International Journal of Applied Research 2015; 1(11): 936-946

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2015; 1(11): 936-946
www.allresearchjournal.com
Received: 06-08-2015
Accepted: 08-09-2015

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Coastal Zone Analyses Around Mumbai – Thane Coast Using Multitemporal Satellite Data and Gis

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Abstract
Mumbai- Thane coastal zone is very vibrant, dynamic and delicate environmental zone, which performs important functions in India. This area is also rich source of food, energy and minerals and therefore a primary source of livelihood for a large population depends on this area. The shoreline of Mumbai- Thane coastal area is one of the most rapidly changing landforms of the country which is influenced by Geomorphic processes such as erosion, deposition and sedimentation, periodic storms, flooding and sea level changes continuously modify the shoreline. Satellite Remote Sensing technique has proved its utility in all fields of earth science studies including coastal processes. The major advantages of RS and GIS are that it allows identifying the spatial relationships between features and temporal changes within an area over time. The main objective of the study is to assess the coastal changes along the Mumbai – Thane coastal area. To fulfill this study few sub-objectives are taken in to consideration to identify the sites of Erosion and Accretion along the coast, to assess the land utilization of Mumbai – Thane coast, to find out the major Vegetation types, to demarcate CRZ boundary and identify the changes, impact of Sea Level Change in Mumbai – Thane coastal region. To fulfill the objectives of the study progressive methodology has been prepared and various satellite data has been collected to analyse the temporal variation and impact of human activities. In this paper an attempt has been made to study the shoreline changes in terms of erosion and accretion using RS and GIS for Mumbai- Thane coastal region.

Keywords: *RS and GIS, CRZ boundary, Vegetation type, erosion and accretion*

1. Introduction

India has got a coast of 7,500km which is intersected by rocky outcrops and shores with stretches sandy beaches. It supports 25% of countries population within 100km of the coastline. As a consequence of anthropogenic and socio-economic factors, costal zones of India are subjected to enormous pressure. Moreover, industrial development and sustainable growth have resulted in degradation of coastal zones and surrounding ecosystem. The processes of erosion and sedimentation, periodic storms and cyclones and sea level changes continuously modify shoreline. The entire stretch of coastal zone of India assumes its importance because of high productivity of its ecosystems, exploitation of natural resources, industrial and port development, discharge of waste effluents and increased tourism activities. According to Perthick (1984) [6] coastal zone is a very complex, dynamic and delicate environment, which performs important functions such as shoreline stabilization, fish nurture, recreation besides providing habitat for nearly all shellfish and finfish of nutritional and commercial value. Apart from these, coastal areas also rich in sources of food, minerals, energy and therefore it becomes a primary source of livelihood for a large part of the world's population.

Remote sensing and GIS techniques have been extensively used in inventory, monitoring and management of natural resources in the coastal areas due to its repetitive, multispectral and synoptic nature. Remote sensing data can be used to evaluate the coastal processes like littoral drift, erosion/ accretion and shoreline changes and to study water geomorphology landforms, coastal wetlands, suspended sediment concentration, water quality, tidal boundaries (high/low), brackish water areas coastal currents, vital coastal habitats etc. (Rao *et al*., 1998; Desai *et al*., 1991; Nayak *et al*., 1991, Bhat and Subramanya, 1993; Chen and Rau, 1998; Sreekala *et al*., 1998, De Solan *et al*., 2001) [5, 2, 3, 4].

2. Rational Of the Study

Mumbai is the vibrant and pulsating capital of Maharashtra. The city has the largest and busiest port, handling more than 46 percent of the total foreign tread of India. The coastal part of Mumbai is rapidly changing its colour of development so the nature of changes has to be addressed. Coastal regions face a grave risk from sea level rise: could flood land and cause damage to coastal infrastructure and other property. One estimate put the cost of climate change related damages for Mumbai, India's largest city at 2, 28, 700 crore rupees if no adaptation actions are taken to reduce vulnerability. Encroachment of coastal areas due to growth of population is another threat for this growing city and for this role of Maharashtra Coastal Zone Management Authority (MCZMA) in CRZ management is very much crucial. Vegetation of the coastal areas of Mumbai is degrading gradually due to anthropogenic pressure and if the sea level is raised in about 1 meter then it can be assessed that more than 13 lakh people who are depending upon this area will be at great risk, so the reason behind this depletion has to be observed.

3. Objectives of the Study

The main objective is to assess the coastal changes along the Mumbai – Thane coastal area. To fulfill this study the sub-objectives are as follows –

- to identify the sites of Erosion and Accretion along the coast
- to assess the land utilization of Mumbai – Thane coast
- to find out the major Vegetation types
- to demarcate CRZ boundary and identify the changes
- impact of Sea Level Change

4. Location of the Study Area

Mumbai, the capital of Maharastra is the financial, commercial as well as the capital of entertainment of India. It is the most populous metropolitan area in India, and the eighth most populous agglomeration in the world, with an estimated city population of 18.4 million and metropolitan area population of 20.7 million as of 2011. Earlier it was spread over seven islands of Colaba, Fort, Byculla, Parel, Worli, Matunga and Mahim. Successive reclamation has linked up the islands into a single larger landmass. The trapezoid shaped island city lies off the northern Konkan coast of Maharashtra which is set in the shimmering waters of Arabian Sea approximately between latitudes 18° 55'N and 19° 19'N and Longitude 72° 45'E and 73° 00'E (Tirkey *et al*.,2005) [11].

