as a single file with an RVC extension to the operating system but functions more like a folder in the TNT products. A project file can hold any combination of raster, vector, CAD, shape, TIN, region, text, and database materials, so all of the data that pertains to a project or task can be kept together easily. The project file was designed with cross-platform users in mind. The TNT processes all use special read and write routines so that any TNT project file can be used interchangeably by any Windows or Macintosh computer.

3.3.2 Atmospheric corrections and image enhancement

The optical multi-spectral image is frequently affected by the atmosphere and radiation from the direct water surface. Moreover, the digital numbers (DN values) in the raw image are not only dependent on the reflectance characteristics of the earth objects, but also contain noise and errors due to viewing geometry of the satellite, the angle of the sun radiation and atmospheric effects like haze and water particles. Digital image processing can achieve an even wider range of image enhancements using numerical procedures that manipulate the brightness values stored in a raster object. The term filter is also commonly used to refer to these image processing operations. Filter operations can be used to sharpen or blur images, to selectively suppress image noise, to detect and enhance edges, or to alter the contrast of the image.

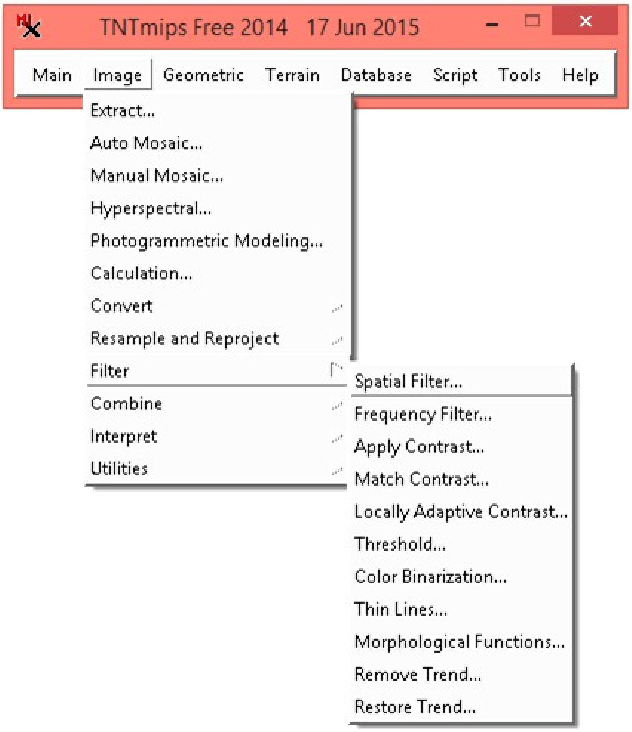


Figure 3.2 Selecting spatial filter from TNTmips

The variations in brightness at different spatial scales within a raster image can be thought of as a collection of spatial frequencies. Major changes in brightness over a short distance represent a high frequency component of the image. Conversely, more widely-spaced shifts in brightness form a low-frequency component. Many filters act to suppress a particular set of spatial frequencies, while leaving others unaltered.

The Spatial Filter operations calculate a new value for each raster cell using values in a surrounding group of cells. Spatial filter window (Figure 3.3) was launched by selecting spatial filter from filter operations list coming under image menu (Figure 3.2). As the filter window is moved through the input raster cell by cell, the process reads the set of input cell values within the current window, applies a specific set of functions to calculate an output value for the central cell, and writes the new value to the corresponding cell in the output raster. This procedure is commonly referred to as spatial convolution filtering. When TNTmips launch the Spatial Filter process, the Raster Spatial Filtering window appears. The spatial filters are organized into six classes: General, Edge Detection, Enhancement, Noise Reduction, Radar, and Texture.

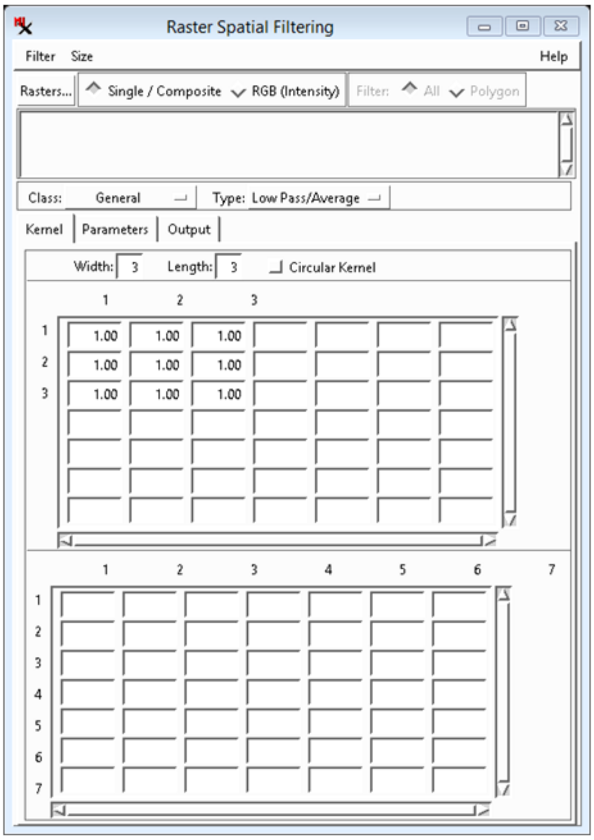


Figure 3.3 Raster spatial filtering window

The spatial filters used to obtain the discrete line between land and water were:

a) Grayscale LACE filter,

b) P-median filter for noise reduction and

c) Volterra / unsharp Filter for enhancement of the imageries.

3.3.2.1 Grayscale LACE filter

The Locally Adaptive Contrast Enhancement (LACE) filter process provides a spatially-varying contrast enhancement for grayscale, colour, or multiband images. The LACE filter is particularly appropriate for images with both areas and large dark areas, where global contrast enhancements (such as linear or normalized) cannot bring out adequate detail in both bright and dark areas. The LACE filter adjusts brightness values in each local area so that the local mean and standard deviation closely match output values that you specify on the Parameters panel. This procedure improves local contrast while reducing the overall contrast between bright and dark areas.

3.3.2.2 P- median filter

The P- median filter is to suppress noise while preserving edge and line detail. The filter calculates median values for two subsets of values in the filter window: 1) combined horizontal and vertical transects through the centre cell and 2) two diagonal transects through the centre cell. These two median values are then averaged. The output of the filter is a weighted average of the averaged median and the original centre cell value. The weighting is controlled by Filter Parameter A, which can vary in value from 0 to 1. For example, the value of 0.20 for Parameter A means that the original input value contributes 20% to the output cell value, and the averaged median value contributes 80%. Decreasing the value of Parameter A will increase the degree of noise removal, at the expense of increasing degradation of edges and line features.

3.3.2.3 Volterra/Unsharp filter

The ability to see a boundary marked by a fixed brightness difference varies with the background brightness: the brighter the background, the more difficult it is to see the boundary. For this reason, edge details in bright areas require more enhancement than those in dark areas of an image. The Volterra / Unsharp filter addresses this problem by providing edge enhancement that is proportional to the local image brightness.

The initial output of the Volterra filter process is approximately equivalent to the product of the local mean and a high-pass filter. This result is scaled and added to the original input image value to produce the final output. The scaling is controlled by Filter Parameter A, which varies from 0.001 to 0.1, with a default value of 0.005. Increasing the value of Parameter A increases the amount of edge enhancement.

3.4 SHORELINE VECTORS EXTRACTION

The spatial data Editor of TNTmips offers a flexible, editing environment that can be used for simple one-object tasks or complex multi-layer, multi-object manipulations. TNT spatial data editor was launched by selecting Main / Edit from the TNTmips menu bar. The editor-layer manager and view windows were opened. Georeferenced image of study area was added as reference layer which provides the georeference for the vector to be drawn. The image added was from 1999 for the first vector and changed correspondingly for further vectors. The new vector object will have an implied georeference, which means that the object coordinates will reflect the georeference coordinates. Automatic transfer of the coordinate reference system is one of the important benefits of using a reference layer when creation of new spatial objects.

New vector object was selected by using ‘Create Object’ icon button from the menu. Now the window was ready to draw the shoreline vector. The discrete line between land and water of the study area was drawn. Colours of vectors from different years were changed for ease of interpretation.

3.5 ESTIMATION OF COASTAL EROSION RATES USING SML

An SML script that generates transects, or lines orthogonal to a shore baseline, has been developed for use with TNT products. A baseline and at least two subsequent shoreline measurements are all that is required to produce transects (lines orthogonal to the baseline) with associated erosion rates. The erosion rate along each transect is provided as a DataTip when the cursor is hovered over that transect. Orthoimages of the area are not required, but greatly enhance display of the results and are one means of attaining shoreline locations at defined intervals.