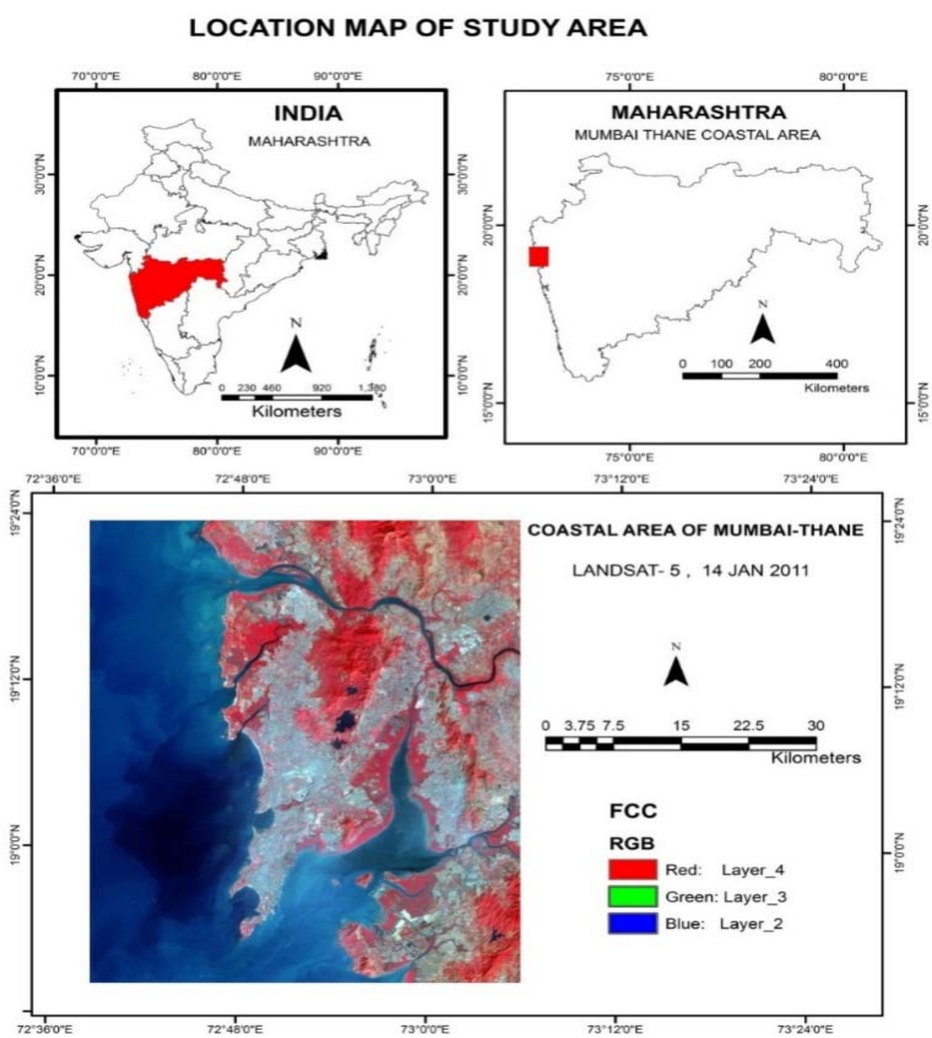


Fig 1: Location Map of the study area

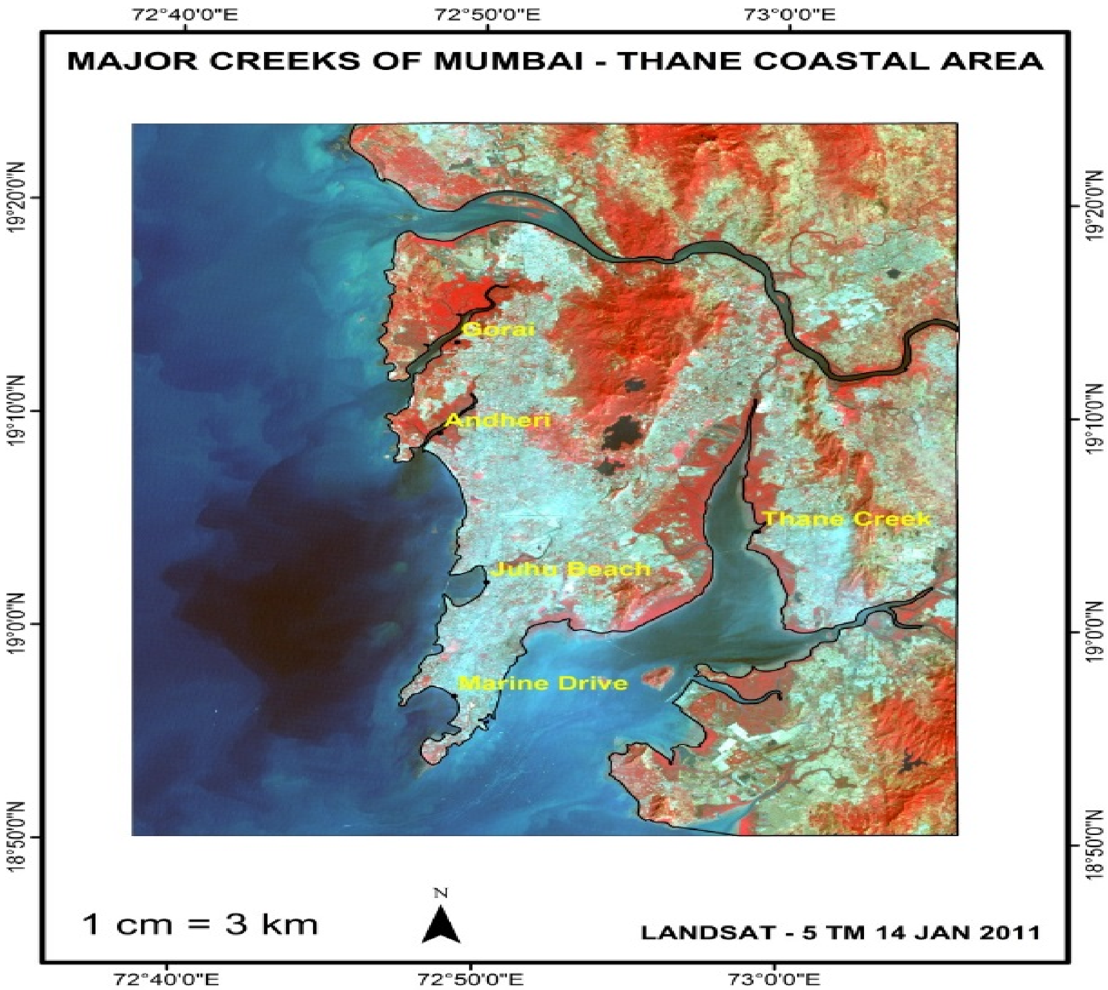


Fig 2: Major creeks of Mumbai- Thane Coastal Area

5. Data Used For the Study

Mumbai – Thane coast have been mapped using the images of Landsat-5 TM, Landsat-ETM. Cartosat DEM is used for Contour mapping. Satellite images of November-1998, April- 2003 and January-2011 are of Landsat-5 TM and November- 2008 belongs to Landsat -7 ETM (Path 148 and Row 47), which are acquired on nearly cloud free date. The Image taken was False Color Composite (FCC) having band combination of B2, B3 and B4 (Green, Red and Near Infrared). Infrared band is suitable for demarcation of shoreline as the contrast between land and water is very sharp.

6. Statement of the Problem

It is observed that the Mumbai – Thane coastal region having huge changes from past few decades. These changes are about erosion and accretion, change in mangrove vegetation cover, huge changes of land use and land cover. Land use/ land cover changes of Mumbai- Thane coastal area is the result of population explosion and it reveals that population pressure has caused drastic land use change and there has been reduction of forest, agricultural land while built up area increased during last few years. So it is very important to identify the reasons behind the changes in regional level and temporal variation also helps to identify the decadal change.

7. Methodology

To fulfill the objectives of the study progressive methodology has been prepared and explained in the form of flow chart. Software EREDAS IMAGINE 2014, Global Mapper 15.1 and ArcGIS 10.1.2 are used for analyzing the images. WGS 84 datum and UTM projection were used while mapping coastal land use. In the present study, image processing of satellite data has been carried out to prepare the maps of erosion accretion of the Mumbai- Thane coastal area, land classification, DEM generation, NDVI, Coastal Regulatory Zone (CRZ) with the help of above mentioned software's.

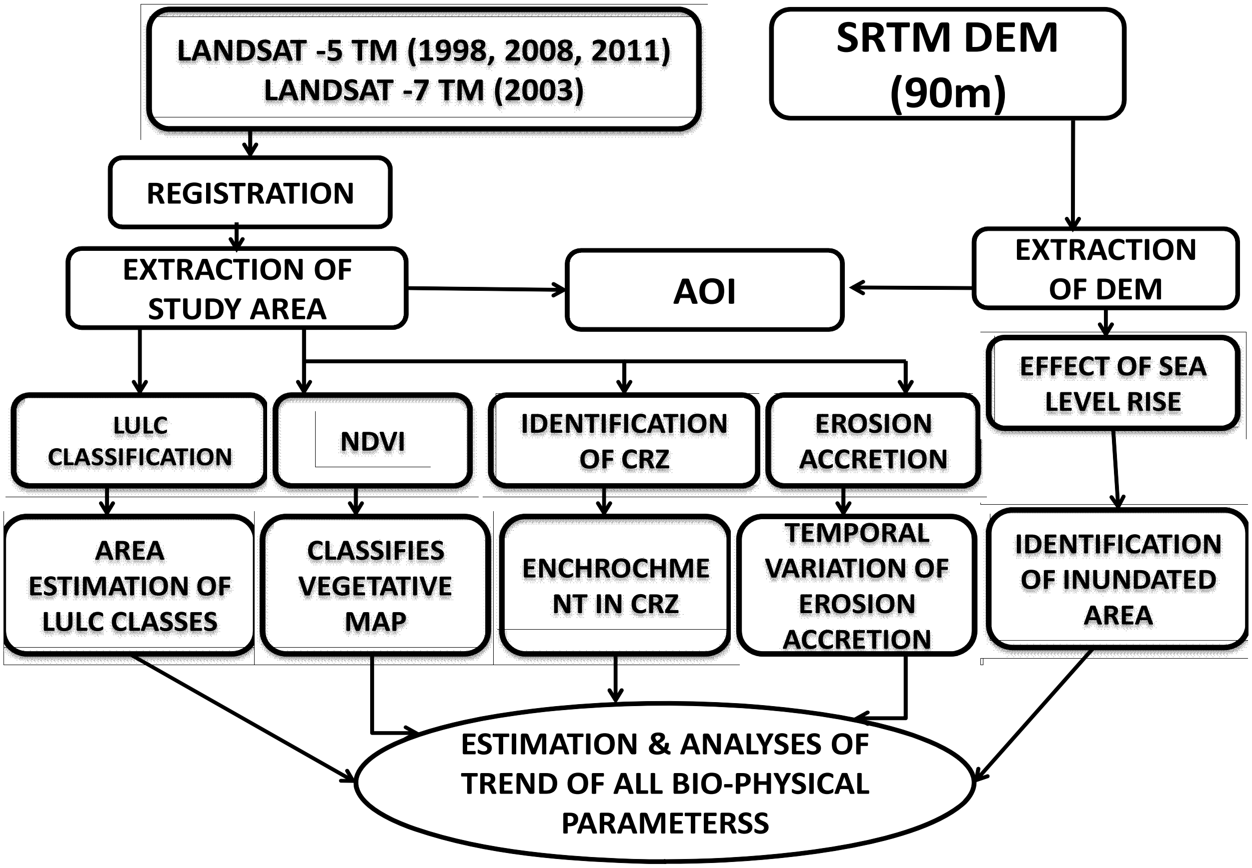
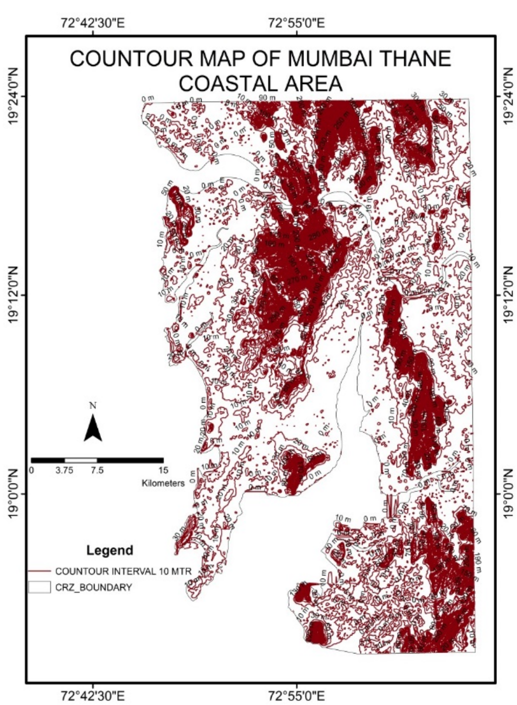


Fig 3: Flow chart of the methodology

8. Results and Discussion

The Digital elevation model of the study area has been prepared with the help of SRTM DEM (90m). 3Dimensional view of the study area and a contour map has been prepared which shows the elevation of the Mumbai- Thane coastal area from the Mean Sea Level.