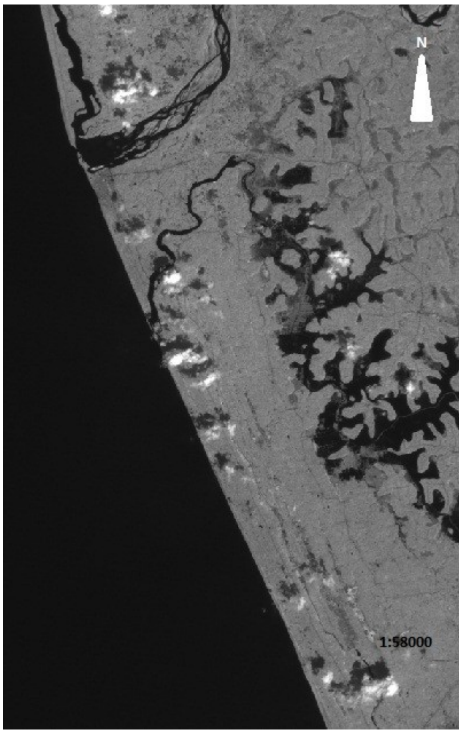


Figure 3.4 Noisy image of study area

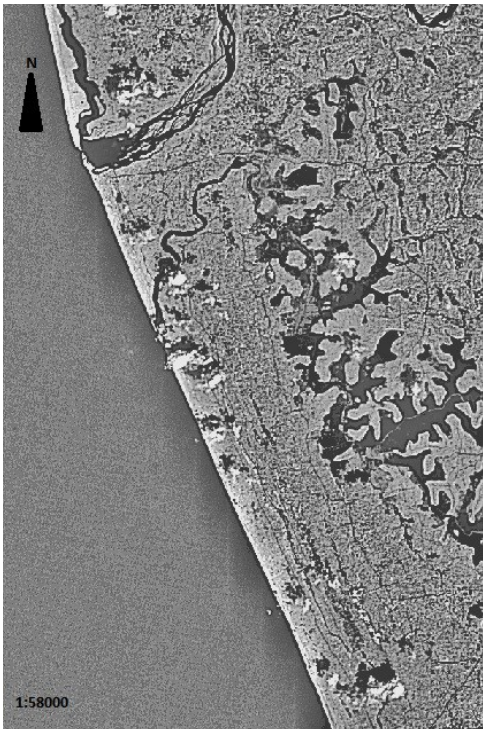


Figure 3.5 Image after filtering

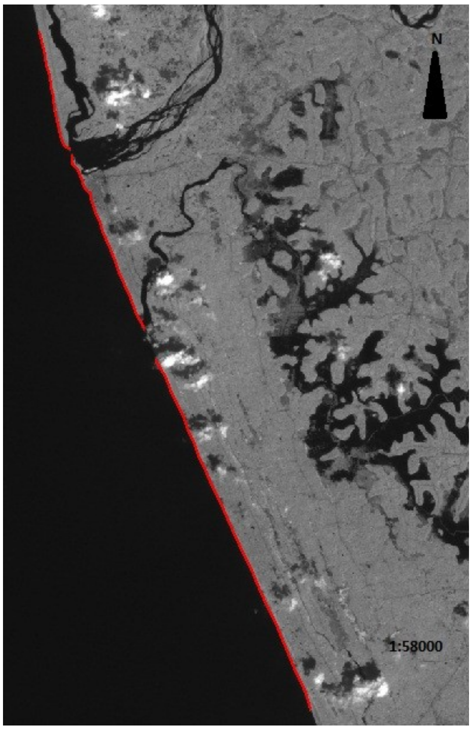


Figure 3.6 Extracted shoreline of year 1999

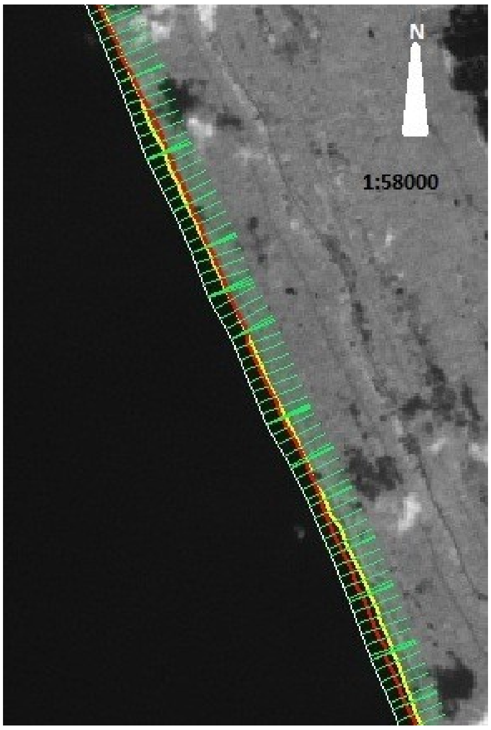


Figure 3.7 Transects created for estimation of erosion

Figure 3.8 Transects creating window

The transect layer is fixed up to provide the mean erosion rate as a DataTip. This DataTip is drawn from the Rates database table that is generated and saved with the transects vector. This table includes fields for transect number, end point

Figure 3.9 Calculated erosion rates after creating transects

rate, mean rate, variance, regression coefficient, standard deviation and jackknife regression. The script is customized to work with different coastal data by changing the object names in the script to corresponding image, baseline, and shoreline object names. The remainder of statistics require shoreline from at least three years. The methodology used to calculate shoreline erosion rates in the SML script was adapted from the DSAS described by Thieler and Danforth (1994) of the US Geological Survey.

The objects needed to run this SML are a baseline and at least two shoreline vector objects with known dates of acquisition. The script can handle up to 20 shoreline vectors if they are available. Shoreline vectors are generally digitized from map sheets, aerial photos, or orthophotos. Shorelines are often convoluted and circuitous, which makes them unsuitable as a reference for generation of orthogonal lines for measurement purposes. The baseline used in this method follows the general direction of the shoreline with relatively few vertices.

The baseline was drawn upland of all of the shorelines, which was easily accomplished in TNTmips' Object Editor. The distance between the baseline and the closest shoreline was not critical because the baseline was not considered in any of the erosion rate calculations. However the position of the baseline will affect the transect length necessary for the transects to intersect all shorelines. The script created a new vector object containing transects whose length can be specified (Figure 3.8). A transect was positioned at the start of the first baseline segment. A baseline segment is the length between two vertices. Subsequent transects were placed along the baseline at the interval designated. Erosion rate statistics was also generated at the end of the segment (Figure 3.9). This same procedure is followed for each of the baseline segments with additional transects that bisect the angles between the transects at the end and start of adjacent segments. Total of 596 transects having 200 m length were cast at a spacing of 30 m.

Multitemporal Landsat TM imageries of 1999 and 2014 were used for analysing long term erosion and accretion along the coast and short term changes were analysed for periods of 1999-2000, 2002-2003, 2005-2006, 2008-2009, and 2013-2014. The erosion rates are recorded as both an end point rate and a mean rate along each transect. The landward movement of the shoreline (erosion) was expressed as a negative number in this system. The end point rate (EPR) reflects the length along a transect between the earliest and most recent shorelines and the time between these two shoreline positions. If the distance along a transect between the earliest and most recent shorelines, for example, was 10 meters and 20 years had elapsed between shoreline measurements, the EPR is 0.5 m/year (or -0.5 m/year if erosion occurred).

The mean erosion rate is the average rate between all combinations of shorelines. For example, if there are three shorelines a, b, and c, the mean erosion rate is the average of the erosion rates between a and b, a and c, and b and c. These two rates and other statistics are provided in a table generated when the transect vector object is created by the script. The other statistics include the standard deviation, variance, and linear and jackknife regression coefficients. In this study the End Point Rate, Net Shoreline Movement, and Mean Erosion Rate were used for the erosion assessment.

CHAPTER 4
RESULTS AND DISCUSSIONS

The temporal changes on the erosion process along the coast of Ponnani was assessed to determine both long term and short term changes, using multi-temporal multispectral remote sensing image assessment and GIS. Imageries of 1999 and 2014 were used for long term assessment and imageries for the period 1999-2000, 2002-2003, 2005-2006, 2008-2009 and 2013-2014 were used for short term assessment of erosion. The image processing software used for this study was TNT mips ® by MicroImages Inc. ©.

4.1 LONG-TERM ASSESSMENT OF EROSION

Ponnani coast was divided into 10 coastal zones: Kuttayi, Padinjarekkara Azhimukham, Ponnani, Puthuponnani, Veliyamcode, Palappetty, Andathode, Punnayur, Edakkazhiyur and Chavakkad. The estimation of long-term erosional process along Ponnani coast was carried out by calculating mean erosion rate at each coastal zone. The variation of erosion is shown in Table 4.1 and Fig. 4.1. The negative values represent erosion and positive values represent sand deposition or accretion.

Table 4.1 Long-term rates of erosion and accretion during 1999-2014

Place	Erosion (m/year)	Accretion (m/year)
Kuttayi	-1.18	0.78
Padinjarekkara Azhimukham	-1.14	1.12
Ponnani	-1.42	1.31
Puthuponnani	-2.74	1.1
Veliyamcode	-3.39	1.17
Palappetty	-3.71	1.06
Andathode	-1.82	1.15
Punnayur	-1.26	0.96
Edakkazhiyur	-1.35	1.16
Chavakkad	-2.45	1.14
Average	**-2.04**	**1.15**

The net rate of erosion along the coast during 1999-2014 was estimated as -2.18 m/year. This value reveals there have been significant changes along the coastal area during this 15 years period under study. Among the coastal zones Palappetty coast was having the highest erosion rate of -3.71 m/year and Padinjarekkara coast was having the lowest observed erosion rate. Ponnani, Puthuponnani, Veliyamcode and Palappetty coastal zones were found to have erosion rates of -2.42 m/year, -2.74 m/year, -3.39 m/year, and -3.71 m/year respectively. It was observed that around 36 % of the coast experienced severe erosion.

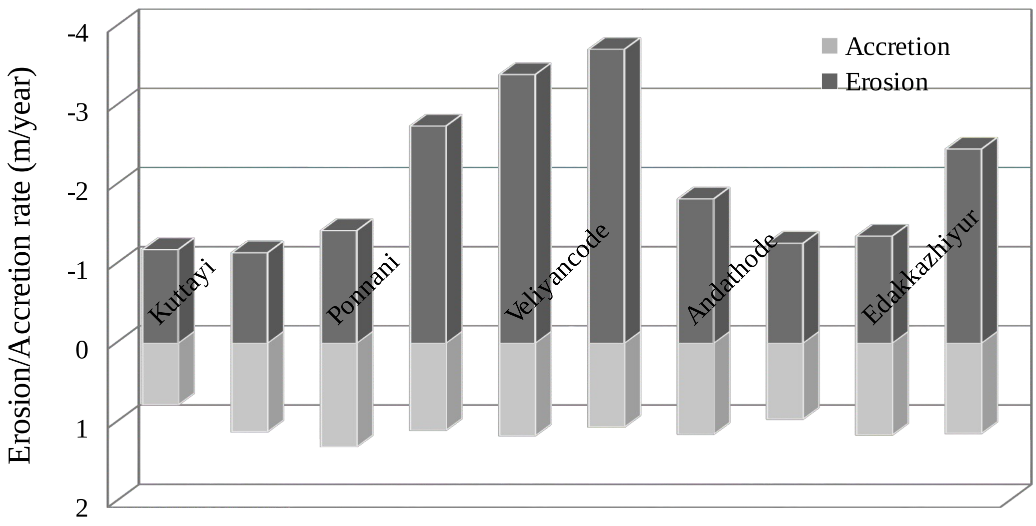


Figure 4.1 Long-term variation of erosion and accretion during 1999–2014

The erosion rate assessment between 1999 and 2014 showed that the entire coast is eroding, even though there were some places with accretional process. Some areas in each coastal zone were found to have deposition of sand. But the mean rate of accretion was found to be very less when compared with the erosion rate around that place. The results show that sand deposition rate is maximum at the Ponnani coastal zone with a rate of 1.31 m/year and minimum at Kuttayi with a rate of 0.78 m/year.