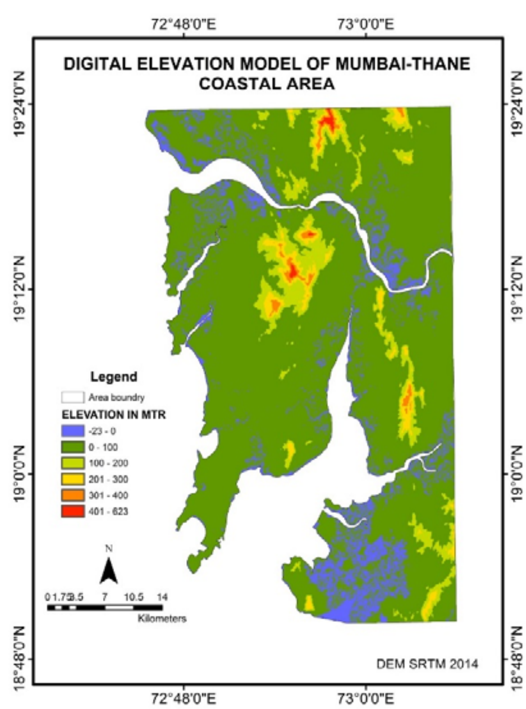


Fig 4 **Fig 5**

Digital Elevation Model and Contour Map of Mumbai- Thane Coastal Area

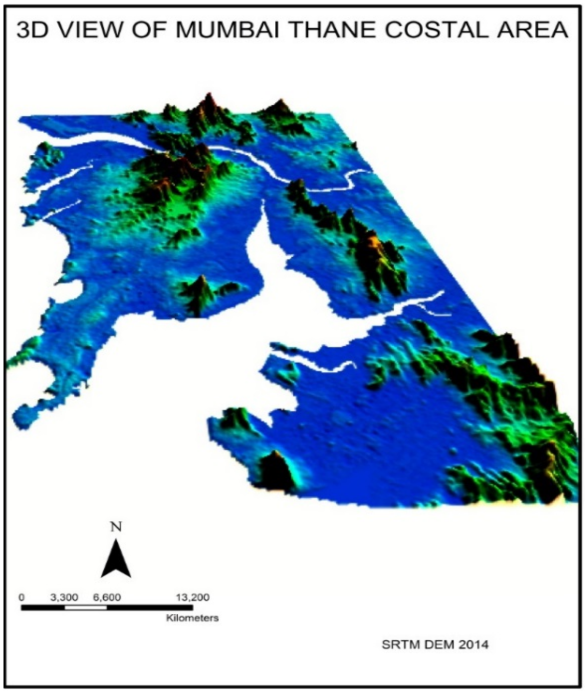


Fig 6: 3D view of Mumbai – Thane coastal area

8.1. Identifying the areas of Erosion and Accretion of Mumbai – Thane Coast

The study of coastal processes includes two major elements i.e. study of shoreline and coastal landforms. The accurate demarcation of shoreline is very important for the planning and conservation. To find out the erosional and depositional sites, we first classified the satellite images (1998, 2003, 2008, and 2011) into two layers (Land and Water) by using the tool supervised classification from the EREDAS IMAGINE interface. While classifying the image we set 8 different values for the classified layers in the signature editor file, so that we can use these values to find out the erosion deposition for each year by setting formulas in the Model Maker. After classifying each image separately we run the three models to find out the erosional and depositional areas, 2011-1998, 2008-1998, 2003-1998 resp. To concentrate on our area of interest i.e. coastal land cover we digitized a boundary of Mumbai coast using panchromatic band and set buffer of 1Km and extracted same area from the satellite image. We got three results after classifying the images which are as follows.

- **2011 Landsat TM -1998 Landsat TM**

In this time period deposition is observed at many places all along the Mumbai shoreline, erosion was observed only a few places that are comparatively insignificant as compared to deposition.

Prominent mudflats are observed along the Thane creek which is covered by dense mangroves and less erosion is seen. Same depositional sites are seen along Marine Drive, Juhu, Andheri, Gorai and Vasai coast. Erosional activity is less prominent in this coast.

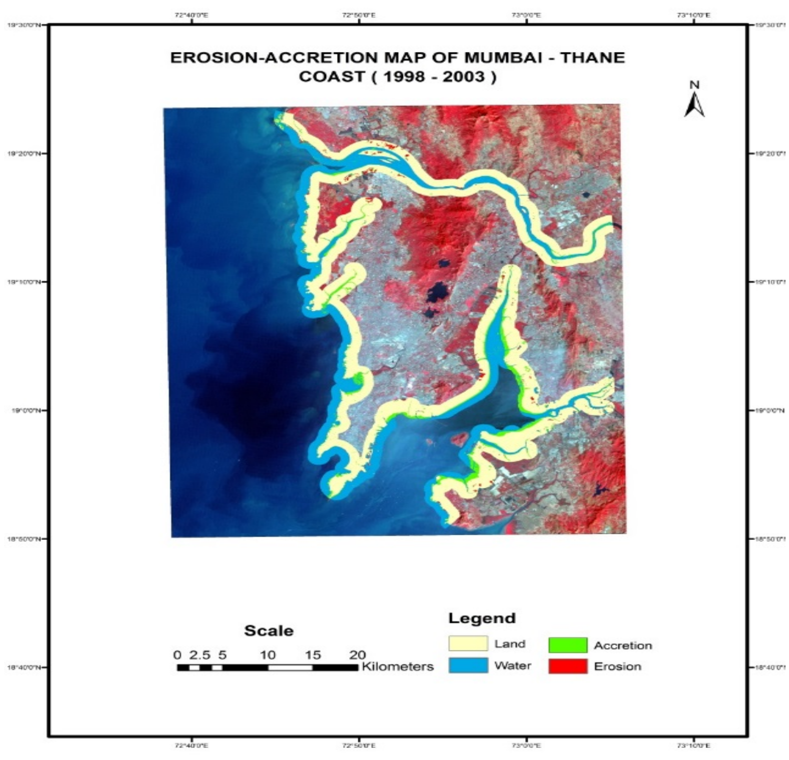
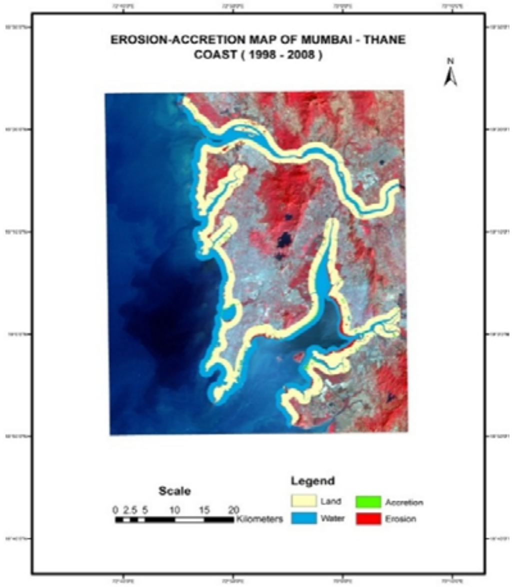


Fig 7: Erosion- accretion map of Mumbai – Thane coast for the year 1998- 2003

- **2008 Landsat TM -1998 Landsat TM**

In this time period deposition erosional activity is more prominent than the depositional activity. Thane creek is likely dominated by erosional activity. Some area shows deposited mudflats. Whereas at Andheri and Gorai creek both activities has been observed simultaneously.



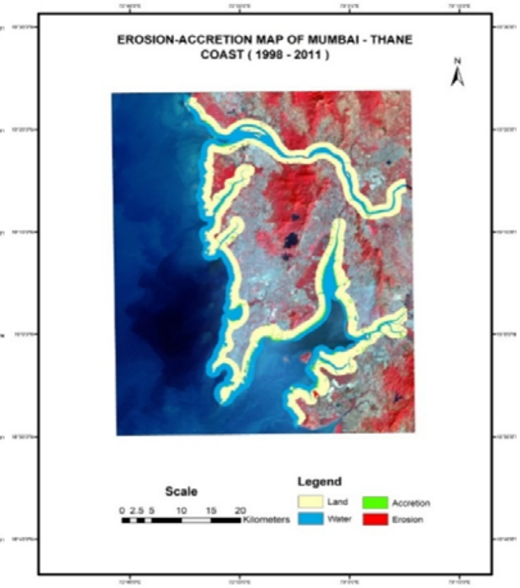


Fig 8 **Fig 9**

Erosion- accretion map of Mumbai – Thane coast for the year 1998 - 2003 and 1998 – 2011

- **2003 Landsat TM -1998 Landsat TM**

In this time period Depositional activity is more prominent all over the Mumbai coast line. Thane creek and Andheri shows mudflats surrounded by mangroves.

- **Analysis**

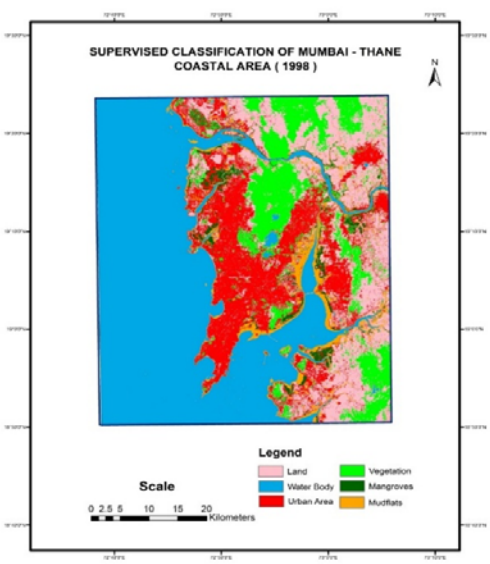
Observation of past 12 years data shows, depositional activity is more prominent near Mumbai thane coast than the erosional activity. These Deposits are found more near the creeks.

Table 1: Estimation of Erosion and Accretion from 1998 to 2011

YEAR	1998 - 2003	1998 - 2008	1998 - 2011
Erosion(Km^2)	5.3998	1.6020	0.3095
Deposition(Km^2)	26.3684	0.8425	1.4420

8.2. Assess the land utilization of Mumbai – Thane coast by Supervised Classification:

From the study of satellite image various geomorphic units has be identified; urban, mudflats, mangroves, water body etc. Among these the most sensitive geomorphic units along the coast are observed to be the coastal mudflats and mangroves that occur between high tide line and low tide line. These mudflats and mangroves are affected mostly by anthropogenic conversion and pollution. As all the images were taken from various season so the comparison between various classes could not be generated to identify the dynamics of change in land use and land cover in the study area. The comparison has been done by GIS methods in ArcGIS.



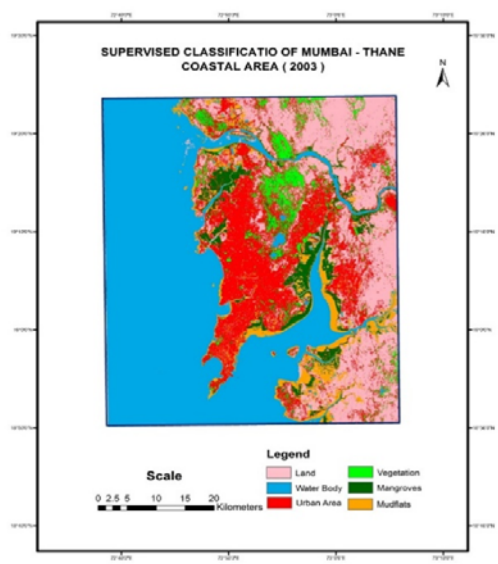


Fig 10 **Fig 11**

Supervised Classification of Mumbai – Thane Coastal Area of 1998 and 2003

- **Supervised Classification of Landsat-5 TM -1998**

From 1998 image, supervised classification has been attempted and six major classes have been classified. According to this map 16.98 percent of area is comes under vegetation cover, 11.35 Percent of area is falls under mangrove along with 12.94 Percent of mudflats. The urban covers 21.54 Percent of the total area and the remaining portion shows the fallow land.

- **Supervised Classification of Landsat-7 TM -2003**

In the classified image of 2003 the mangrove and other vegetation covers 9.14 percent and 12.70 percent respectively. Urban settlement (28.12.percent) area has been increased from the previous years and the mudflats (12.70 percent) areas are decreased.

- **Supervised Classification of Landsat-5 TM -2008 and 2011**

The urban area (26.84 Percent) has been enlarged from its former shape and the mudflats (6.68 Percent) become narrower in 2008 image. From 2011 image, it is clear that anthropogenic activities are stronger than natural rules. Increasing population, developmental activities are the main driving force behind the depletion of natural resources. The urban boundaries (28.14 percent) have also been increased after destroying mangroves (6.61 percent) and gradually overshadowed the coastal regulatory zones.

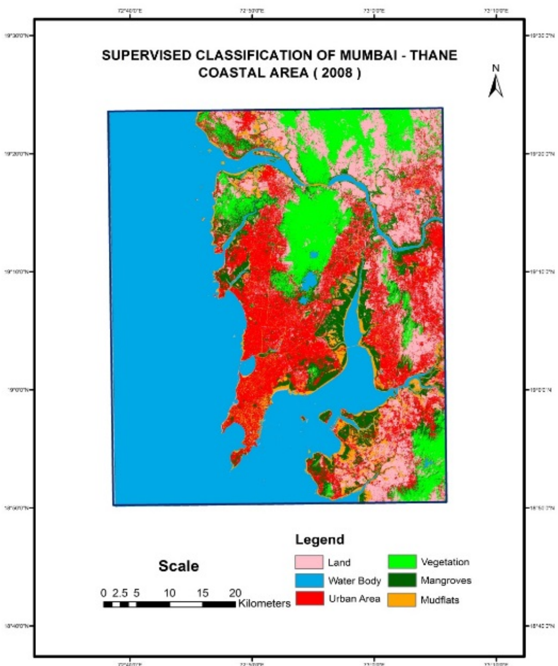


Fig 12

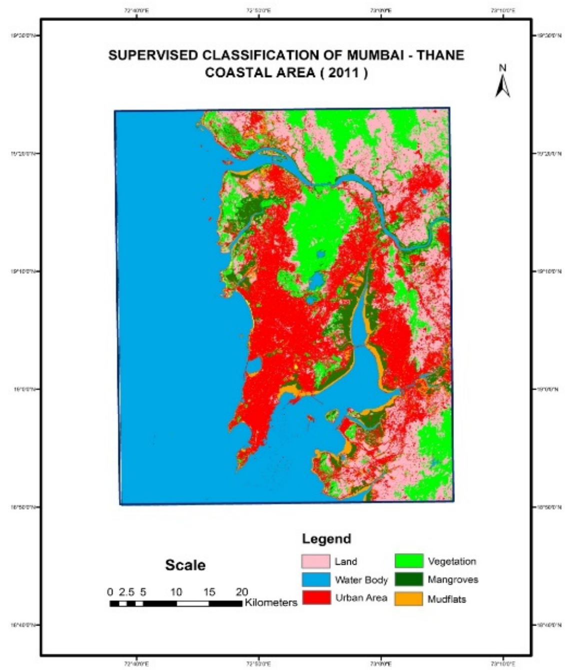


Fig 13

Supervised Classification of Mumbai – Thane Coastal Area of 2008 and 2011

- **Analysis**

From 1998 to 2011 the trend and pattern of land use/ land cover changes shows the overall increase of anthropogenic activities. The proportion of change in land use classes do indicate where development pressure has occurred over recent decades and they demonstrate an increase in built – up areas to the detriment of dense vegetation. In 1998, there were many land parcels covering the category of forest, vacant land, mudflats, but not yet many residential areas. Built up areas arose from areas of dense vegetation. Dense vegetation is now found only in a few preserved areas in the immediate coastal boundary. Sparse vegetation remained almost unchanged from 1998 to 2011. Water bodies reduced from 1998 to 2011.