Thus the long-term erosion assessment revealed that various zones of the coastal area between Ponnani and Chavakkad were facing severe erosion during the period of assessment. Even though some areas in these zones had experienced the accretion process, it was having very little effect on the net erosion as the entire Ponnani coast other than these areas is predominantly erosive.

Now, most of the coastal area is protected with sea erosion control structures. The fifteen year time duration of the analysis cover periods before and after the construction of the sea erosion control structures along the coast. Hence to better understand the influence of these structures on erosion/accretion rates and the seasonal variations in erosion process, erosion/accretion rates for different short term periods within the fifteen year period was also calculated.

4.2 SHORT-TERM ASSESSMENT OF EROSION

The landward shifting of coastline during five different periods was explored for calculating the site specific erosion rates. There were interventions to stabilize the shoreline such as Sea Erosion protection structures (sea wall) by Water resources (Irrigation) Department, Government of Kerala, along the different erosion zones considered. This shoreline protection measures influenced the erosion pattern along the coast. Sea Erosion Prevention Work commenced along the Ponnani coastline in the year 2002, with breakwater structure at Padinjarekkara Azhimukham and sea wall along the coast between Ponnani and Puthuponnani. Kuttayi, Andathode, Punnayur, and Edakkazhiyur coastal zones are without any erosion protection structures while coastal zones of Padinjarekkara, parts of Ponnani, Puthuponnani, Veliyamcode, Palappetty, and Chavakkad are protected with sea wall.

Shoreline changes were calculated for different time periods of 1999-2000, 2002-2003, 2005-2006, 2008-2009 and 2013-2014. Erosion trend analysis of each coastal zone was also conducted. Before 2002, places between Kuttayi and Palappetty had severe erosion and all other coastal zones were having an average erosion rate of -1.5 m/year. But after sea erosion prevention work was undertaken, Kuttayi, Padinjarekkara and Ponnani coastal zones were observed to have reduced erosion rates than that in Puthuponnani, Veliyamcode and Palappetty. The coastal zones protected with sea wall had reduced erosion rates whereas places without any protective structure continued to erode at higher rates. The short-term assessment of erosion is given in the Table 4.2.

Table 4.2 Short-term variation of erosion during different periods

Place	1999-2000 (m/year)	2002-2003 (m/year)	2005-2006 (m/year)	2008-2009 (m/year)	2013-2014 (m/year)
Kuttayi	-3.82	-1.21	-1.42	-1.23	-1.46
Padinjarekkara	-6.74	-3.13	-1.19	-1.02	-0.91
Ponnani	-5.97	-3.99	-2.42	-2.94	-3.86
Puthuponnani	-5.39	-3.55	-3.94	-4.12	-4.59
Veliyamcode	-5.84	-3.64	-3.68	-4.72	-3.58
Palappetty	-4.78	-3.47	-3.83	-4.04	-3.19
Andathode	-2.36	-1.25	-2.21	-2.42	-2.51
Punnayur	-1.56	-1.78	-1.22	-2.15	-1.38
Edakkazhiyur	-0.99	-1.05	-0.25	-1.09	-0.92
Chavakkad	-4.04	-3.67	-3.91	-3.87	-3.03

The maximum erosion rate (-6.74 m/year) during the 15 years of study was observed in Padinjarekkara during 1999-2000 and the minimum erosion rate of -0.25 m/year was at Edakkazhiyur during 2013-2014. The long-term erosion analysis results showed that the places between Padinjarekkara and Palappetty were having more erosion rates compared to the other coastal zones. After 2000 these areas had experienced higher erosion rates more than -4 m/year and along with these places, Andathode and Punnayur also experienced more erosion than what they had in previous years. Among the different time periods considered, the period between 1999 and 2000 corresponded with maximum erosion rates in almost all the coastal zones. Padinjarekkara, Ponnani, Puthuponnani, Veliyamcode, Palappetty and Chavakkad coastal zones were observed to have high erosion rates with an average rate of -5.7 m/year and the minimum erosion rate was found at Edakkazhiyur with a rate of -0.99 during the same period. From Table 4.2, it is clear that Ponnani, Puthuponnani, Veliyamcode, Palappetty and Chavakkad are the coastal zones experiencing notable erosion rates. Table 4.2

reveals that the erosive coasts have almost three times more erosion rates than that of the other areas.

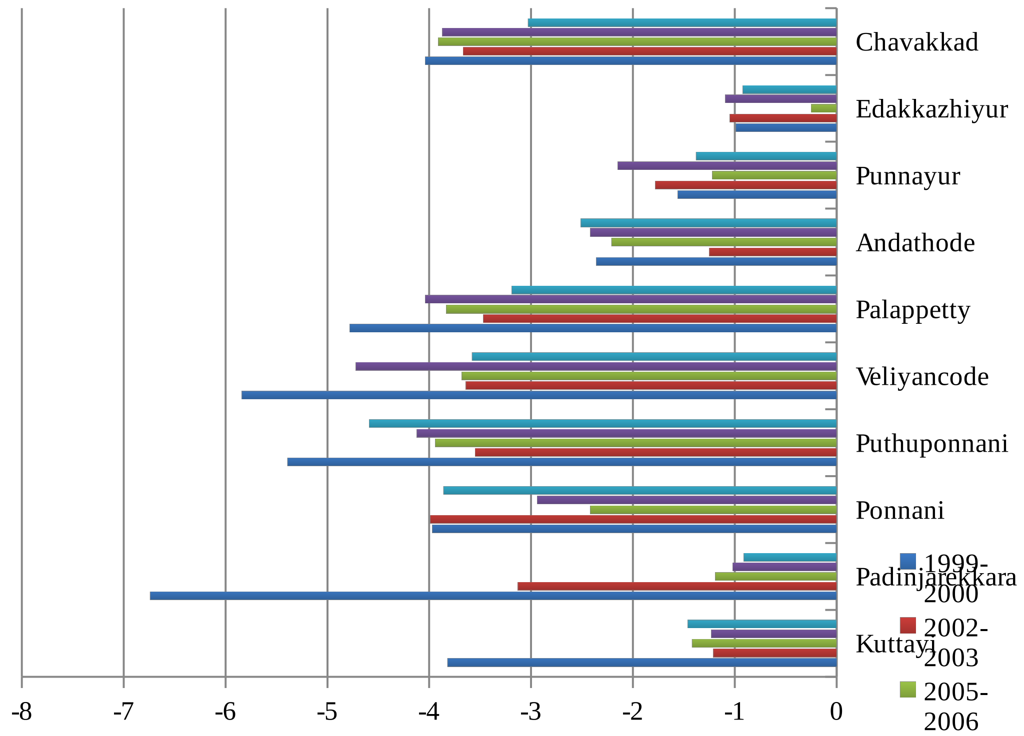


Figure 4.2 shows that after 2005-2006, erosion rates gradually reduced from that

Figure 4.2 Short-term variation of erosion rate during different periods

during 1999-2000. The highest variation in erosion rates with time was observed in Padinjarekkara, where there was maximum erosion rate among different coastal zones. Kuttayi and Ponnani, the coastal zones on either side of the Padinjarekkara Azhimukham, also experienced net reduction in erosion rates from 1999-2000 but during the last two time periods of 2008-2009 and 2013-2014 they had an increasing trend in erosion rates. The trends of erosion rates variation at Puthuponnani, Veliyamcode and Palappetty are somewhat similar as both these zones underwent higher erosion rates during 1999-2000 which further decreased except at Veliyamcode where the erosion rate of -4.59 m/year experienced in 2008-2009 was higher than 2002-2003. Puthuponnani had a sharp drop in erosion rate from 1999-2000 to 2002-2003 and thereafter a steadily increasing trend. The least erosion rate estimated at Palappetty was-3.19 m/year during 2013-2014 and the maximum rate estimated was -4.78 m/year during 1999-2000. After 2000, this area had experienced higher erosion rate during 2008-2009 and it was estimated as -4.04 m/year.

Andathode experienced similar erosion rate trends and the erosion rate estimated was more than -3 m/year. The land degradation at Punnayur was less than that at Andathode but this coast also experienced maximum erosion rate during 2008-2009. Punnayur, Edakkazhiyur and Chavakkad can be classified under high erosion rate areas as the estimated erosion rates are higher in every period. The erosion rates at Chavakkad were less than Puthuponnani and Veliyamcode and it experienced a maximum erosion of -4.04 m/year during 1999-2000. Among all the coastal areas, Edakkazhiyur was found with very less erosion rates compared to all other rates, and it experienced less than -1 m/year in three different periods with a minimum of -0.25 m/year during 2005-2006.