Table 2: Statistical profile of Supervised Classification

Year	Overall classification Accuracy	Overall Kappa Accuracy
1998	79.06%	0.709
2003	78.41%	0.734
2008	82.07%	0.729
2011	76.67	0.690

Table 3: Area assessment from Supervised Classification

	YEARS							
LANDUSE (Area in sq. Km)	1998	Area in %	2003	Area in %	2008	% of area	2011	Area in %
Mudflats	229.95	12.94	177.18	12.70	127.57	6.68	126.17	6.61
Mangroves	201.74	11.35	127.45	9.14	204.56	10.72	223.00	11.70
Vegetation	301.83	16.98	129.44	9.28	264.96	13.88	237.12	12.43
Land	527.91	29.71	437.31	31.36	664.59	34.83	651.04	34.14
Urban	382.80	21.54	392.20	28.12	512.24	26.84	536.70	28.14
Water	132.57	7.46	130.71	9.37	134.05	7.02	132.665	6.95

Visually comparing the classified images, we can see that the urban growth is advancing upon areas of high landscape value, such as the Juhu beach, Marin Drive and Thane creek area. The coastal area has been impacted by the urban growth in recent years in the region, due to a combination of its proximity of the Arabian Sea which has led to extensive property speculation. The main driving force to change in land use/ land cover is the urbanization process. The urban expansion has been triggering the removal of natural vegetation and the occupation of ecologically protected areas, especially along the coastal boundary. Increasing trend of built up area from 1998 to 2011is very much clear by the temporal variation. Changes are determined by the area estimation.

8.3. Assessment of Major Vegetation types by Normalized differential Vegetation Index (NDVI)

Forest ecosystems are an essential economic and environmental resource which is widely spread in most regions of the world. Unfortunately, both in developed and developing countries, many forests are presently threatened by the expansion of agricultural, urban and industrial land or by degradation phenomena caused indirectly by human activities (Waring and Running, 1998) [12]. Traditionally, vegetation monitoring by remotely sensed data has been carried out using vegetation indices, which are mathematical transformations designed to access the spectral contribution of green plants to multispectral observations. Normalized differential Vegetation Index are mainly derived from reflectance data from discrete red (R) and near- infrared (NIR) bands. They operate by contrasting intense chlorophyll pigment absorption in the red against the high reflectance of leaf mesophyll in the near infrared. Such is the case of the well- known normalized difference vegetation index NDVI= (NIR-R) / (NIR+R) (Bannari *et al*., 1995) [1].

The current study aimed primarily to assess the mangrove vegetation of the coastal area of Mumbai – Thane based on remote sensing. The temporal variation of the vegetation and its classification has been done according to the crown density. For the study LANDSAT-5 and 7 images has been selected at the interval of five years. The images of consecutive four years has been acquired in various season so the NDVI values of the same location depicted differently.

- **NDVI of Landsat-5 TM -1998**

From this satellite it is been cleared that the inland areas are densely vegetated than that of the coastal areas. In coastal areas, the NDVI values ranges from 0.15 to 0.36 (moderately dense vegetation) but in the interior part of the land it ranges from 0.37 to 0.73 (dense vegetation).

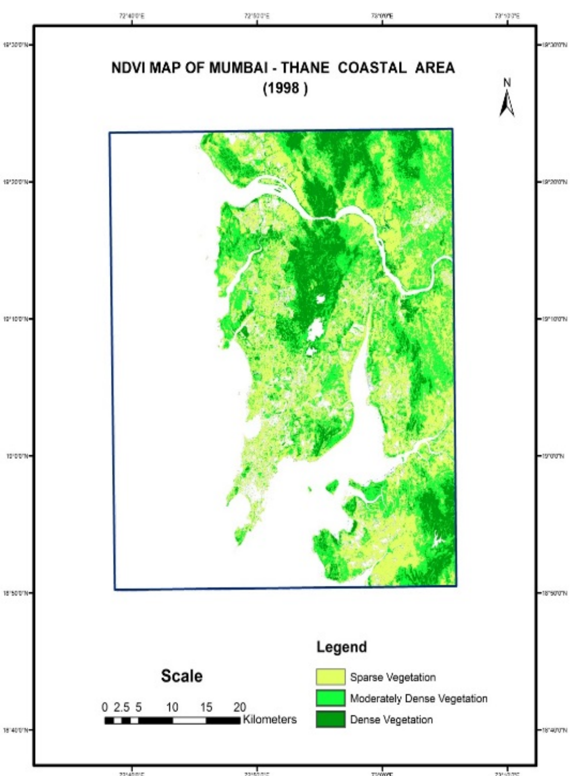


Fig 14

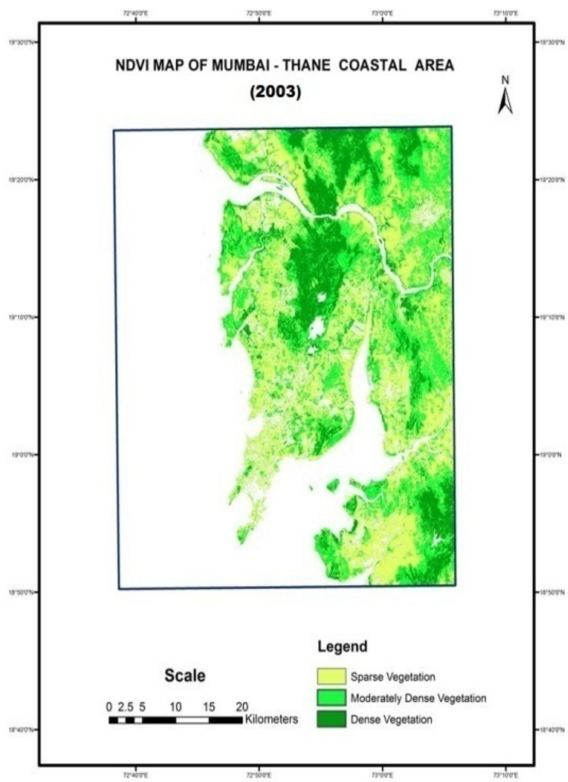
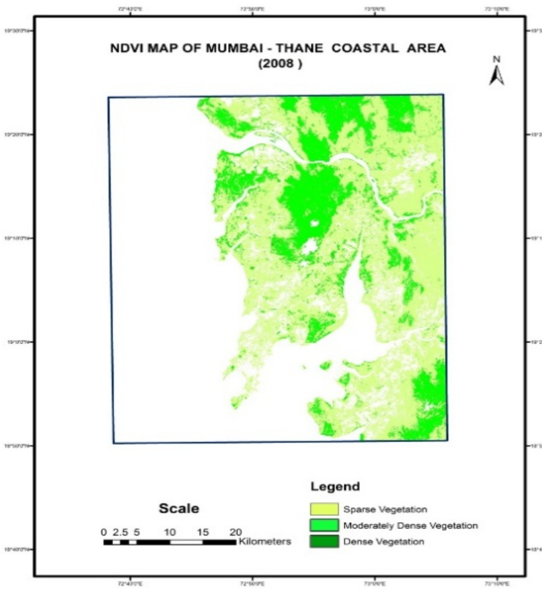