4.3 EROSION TREND ANALYSIS

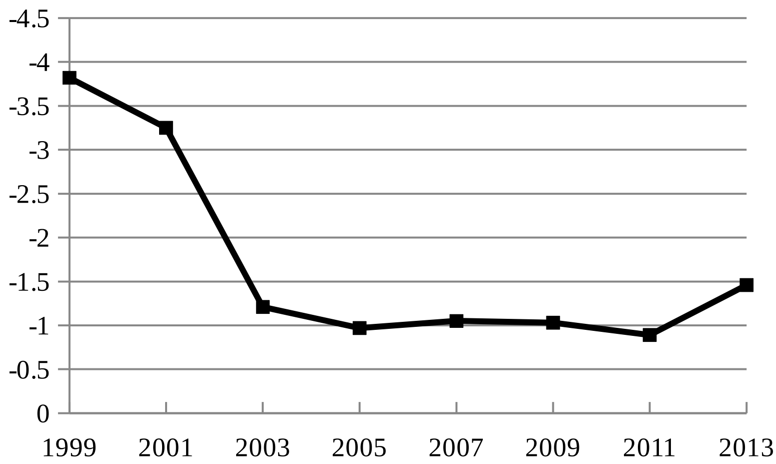
The trend in the temporal variation of erosion rates along the study area was explored by estimating the rate of erosion occurred at each coastal zones namely Kuttayi, Padinjarekkara Azhimukham, Ponnani, Puthuponnani, Veliyamcode, Palappetty, Andathode, Punnayur, Edakkazhiyur and Chavakkad in different time periods during the period under study. Data is provided in appendix I. According to the erosion rates, the erosion affected areas are classified as;

- High (Erosion rates more than -4 m/year)
- Medium (Erosion rates between -2 and -4 m/year)
- Low (Erosion rates between 0 and -2 m/year)

4.3.1 Kuttayi zone

Kuttayi beach lies at the location between 10°51’31” N, 75°53’44”E and 10°48’33” N, 75°54’22” E. This coast is adjacent to Padinjarekkara Azhimukham where the Bharathapuzha and Tirur river join together and drain in to the Arabian Sea. This coast was under severe erosion before 2002 with a maximum rate of

-3.82 m/year in 1999 and followed by -3.25 m/year in 2001. But after 2003 there



was abrupt reduction in erosion rate which may be due to the construction of the breakwater

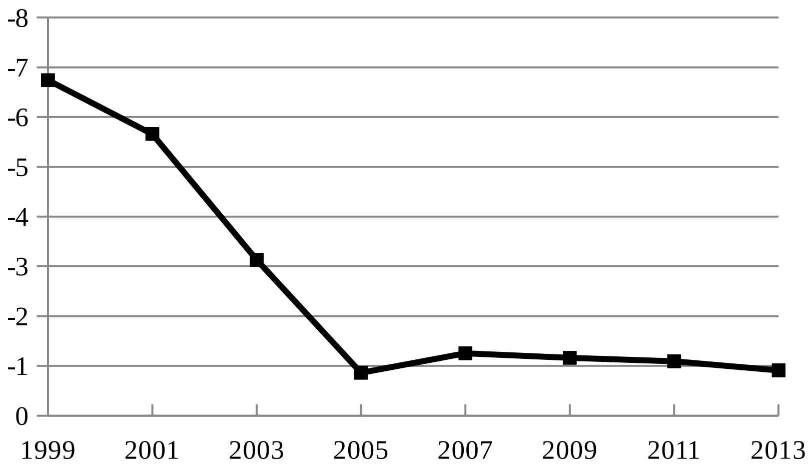
Figure 4.3 Erosion trend along the Kuttayi coast

at Padinjarekkara which lead to the deposition of sand near the structure. After 2003, the coast undergoes almost a uniform rate of erosion of average value -1 m/year which is comparatively very less than that experienced during 1999-2001. The Net Shoreline Movement (NSM) that was calculated at this zone was -17.7 m during the time period under study. The data is given in appendix II. The average landward shift of the shoreline at Kuttayi coast was around 1 m per year. The study of shoreline changes at Kuttayi coastal zone reveals its low erosion rate, which indicates fair stability of the coast.

4.3.2 Padinjarekkara Azhimukham zone

Padinjarekkara Azhimukham extending between 10°48’33” N, 75°54’22” E and 10°47’09” N, 75°54’42” E was the zone with the maximum erosion rate during the fifteen years under study. The variation of erosion rate here is having a similar pattern as that of Kuttayi zone in which a drastic variation in coastal changes was identified after 2001. The Net Shoreline Movement was recorded as

-17.1 m. The estuary here is protected against erosion with the aid of two breakwaters of 780 m (north) and 570 m (south) constructed with a centre to centre distance of 270 m. It was observed that there was tremendous reduction in the coastal changes after the establishment of the breakwaters in the estuary. The analysis of the shoreline change data shows that there is considerable accretion and net advancement of coastline on the north breakwater (between Kuttayi and Padinjarekkara) and net erosion on the south of southern breakwater (Ponnani).

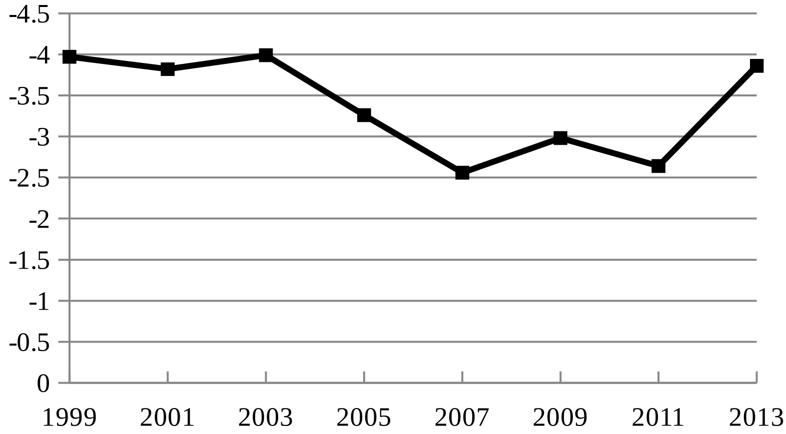


The erosion rates along the coast show stability from 2005 onwards and the lowest erosion rate was recorded in 2005. The estimate of the erosion trend of the estuary in the present study is analogous to the results reported in two other previous studies (Kunhimammu*et al.*, 2008 and Ramesh *et al.*, 2013). As this is a protected shoreline, it is an artificial coast and even though the zone is provided with erosion control structures, it is an eroding coast. The rise of sea level during monsoon is more in this area, leading to high erosive velocities of waves but the breakwaters ensure protection along the coast.

Figure 4.4 Erosion trend along Padinjarekkara Azhimukham coast

4.3.3 Ponnani zone

Ponnani zone lies between 10°47’09” N, 75°54’42” E and 10°45’35” N, 75°55’26” E to the south of the Padinjarekkara zone. Erosion trend analysis along this coast is given in Figure 4.5. Erosion along this coast follows a different pattern than that in Padinjarekkara and Kuttayi zones. The coast was identified with more coastal changes before 2003 and the estimate crossed -4 m/year. Some parts of the coasts are protected with sea wall. After 2003 erosion rate reduced to a value of -2.56 m/year in 2007 and again increased to -2.98 m/year during 2009



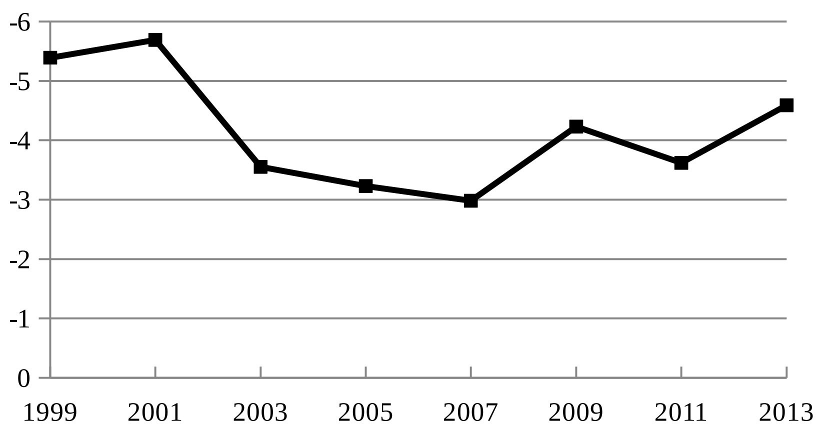
and finally it has reached a high rate of -3.86 m/year in 2013.

During the fifteen year study period, the estimated NSM at this coast was -21.3 m. A speciality of this coast is the presence of mangroves in this place, which are found distributed over the shores of Ponnani near the fishing harbour. Mangroves were identified along the banks of Tirur River also but it has no role in the coastal erosion, as it is away from the coast. Mangroves can reduce erosion as they store water for long periods and their capacity during heavy rainfall to retain excess floodwater results in maintaining a constant flow as well as less erosive effects of sea waves. But now there is no significant cover of mangroves there to

Figure 4.5 Erosion trend along Ponnani coast have an impact on the coastal erosion and at present, the mangroves in Ponnani are nearing extinction.

Analysis of erosion trend along Ponnani coast showed continuous erosion every year with a decreasing trend from 1999 to 2011 and a sudden increase in rate in 2013. This may be due to the entry of surging waves to the land through the gaps formed in the sea wall (Anon, 2013). Many parts of this coastline are having houses and coconut cultivation very close to the sea, so that the high energy waves during monsoon season causes destruction of houses and cultivation. During every monsoon season, people along the coastal belt here face the threat of destruction by the furious waves and lot of families are forced to shift to shelter camps opened by the government annually.

At many places along this zone, the sea wall is destroyed by the high energy waves and the remains are ineffective in controlling the erosion. It was reported that steps are being taken to reconstruct the sea walls destroyed in sea erosion at Beevi and Marakadvu Masjids in Ponnani coast (Anon., 2009). As in the case of Padinjarekkara coast, Ponnani zone is also categorized as eroding coast. This coast had undergone higher erosion with an average rate of -3.38 m per year.



4.3.4 Puthuponnani zone

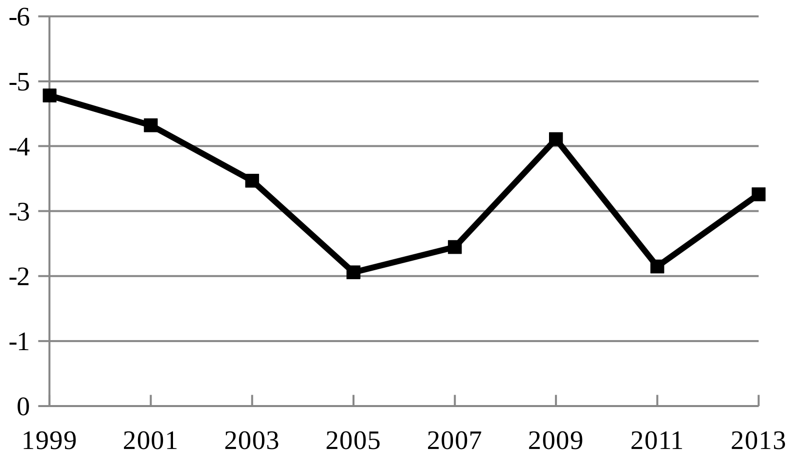
Puthuponnani coast extends south of Ponnani zone between 10°45’35” N, 75°55’26” E and 10°43’26” N, 75°56’22” E. It is in this zone that the Lake

Figure 4.6 Erosion trend along Puthuponnani coast

Biyyam joins Arabian Sea. Like the Ponnani zone, a major portion of the coastline is protected with sea wall except for the stretch where the Biyyam Lake joins sea. Analysis of sea erosion trend at Puthuponnani is shown in Figure 4.6 and it shows a varying pattern over the study period. The coast had higher erosion before 2003 and the reduction in erosion rate after 2003 may be due to the influence of the erected sea wall. The coast has experienced a low erosion rate of average value -3.25 m/year from 2003 to 2007. This value is almost equal to the rate of erosion that Ponnani zone has experienced in 2002.