Fig 15

NDVI Map of Mumbai- Thane Coastal area 1998 and 2003

- **NDVI of Landsat-7 TM -2003**

In 2003 image, the concentration of dense vegetation (0.10 to 0.38) is found near the sea facing creek areas of Thane, Gorai, Andheri and Vasai. Moderately Dense vegetation (0.24 to 0.10) is found in the inland part of this area. Sparse vegetation (0.41 to 0.23) is spread here and there. Due to the seasonal variation the crown density of the vegetation is varies from 10 percent to 40 percent in this image.



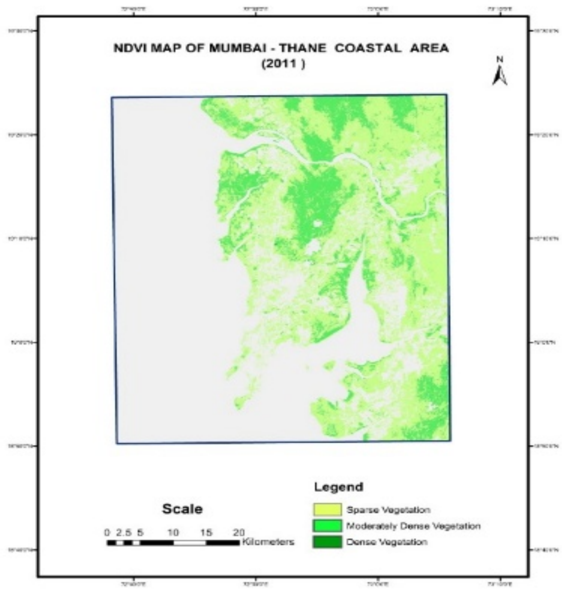


Fig 16 **Fig 17**

NDVI Map of Mumbai- Thane Coastal area 2008 and 2011

- **NDVI of Landsat-5 TM -2008**

The vegetation index of this image depicts that the lion portion of the area comes under the category of moderately dense vegetation (0.068 to 0.23), the inland uplands and the coastal parts are covered by dense flora (0.24 to 0.59) and rest of the area is comes under the coverage of sparse vegetation (0.0019 to 0.067).

- **NDVI of Landsat-5 TM -2011**

The NDVI of this coastal area displays the classification of natural vegetation according to crown density. Here the dense vegetation (0.22 to 0.56) is again covers the inland part of the study area as well as the coastal creeks of Thane Andheri, Gorai and Vasai. Moderately dense (0.06 to 0.21) and rest of the area is sparsely vegetated (0.0017 to 0.05). Table no: 3 shows the area estimation of classified vegetation.

Table no. 4: Area under different types of vegetation

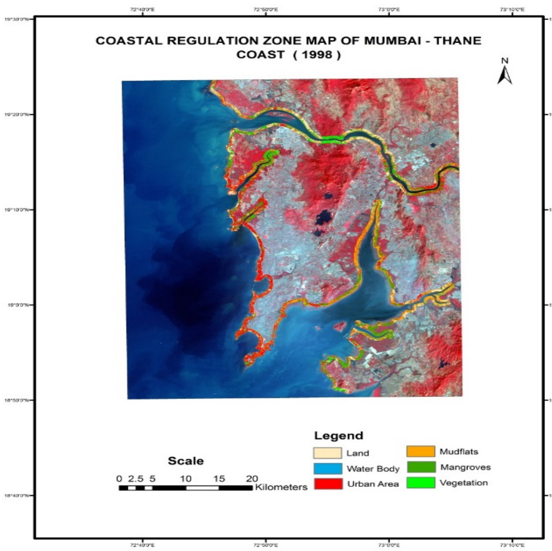
	YEARS			
Vegetation Classes (Area in sq. Km)	**1998**	**2003**	**2008**	**2011**
Sparse Vegetation	651.28	711.83	494.04	841.90
Moderately Dense Vegetation	517.67	367.92	365.56	333.80
Dense Vegetation	265.42	287.06	216.30	246.12

The spectral indices parameters indicated that lush green vegetation with high green leaf density represent healthy vegetation (high NDVI), while mature forest under environmental stress show an unhealthy situation (low NDVI). The NDVI values are the main indicator of the temporal vegetation of the study area.

8.4. Demarcation of CRZ boundary and identify the changes due to encroachment

The coastal zone of the country contains sensitive ecosystems such as mangrove forests, breeding grounds of several endangered marine and estuarine species. The densely populated low lying coastal areas susceptible to sea level rise. Increased developmental activities due to urbanization lead to encroachment of coastal areas and reclamation of tidal flats, backwaters and estuaries and causing pollution and severe damages to coastal eco systems. Landscaping and unplanned construction drastically change the morphology of the coastal areas. In addition to all these, there are always the threats to land and property loss due to coastal erosion and coastal flooding. These damages could be controlled to a certain extent by regulating high impact activities in the coastal zone. It was with this objective the Coastal Regulation Zone (CRZ) Notification was introduced in the country. The CRZ provides a spatial planning framework for Coastal Zone Management. It effectively controls pollution of the coastal and near shore systems from land based activities. For this, a spatial planning framework has been prepared which provides setbacks around sensitive zones restricting development and other activities close to it. The High Tide line (HTL) forms the cardinal reference line for determining the setbacks for CRZ. The Low Tide Line (LTL) forms the seaward setback while 200m and 500m CRZ lines are the landward setback lines in the context of CRZ. A new setback line called hazard line, has been introduced in addition to the HTL and LTL in 2010 CRZ notification (Thomas, K. V., 2010). The Coastal Regulation Zone (CRZ) was declared in 1991. It aimed at preventing new industries being established in the coastal region. The authorities were to guard against encroachment of the area within the CRZ. Seas, bays, estuaries, creeks, rivers and backwaters influenced by tidal action within 500 meters high tide line come under CRZ (The Hindu, 27th February,2008).

The mixing of freshwater from rivers and saline water from the sea creates a different marine ecosystem in the CRZs of Mumbai – Thane coastal region. This system gives rise to mangrove forests. Mangrove forests are nature's best protection against harsh tidal effects of the sea, especially tsunami. The Maharastra Coastal Zone Management Authority (MCZMA) looks after all the activities regarding CRZ of its coastal areas.