But after 2007, the coastline had recorded high erosion rates which cross -4 m/year during 2009 and 2013 and in 2011 it was -3.62 m/year. Sea erosion at Puthuponnani worsened and the surging sea waves destroyed houses and coconut trees along the coastal belt (Anon, 2012., Anon, 2013). In this study, high erosion rate was observed along Puthuponnani coast during this period. The highly erosive waves destructed the sea wall at many places during this period. The government has taken steps to reconstruct the sea wall destroyed during this period also. So this shows that the already built structure was inadequate to resist the erosive high energy waves in this coastline. During the time of monsoon, destruction of trees, houses and sea wall occurs every year in this zone.

The NSM recorded at this zone was -24.6 m that indicated that the coastline has reached the sea wall which was 20-25 m away from the sea, initially. This means that the coastline without protection has advanced 25 m landward during the fifteen years of study period and this landward advancement was found to be more near the point where the Lake Biyyam joins sea. This coastal zone is also categorized under eroding coast.



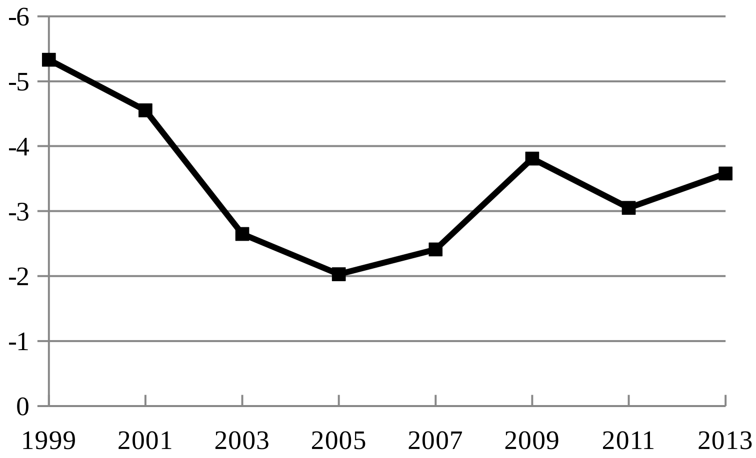
4.3.5 Veliyamcode zone

Veliyamcode beach is located to the south of Puthuponnani area and lies between 10°43’26” N, 75°56’22” E and 10°42’27” N, 75°56’50” E. Figure 4.7 shows that Veliyamcode is a an erosion affected area. During 1999-2002 rate of erosion was recorded as more than -4 m/year with maximum erosion in 1999. In 2003 the coastal change was found to be -2.65 m/year and reached a minimum change in 2005 with a rate of -2.03 m/year. The erosion rate observed has increased in 2007 and followed by more coastal changes in the proceeding periods. After 2007, the coast has undergone higher erosion rate in the year 2009

Figure 4.7 Erosion trend along Veliyamcode coast

with an estimated erosion rate of -3.81 m/year. Sea wall at different parts along Veliyamcode coastline was found to be damaged (Anon., 2009). The increased erosion rates after 2009 may be due to the destruction of the sea wall and here also the inadequacy of the present sea wall to resist the high energy waves can be recognised. The NSM recorded at this place was -50.85 m. Just like the other coastal zones, Veliyamcode zone is also categorized under the eroding coasts.

Figure 4.8 Erosion trend along Palappetty coast



4.3.6 Palappetty zone

Palappetty coast extends south of Veliyamcode between 10°42’27” N,

75°56’50” E and 10°41’10” N, 75°57’22” E. The erosion pattern along this coast is somewhat similar to the Veliyamcode zone. The coast has experienced maximum erosion during 1999 with a rate -4.78 m/year and followed by a gradually reduced coastal change till 2005. After this period erosion was found to be increasing and reached a higher value in 2009 like in the Veliyamcode zone. But a sudden reduction in erosion was noted in 2011 which was -2.15 m/year and again in 2013 it had increased to -3.26 m/year.

Palappetty is a place that undergoes severe erosion during every monsoon season. During this time, people reel under the threat of being washed away as the sea water crosses the protective structure. The highly erosive waves cause damage to the sea wall and government has decided to build new sea wall for a length of

Plate 4.1 Eroding coast of Palappetty (Mathrubhumi, 2015)

625 m and reconstruct the destroyed portions in 2010. In this study, this region had recorded a higher erosion rate during 2009. Like the other four coastal zones, this place also is coming under the eroding coast category with NSM of -55.65 m in the period under study.

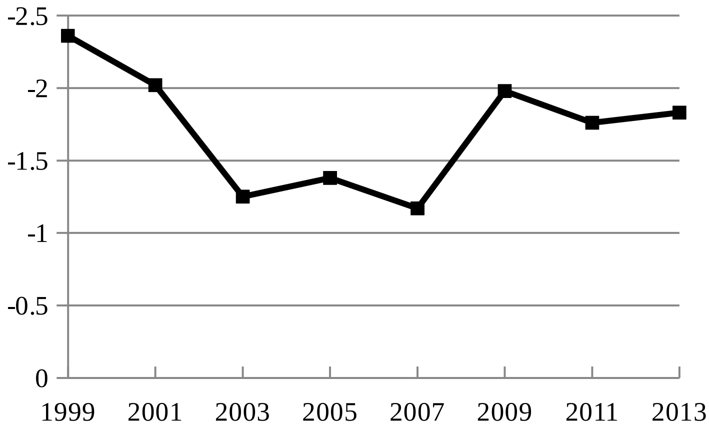
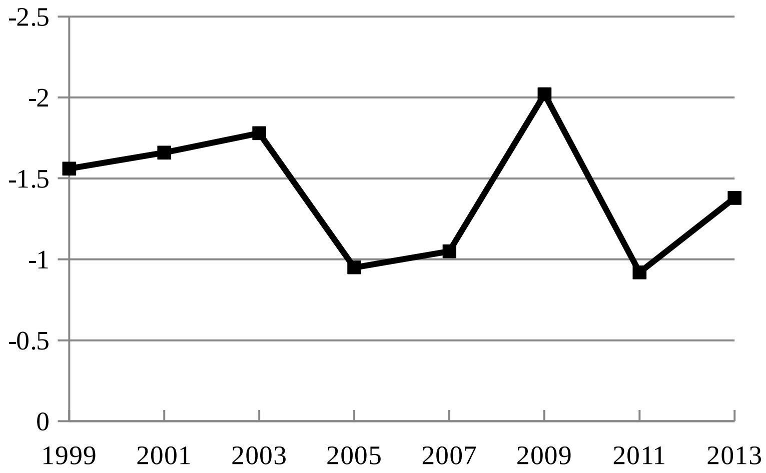


Figure 4.9 Erosion trend along Andathode coast

4.3.7 Andathode zone

Location of Andathode coast is between 10°41’10” N, 75°57’22” E and 10°39’44” N, 75°58’02”E to the south of Palappetty coast. Analysis given in Figure 4.9 shows that this area is not under severe erosion as the coast has not experienced erosion rate more than -2.5 m/year. The maximum erosion estimated along the coastline was -2.36 m/year in 1999 in which all other coasts has experienced highest erosion. From 1999 to 2007, the erosion rates reduced gradually with an increase in 2005. In 2009, the year in which all the previous coast zones also experienced comparatively high erosion, this coast was found to have an erosion rate of -1.98 m/year which is the maximum rate after 2001.

The results reveal that Andathode coast was under medium erosion with estimated NSM of -27.3 m. In this zone, the area where people live and cultivate is away from coastline, thus avoiding the threat of destruction as sea water does not reach this area. This is not an artificial coast and is categorized under low erosion areas.

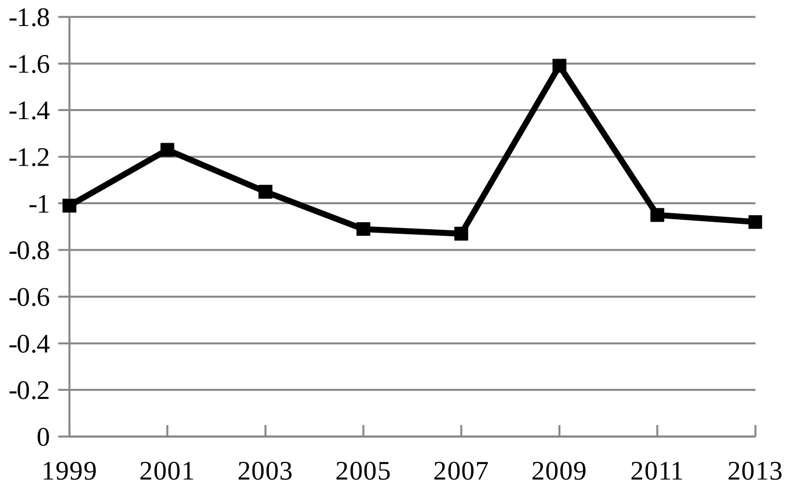


4.3.8 Punnayur zone

Figure 4.10 Erosion trend along Punnayur coast

Punnayur zone lies to the south of Andathode zone between 10°33’44” N, 75°58’02”E and 10°37’45” N, 75°58’53” E. Erosion pattern over this area is different from other zones. This area has not experienced erosion more than -2 m/year except in 2009. During 1999, the coast has undergone less erosion with a rate -1.56 m/year and upto 2003 erosion was gradually increasing to a value of -1.78 m/year. During 2005-2007, erosion was very less which again increased to a maximum rate of 2.02 m/year. Sea water entered into few houses and caused loss of properties (Anon., 2012) in monsoon season. Punnayur coast is the place identified with more erosion than that in 1999.

Grasslands were identified along the coast of Punnayur with the help of Google map which is few meters away from coastline which may be the reason for reduced erosion in this area compared to previous coastal zones. The NSM calculated for this coast was -18.9 m and is categorized under low erosion areas.



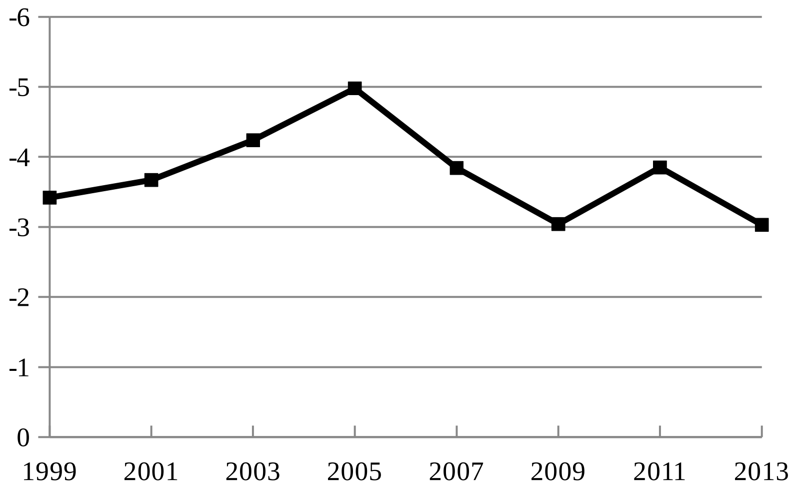
4.3.9 Edakkazhiyur zone

Location of Edakkazhiyur coast is between 10°37’45” N, 75°58’53” E and 10°35’29” N, 75°59’59” E and it is situated to the south of Punnayur area. The erosion trend analysis along this area reveals that it had a maximum rate of erosion during 2009 and this value crossed erosion rate during 1999 like in the case of Punnayur coast. But highest erosion rate recorded in this area was -1.59 m/year, which is comparatively low. From 2005 to 2013 the coastline has undergone almost similar erosion process with an increase in 2009.

Presence of grassland cover along the coastal belt was identified as in Punnayur. The grassland is few meters away from shoreline which may acts as

Figure 4.11 Erosion trend along Edakkazhiyur coast

protective layer along the coastal area. Destruction of land area, crops and houses during monsoon season was found to be rare in this area. The NSM calculated in this zone was -20.25 m and this zone is coming under low erosion areas.



4.3.10 Chavakkad zone

Chavakkad zone lies to the south of Edakkazhiyur coast between 10°35’29” N, 75°59’59” E and 10°33’21” N, 76°0’57” E. This coast has experienced erosion rate more than -4 m/year. The NSM estimated for this area was -36.75 m during the 15 years under study. The highest rate of erosion calculated along the coast was -4.98 m/year in 2005. After this, erosion recorded was found to be less than -4 m/year in 2007 and 2011 but an increasing trend was observed after 2013. The average erosion was much more in this coast, compared to Edakkazhiyur.

Presence of grassland at some part of this coast also has been identified with the aid of Google maps, which may act as a preventive measure against erosion.

Figure 4.12 Erosion trend along Chavakkad coast

After Chavakkad beach, the coast is protected by sea wall. Damage of many houses, sea wall and uprooting of several trees due to tidal waves during monsoon season were reported in Anon, 2004 and Anon, 2012. The news reveals that attempts to form a green wall with casuarinas did not yield the expected results, as the lashing tidal waves uprooted most of them. This coast is also categorized under eroding coasts and the higher erosion rate over this area is a matter of concern.

4.4 IMPACT OF COASTAL PROCESSES ON EROSION

The coastal erosion along Ponnani area, which is interspersed with beaches, estuary, lake mouth and man-made sea wall structures, is affected by the hydrodynamic processes such as tidal fluctuation, high energy waves, littoral flows and sediment motion under wind. In addition to that, rate of coastal changes depends on coastal slopes, sea level fluctuations and artificial structures along the coast. All these factors influence the fluctuating coastal changes due to erosion in long and short- term period.

The beaches of Ponnani stretch are narrow with width less than around 30 m except in the sector without sea wall. On closer observation, it can be seen that the coastline is sandy, highly irregular, and under considerable erosion. It can be classified under soft coast with coastal slope varying from gentle to steep slopes. Coconut trees are very common along this coastal belt. Results of erosion assessment show that the coastline of Ponnani is very dynamic and fluctuates seasonally. This shows that the coastline is very sensitive to the coastal processes and this characteristic directly influences the erosion. As the erosion continues, the shoreline retreats landward because of the undercutting of slope by wave action.

One of the pronounced effects of climate change is accelerated sea level rise. Unnikrishnan (2012) reported that sea level trend along Indian coasts are about 1.3 mm/year. Sea level rise produces a range of erosional problems along the coastline. Water depth increases as the sea level rises, and the wave base gets deeper. This increases the energy of the waves reaching the coast and therefore can erode and transport larger quantities of sediment. Thus the coast begins to maintain a new sea level. The impacts of sea level rise include increased coastal erosion, storm surge flooding, negative effects on coastal ecosystem (mangroves) etc. Results of the analysis show that the Ponnani coast has undergone all these processes during the period under study.

Wind is the main force in wave generation and waves are the most important cause of fluctuation of coastlines. They introduce energy to the coast and also a series of currents that move sediment (drift) away from the shore. Energy, mainly from wind, imparted to the water produces wave motion so the erosive energy of waves is dependent up on wind energy. And also the monthly mean wind speed varies from 8.1 kmph in November to 12.4 kmph in May (GOK, 2015). Wind may transfer sand from coastal environment landward under proper environmental conditions. This is significant in the area without sea wall protection as the coast is sandy. During monsoon, wind action becomes strong enough to cause severe erosion along the coast of Ponnani as the wind .

Tide is an important factor that affects coastal dynamics. They drive tidal currents, regulate wave action and control energy arriving on the coast. The oscillatory nature of tidal currents transport sediments but the effect is more in estuaries. The tide has very low effect, except in the areas with greater tidal ranges. But according to the studies conducted on the beach dynamics of Kerala coast by Sajeev (2013), tidal range along Kerala coast is within 2 m. So the impact of tides on erosion along the coast of Ponnani can be assumed to be very less.

Human activities are equally significant and that must be considered in evaluating influence of coastal processes on erosion. The study area consists of breakwater at Bharathapuzha river mouth, sea wall along many parts of coasts and natural barriers (grassland) along Punnayur, Edakkazhiyur and Chavakkad. Grasslands are well adapted to the dynamic environment of moving sand away from coast. The beaches of Punnayur, Edakkazhiyur and parts of Chavakkad with grassland have coastal stretch with a width of more than 50 m and considering the erosion rates along with this, reveal that the grassland plays a great role in controlling the erosion.

Out of the 35 km coastal stretch under study, around 10 km stretch is protected with sea wall. Activities along the coast such as building houses via land reclamation, port development, establishment of sea wall etc. have long-term impact on coastal changes. The breakwater built on the shoreline, interfere with the sediment drift and results in sedimentation. After the establishment of the breakwater at Bharathapuzha river mouth, there was a decreasing trend to the erosion rate. The river mouths are already in equilibrium with the littoral drift but the regulated mouth obstructing this causes erosion in nearby shoreline. This is the reason why Padinjarekkara zone is identified with reduced erosion but the coast of Ponnani is found with more erosion.

Construction of sea wall is intended to protect the upstream end of coastline from erosion; however this also causes increased erosion (Plant,1992). An eroding coast supplies sediments to sediment transport. But when the erosion is controlled at certain sections by the establishment of seawalls, the supply of sand from this section of the shoreline to the sediment transport along the adjacent shorelines will get stopped, thereby the shorelines at the end of structures is exposed to increased erosion (Kraus, 1988). The sea wall exist in Ponnani is rubble mound with height ranging from 3 to 5 m. This may be the reason for the increased erosion at certain portions without protective structure along Ponnani, Puthuponnani, Veliyamcode and Palappetty zones. The increased depth of water near the sea wall will produce high energy waves causing destruction of the structure as the waves gets stronger.

4.5 IDENTIFICATION OF PRIORITY AREAS AND SUGGESTION OF SUITABLE STRUCTURES

The destruction of the sea walls along the different places of the study area, destruction of houses and loss of cultivation along the coast during monsoon and the reduced width of the shoreline stretch at different beaches were considered as the indicators of coastal erosion, for the study. Overall assessment of coastal erosion in the study area reveals that Ponnani coast is an eroding coast with fluctuating erosion rates. The erosion process along this coast indicates accelerated erosion rates as well as the instability of sea wall over certain places. This area needs proper erosion control measures in order to protect the coastal ecosystem, life, property and cultivated crops from destruction due to severe erosion, especially during the monsoon season. The coastline along Ponnani needs urgent attention and development of suitable erosion control measures are presented in the following figures. According to the rate of erosion estimated the erosion affected areas along the coast are classified into different groups.

1. High erosion (Erosion rates more than -4m/year)
2. Medium erosion (Erosion rates between -2 to -4 m/year)
3. Low erosion (Erosion rates between 0 to -2 m/year) and
4. Low accretion (Accretion between 0 to 2 m/year)

Certain places along Kuttayi was identified with low accretion but the area under accretion was very less compared to the area under erosion (Figure 4.13). Rate of accretion estimated was less than 1 m/year. This zone involves coastline with all the ranges of erosion rates classified and overall analysis shows that the zone is under medium erosion. The priority area needing proper protection against high erosion was found to be located along a 600 m stretch at 10°47’02” N, 75°54’48 E”. As this coast is not provided with any erosion control structures, vegetative methods of erosion control can be adopted as the primary step of management practices.

Area north of Padinjarekkra beach was found to be with accretion but the area south of it was observed to have high erosion (Figure 4.14). At the end of south breakwater of 570 m legth, medium erosion rates were estimated. During field verification, damaged part of old breakwater structure was found at this place (Plate 4.2, 4.3). Proper maintenance of breakwater at this place can reduce erosion at this place and protect the structure as well as the beach from increased erosion rates.

Along the portion between the south breakwater and the sea wall established over Ponnani, high erosion rates were estimated (Figure 4.15). But the width of the stretch over this place was found to be more than 60 m so the coast is not under the immediate threat of destruction but it causes landward retreat of coastline in an accelerated rate. So proper erosion control measures along this place is important. Certain spots along the protected coastline of Ponnani where the width of the stretch from the sea wall to the sea is very small or nil was also identified with high erosion rates. Every year during the monsoon season, destruction of the sea erosion protection structure at many places was reported by newspapers. The shoreline stretches where there is destruction of sea wall and where there are no sea walls established was found to be more eroding. The pesence of significant cover of mangroves along the coast was not observed (Plate 4.4). Conservation of the mangroves and proper design and maintenance of the structure over these areas is suggested.

High erosion rates were observed along most of the coastline along Puthuponnani (Figure 4.16). The mouth of Beeyam Lake was not protected and this may be the reason behind the increased erosion occuring over there. The location between 10°44’09” N, 75°56’01”E and 10°43’29”N 75°56’21”E was found to be in need of urgent erosion control measures, as this portion is without sea wall.

Recently, about 625 m of Palappetty coast was protected with sea wall but the landward shoreline shift towards the structure indicates the high intensity of erosion along this place (Figure 4.18). So protecting the entire coastline from erosion may be the best way to solve these kind of problems. Properly designed structure, strong enough to handle the fury of high energy waves during monsoons, is an important factor becouse the structure is found to be ineffective at many places.

In Veliancode block (Figure 4.17), only few meters was found to be erosion prone area and at many places the structure was damaged. Due to the high erosion rates at these places, the shoreline moved landward and reached near the sea wall and this again causes the destruction of sea wall with strong waves. The portion between the ends of the structure at the two sides where the sea wall ends is found with higher erosion rates and hence the end of the strucutre is also under the threat of erosion. Only few meters of the Palappetty coast was identified with reduced erosion, as these places alone are protected. During the field visit, the shoreline between the ends of the sea wall, where there is no sea wall, was observed to have a 10 m landward shift of the shoreline due to the severe erosion there.

Only Periyambalam beach was found with high erosion rate along the Andathode (Figure 4.19) and Punnanyur zone (Figure 4.20). But parts of these beaches contains grasslands along the coast, so establishment of vegetation and maintenance of grassland present here may make the coastline resistant against erosion.

Edakkazhiyur zone (Figure 4.21) was also found without erosion prone areas and the width of coastal stretch also was found to be fair. But many places of Chavakkad zone (Figure 4.22) was observed with erosion at greater rates. From south of Chavakkad beach, the coastline is protected with sea wall and some places are protected with green wall with Casuarinas. But during monsoon, the tidal waves cause damage to this green wall as well as the sea wall structure. So better management of erosion immediately along this area is very important.

Overall analysis of the extent of erosion by direct inspection at various parts (Ponnani, Bharathapuzha River mouth, Veliancode and Palappetty zone and Periyambalam beach in Punnayur zone) of study area revealed that many parts of the shoreline with or without protection are under the threat of acclerated erosion. At many places the structure was found to be very ineffective against the tidal waves, as they cause damge to life, property and cultivation along the coast. Anon, 2012 reported that attempt to achieve protection with green wall was fruitless and stability of the sea wall is low as it is found to be damaged at many places. The authorities have been trying to check the sea waves by putting sand bags in the gaps between the ends of the sea walls. The tidal waves uprooted most of the Casuarina trees which was established to make a green wall.

As the sea wall is found ineffective at many places, a better sea wall or other hard structure can be considered on these high energy wave areas prone to erosion. Groyne is a rigid structure built along sea shore, perpendicular to the coastline from the shore into the sea to settle down longshore sediment drift or control severe erosion, as they interrupt the waves and reduces its energy. This type of structure is easy to construct from a variety of materials such as wood, rock or bamboo and is normally used on sandy coasts. In 2012, the Hindu also reported that groyne is a suggestion of scientists, which is a permanent solution to the sea erosion according to them. But all the structures need proper care and maintenance for effective working. The coasts of Punnayur, Edakkazhiyur and Andathode are the areas with soft structures. So these areas can be provided with coastal vegetation as they function satisfactorily.

CHAPTER 5

SUMMARY AND CONCLUSIONS

A study of coastal erosion along the Ponnani coast using multispectral imageries and GIS was undertaken to assess the temporal changes in coastal erosion, its extent, magnitude and trends in the region under study. The study also aimed to evaluate the impact of the existing coastal erosion control structures with a view to assess its efficacy and to identify priority areas for coastal erosion prevention along the study area. The study utilized medium resolution LANDSAT imageries for the mapping and monitoring of the coastline erosion. The study revealed the usability of multispectral satellite imageries like that obtained from LANDSAT, IRS and other satellites in assessing the temporal changes along the coastline by the combined application of remote sensing and GIS techniques.

The main advantage of using remote sensing for assessing the coastline changes is the availability of multitemporal data. The LANDSAT imageries of Ponnani area were available from 1999 hence the study was carried out for the period between 1999 and 2014. The digital image processing software used for calculating the erosion rate is TNTmips 2014 professional version (**M**ap and **I**mage **P**rocessing **S**ystem - MIPS) by MicroImages, Inc. The coastal erosion rates were estimated using a script written in TNT's geospatial scripting language (SML) and the methodology used to calculate shoreline erosion rates was adapted from the *Digital Shoreline Analysis System* (DSAS) of US Geological Survey (USGS). The script requires a baseline vector and at least two shoreline vectors with known date of acquisition to analyse the shoreline changes. The changes in coastline are calculated along the transects (orthogonal lines) produced from the baseline. The shorelines are often tortuous which makes the vector unsuitable for generation of transects. Then the script creates a new vector object containing transects whose length can be specified. The erosion rates are estimated as both end point rate and mean rate along each transect.

The temporal change detection study on coastal erosion along Ponnani shoreline was carried out for the period between year 1999 and 2014 for analysing long term erosion along the coast and short term changes were analysed for periods between 1999-2000, 2002-2003, 2005-2006, 2008-2009, and 2013-2014. Both long-term and short-term erosion assessment showed that many places along the Ponnani shoreline are under severe erosion. Ponnani, Puthuponnani, Veliyamcode, Palappetty and Chavakkad are the zones identified with higher erosion rates. There were many places like Kuttayi, Padinjarekkara, Andathode, Punnayur and Edakkazhiyur with low erosion rates. The highest coastal erosion rate of -3.71 m/year in the long-term erosion assessment was observed at Palappetty. However, short-term erosion assessment revealed that many places were having coastal erosion rates more than -4 m/year. During 1999-2000, highest erosion rates were observed in almost all the zones, but after this period only three coastal zones have experienced more erosion than this. Hence the objectives of the study to apply remote sensing to assess the temporal changes occurred along the coastal areas of Ponnani, to determine the shoreline changes using digital change detection techniques and to study the extent and magnitude of the coastal erosion occurred were achieved.

Water Resources (Irrigation) Department of the Government of Kerala as part of their Sea shore erosion prevention work have established sea walls along the coastal erosion prone coasts of Ponnani to stabilize the shoreline. The impact of these shoreline protection structures on erosion process was also taken in to account in this study. The erosion trend analysis shows that the erosion rate is decreasing from the point of commencement of the breakwater at the mouth of the Bharathapuzha River to the Southern side where shoreline protection structures are in place.

However it was found that these structures could not withstand the continued severe erosive action of the sea waves during the monsoon season, resulting in the failure of these structures at many places causing loss of life and property along the coast during fierce monsoon climate. This indicates that the accelerated erosion at these spots led to the instability of the structure and additional measures are required at these spots. In areas with low erosion rate, protection with grass and vegetative barriers was found to be effective but the mangrove cover present along the shoreline in the Ponnani coast was found to have depleted over years and is now insignificant to act as an effective barrier against the high rate of erosion.

The coastal erosion rates along the Ponnani shoreline are not only affected by hydrodynamic processes such as tidal fluctuation, high energy waves, littoral flows, and wind but also these are affected by other factors like coastal slope and existence of artificial structures. This is because the coastline is sensitive to coastal processes. Activities along the coast such as construction of buildings after filling and reclamation of low land, port development, establishment of sea wall etc. were found to have long-term impacts on the coastal accretion rates. The occurrence of high energy waves during monsoon season is the main reason for severe erosion occurring along the Ponnani coast. There are gaps in the shoreline protection structures due to their destruction and these areas were observed to have increased erosion rates, since there are no shoreline protection measures. The destruction of these structures at specific spots may be due to the variations that have occurred in the equilibrium of sediment transport before and after the construction of the erosion control structures. The construction of shoreline protection structures might have caused increment in the depth of water near the sea walls, resulting in the formation of high energy waves and subsequent destruction of the structures. The results of the analysis show that the coastline of Ponnani is very dynamic and the accretion rates fluctuate seasonally and that many coastal processes as well as anthropogenic factors influence the change in this coast.

The priority areas needing erosion protection measures and preventive measures that are suitable for these areas have also been looked into. The study revealed that Ponnani is an actively eroding coast with fluctuating erosion rates. The erosion rates were found to be high with a rate more than -4 m/year for about

15 km of the coastline considered. The erosion rates along the Kuttayi coast and the areas north of Padinjarekkara were found to be slightly less. But the areas south of the breakwater were observed with high erosion rates and proper maintenance of the erosion prevention structure along these areas is suggested. It was found that the coastline erosion protection wall constructed along the coast of Ponnani, Puthuponnani, Veliyancode and Chavakkad have gaps due to destruction of the structure at many places. The renovation and maintenance of the sea wall at these places is an effective measure in reducing the present accelerated rates of erosion at these spots. The coastline of Kuttayi, Andathode, Punnayur and Edakkazhiyur were found to be having low erosion rates even though the coastline is not provided with any coastal protection structures and hence erosion control using vegetative barrier methods will be sufficient for these areas. The establishment of Groynes, at areas experiencing accelerated erosion rates and destruction of the coastline protection structures will be a more effective solution. The areas with accelerated erosion along the coast of Ponnani need sustainable management and protective measures.

Thus the objectives of this study to determine the temporal shoreline changes along the coastal areas of Ponnani using remote sensing and digital change detection techniques and to study the extent and magnitude of the coastal erosion occurred to identify priority areas and suggest suitable preventive measures were met. The coastal erosion study using remote sensing and GIS techniques provided realistic information about the erosion process along Ponnani area and this method can be successfully used for mapping and monitoring coastal changes.

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APPENDIX I

Place	Erosion rates during different year (m/year)							
	1999	2001	2003	2005	2007	2009	2011	2013
Kuttayi	-3.82	-3.25	-1.21	-0.97	-1.05	-1.03	-0.89	-1.46
Padinjarekkara	-6.74	-5.66	-3.13	-0.86	-1.25	-1.16	-1.09	-0.91
Ponnani	-3.97	-3.82	-3.99	-3.26	-2.56	-2.98	-2.64	-3.86
Puthuponnani	-5.39	-5.69	-3.55	-3.23	-2.98	-4.23	-3.62	-4.59
Veliyancode	-5.33	-4.55	-2.65	-2.03	-2.41	-3.81	-3.05	-3.58
Palappetty	-4.78	-4.32	-3.47	-2.06	-2.45	-4.11	-2.15	-3.26
Andathode	-2.36	-2.02	-1.25	-1.38	-1.17	-1.98	-1.76	-1.83
Punnayur	-1.56	-1.66	-1.78	-0.95	-1.05	-2.02	-0.92	-1.38
Edakkazhiyur	-0.99	-1.23	-1.05	-0.89	-0.87	-1.59	-0.95	-0.92
Chavakkad	-3.42	-3.67	-4.24	-4.98	-3.84	-3.04	-3.85	-3.03

Erosion trend analysis along different coastal zones

APPENDIX II

Net shoreline movement calculated for coastal zones

Place	Erosion (m/year)	Accretion (m/year)	NSM (m)
Kuttayi	-1.18	0.78	-17.7
Padinjarekkara	-1.14	1.12	-17.1
Ponnani	-1.42	1.25	-21.3
Puthuponnani	-2.74	1.1	-41.1
Veliyancode	-3.39	1.32	-50.85
Palappetty	-3.71	1.56	-55.65
Andathode	-1.82	1.15	-27.3
Punnayur	-1.26	0.96	-18.9
Edakkazhiyur	-1.35	1.16	-20.25
Chavakkad	-2.45	1.14	-36.75

COASTAL EROSION STUDY OF PONNANI REGION USINGMULTISPECTRAL IMAGES

by

SHEEJA P.S

(2013 – 18 – 104)

ABSTRACT

Submitted in partial fulfilment of the

requirement for the degree of

MASTER OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

(Soil and Water Engineering)

Faculty of Agricultural Engineering & Technology

Kerala Agricultural University

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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KERALA

2015

ABSTRACT

A study of coastal erosion along the Ponnani coast using multispectral imageries and GIS was undertaken to assess the temporal changes in coastal erosion, its extent, magnitude and trends in the region under study. The study also aimed to evaluate the impact of the existing coastal erosion control structures with a view to assess its efficacy and to identify priority areas for coastal erosion prevention along the study area. The study utilized medium resolution LANDSAT imageries for the mapping and monitoring of the coastline erosion. The digital image processing software used for calculating the erosion rate was TNTmips 2014 professional version (**M**ap and **I**mage **P**rocessing **S**ystem - MIPS) by MicroImages, Inc. The study revealed the usability of multispectral satellite imageries like that obtained from LANDSAT, IRS etc. satellites in assessing the temporal changes along the coastline by the combined application of remote sensing and GIS techniques.

Both long-term and short-term erosion assessment showed that many places along the Ponnani shoreline are under severe erosion. Short-term erosion assessment revealed that many places were having coastal erosion rates more than -4 m/year. The impact of these shoreline protection structures and coastal processes on erosion process was also taken in to account in this study. The study revealed that Ponnani is an actively eroding coast with fluctuating erosion rates. The erosion rates were found to be high with a rate more than -4 m/year for about 35 km of the coastline considered.

The areas with accelerated erosion along the coast of Ponnani need sustainable management and protective measures. The coastal erosion study using remote sensing and GIS techniques provided realistic information about the erosion process along Ponnani area and this method can be successfully used for mapping and monitoring coastal changes.

സംഗ്രഹം

പൊന്നാനി കടൽ തീരത്ത് അനുഭവപ്പെടുന്ന തീരദേശ മണ്ണൊലിപ്പിന്റെ അളവിലും വിസ്തൃതിയിലും ഉണ്ടായ കാലികമായ മാറ്റങ്ങൾ റിമോട്ട് സെൻസിംഗ് ഉപഗ്രഹ മൾട്ടിസ്പെക്ട്രൽ ഇമേജറികൾ ഉപയോഗിച്ച് പഠിച്ചു. 1999 മുതൽ 2014 വരെയുള്ള ഉപഗ്രഹ ചിത്രങ്ങൾ ഉപയോഗപ്പെടുത്തി തീരദേശ മണ്ണൊലിപ്പിന് കാലാനുസൃതമായി എന്ത് മാറ്റങ്ങൾ ഉണ്ടായി എന്നും അതിൽ കണ്ടലുകളും മറ്റ് ജൈവ മണ്ണൊലിപ്പ് പ്രതിരോധകങ്ങളായ വൃക്ഷലതാദികളുടെയും കടലാക്രമണ നിയന്ത്രക സ്ട്രക്ചറൽ എഞ്ചിനീയറിംഗ് നിർമ്മിതികളുടെയും പങ്ക് എന്തെന്നും കണ്ടെത്താൻ ശ്രമിച്ചിട്ടുണ്ട്. തീരദേശ മണ്ണൊലിപ്പും കടലാക്രമണവും നിയന്ത്രിക്കാനുണ്ടാക്കിയിട്ടുള്ള സ്ട്രക്ചറൽ എഞ്ചിനീയറിംഗ് നിർമ്മിതികളുടെ കാര്യക്ഷമതാ പഠനവും തീരദേശ മണ്ണൊലിപ്പിന്റെ തീവ്രതയനുസരിച്ചുള്ള പ്രദേശങ്ങളുടെ വർഗ്ഗീകരണവും അടിയന്തിര ശ്രദ്ധ ചെലുത്തേണ്ട വിധം മണ്ണൊലിപ്പുള്ള സ്ഥലങ്ങളുടെ നിർണ്ണയവും നടത്തി.

ഈ പഠനത്തിൽ അമേരിക്കയുടെ ബഹിരാകാശ ശാസ്ത്ര സ്ഥാപനമായ നാസയുടെ ഭൂവിഭവ നിർണ്ണയ റിമോട്ട് സെൻസിംഗ് ഉപഗ്രഹമായ ലാന്റ്സാറ്റ് ഉപഗ്രത്തിന്റെ ഇമേജറികളാണ് തീരദേശ മണ്ണൊലിപ്പിന്റെ പഠനത്തിന് ഉപയോഗിച്ചത്. മൈക്രോഇമേജസ് ഇൻകോർപ്പറേറ്റഡ് എന്ന കമ്പനിയുടെ പ്രശസ്തമായ TNTmips 2014 (മാപ്പ്സ് ആൻഡ് ഇമേജ് പ്രോസസ്സിംഗ് സിസ്റ്റം) എന്ന റിമോട്ട് സെൻസിംഗ് ഇമേജ് പ്രോസ്സസ്സിങ്ങും GIS ഉം ഉൾപ്പെട്ട സോഫ്റ്റ്‌വെയർ ഉപയോഗപ്പെടുത്തിയായിരുന്നു പഠനം.

ദീർഘകാല-ഹ്രസ്വകാല മണ്ണൊലിപ്പ് നിർണ്ണയം വ്യക്തമാക്കുന്നത് പൊന്നാനി തീരപ്രദേശത്തെ പല ഭാഗങ്ങളിലും കടുത്ത മണ്ണൊലിപ്പ് അനുഭവപ്പെടുന്നു എന്നാണ്. ഹ്രസ്വകാല മണ്ണൊലിപ്പ് നിർണ്ണയത്തിൽ പല സ്ഥലങ്ങളിലും -4 മീറ്റർ/വർഷം എന്ന നിരക്കിൽ മണ്ണൊലിപ്പ് ഉണ്ടെന്ന് കണ്ടു. പൊന്നാനി തീരപ്രദേശത്ത് വ്യത്യസ്തമായ പ്രദേശങ്ങളിൽ പല നിരക്കുകളിൽ സജീവമായ മണ്ണൊലിപ്പ് നടക്കുന്നു എന്ന് കണ്ടെത്തി.

35 കിലോമീറ്റർ നീളം വരുന്ന പഠനസ്ഥലത്തിന്റെ പല ഭാഗങ്ങളിലും മണ്ണൊലിപ്പ് -4 മീറ്റർ/വർഷം എന്ന ഉയർന്ന നിരക്കിന് മുകളിലാണ്. പൊന്നാനി തീരത്ത് ഉയർന്ന നിരക്കിൽ മണ്ണൊലിപ്പ് ഉള്ള പ്രദേശങ്ങളിൽ സുസ്ഥിരമായ സുരക്ഷാ നടപടികൾ ആവശ്യമാണ്. ഭൂവിഭവ നിർണ്ണയ റിമോട്ട് സെൻസിംഗ് ഉപഗ്രഹ ചിത്രങ്ങളെ റിമോട്ട് സെൻസിംഗ്, ജിഐഎസ് സാങ്കേതികവിദ്യകളുടെ സംയുക്തമായ പ്രയോഗം വഴി അപഗ്രഥിച്ച് തീരദേശ മണ്ണൊലിപ്പ് നിർണ്ണയിക്കാമെന്ന് ഈ പഠനം വ്യക്തമാക്കുന്നു.