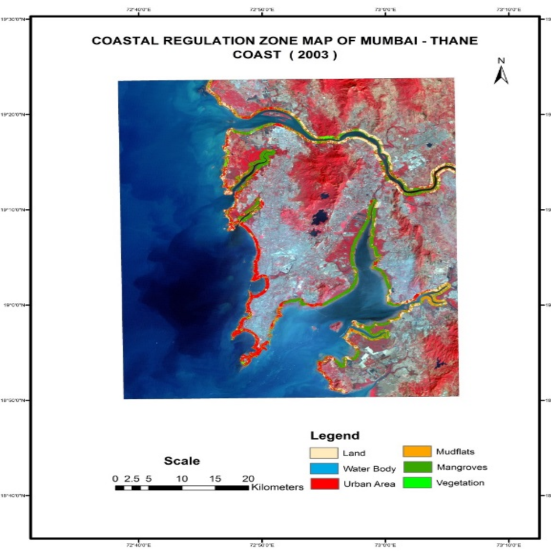
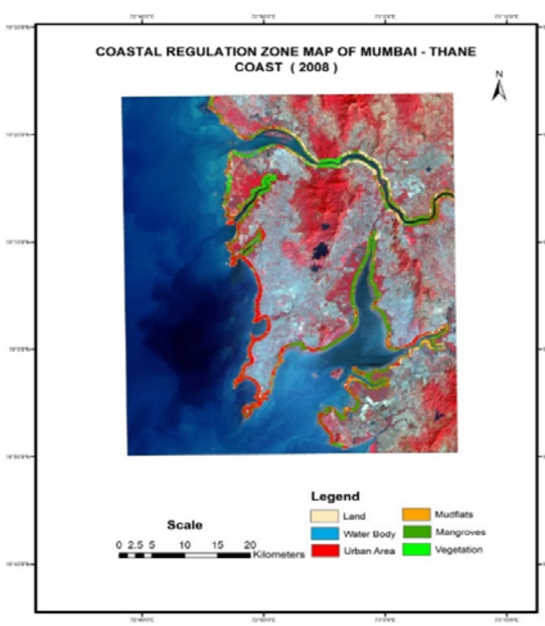


Fig 18 **Fig 19**

Coastal Regulation Zone map of Mumbai – Thane coast of 1998 and 2003

To analyze the encroachment of coastal areas, temporal data (i.e. 1998, 2003, 2008, 2011 satellite images) has been taken into consideration. CRZ map has been prepared out of these images showing 500 meter and 1 km buffer zones along the Mumbai – Thane Coastal area. From 1998 image it can be understood that in the Thane creek area, the mudflats are predominant. Healthy mangroves are sparsely distributed over the mudflats along the shoreline. Due to anthropogenic activity the mangroves are being destroyed and urban settlement, industries and other activities are flourished here. In Marin Drive area, the mudflats have been converted into landscaped areas where modern urban amenities glorify. Minimum amount of healthy mangroves are scattered here and there. In Juhu area, the urban settlement plays an important role rather than mudflats and mangroves. Here the actual CRZ area has been converted into high density populated zone. Urban settlement encroached the mudflats and destroyed the mangroves of Andheri creek. Gorai and Vasai creek area also experienced same kind of activities. Here the sea facing creek areas has been converted into populated zones and some amount of healthy green mangroves were found in the inland creeks.

In the 2003 image the Juhu, Marin Drive and some parts of Thane creek is completely converted into urban settlement areas from existing mudflats and mangroves. But in Gorai and Vasai creeks are dominated by Mangroves. Internal part of these creek are portraying differently by having the land and urban settlement association along with dense vegetation.



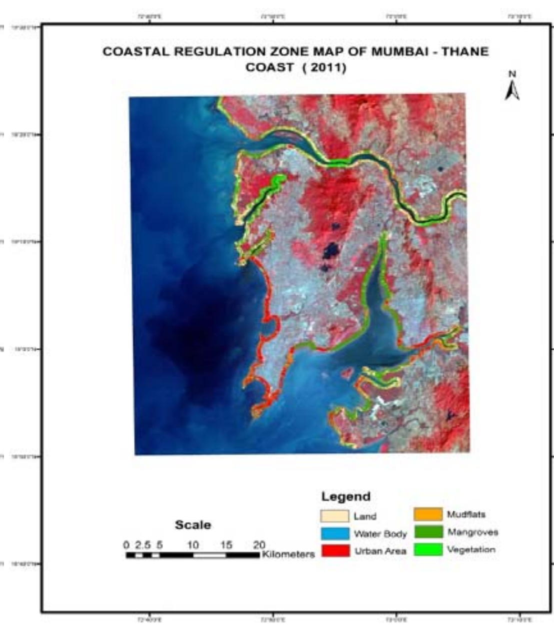


Fig 20 **Fig 21**

Coastal Regulation Zone map of Mumbai – Thane coast of 2003 and 2011

From 2008 CRZ map it is easily understandable that the concentration of urban population is in increasing trend in Juhu, Andheri, Marin Drive area. In the northern part the vegetation is depleting due to developmental activities throughout the Vasai creek. In the southern part of Thane creek all the CRZ area has been converted into arable land progressively.

From supervised classification of the image 2011 one can easily understand that urban areas are sprawling and the pressure on land is increasing due to population growth of Mumbai – Thane coastal area because the area have the promising developmental goal. So the CRZ areas are also affected by the showers of various developmental activities. The mangroves are being cutting down and the newly generated lands are in the use of various industrial works. The coastal areas are getting modern landscape and the natural resources are in the threat of human interference.

9. Conclusion

In the concluding note the analysis and the result parts should be discussed in nutshell. The objectives of the study have been fulfilled and results are depicting the same hypothesis. The coastal area of Mumbai- Thane is very vulnerable in nature. All the developmental activities are carried out there without following any norms. The anthropogenic activity plays an important role for the changing scenario of Thane, Juhu, Andheri creeks. Government should take measures to stop all the ill- legal construction on the vicinity of the CRZ as well as for the protection of natural vegetation which are being depleted rapidly.

10. Acknowledgement

At this moment of acknowledgement, we want to mention the name of that person who not only has shared his profound knowledge on the subject and wisdom with us but also shown how to explore the intricacies of a problem with ease and discipline, he is our guide Dr. Debashis Mitra Scientist/ Engineer SF and Head, MASD, IIRS. We are thankful to Dr. Puja Jindal, Dr. Suresh Kumar, Course coordinator, Dr. S.P.S Kushwaha, Group Director ER & SS Group and Dean (Academics) IIRS and Dr. A.K. Senthil, Director IIRS for their valuable advices and support. We pay homage to the Indian Institute of Remote Sensing (IIRS), Dehradun for providing us the necessary infrastructure and resources during our project work as because this article is an outcome of NNRMS Course effort. Our Laboratory friends Rajkumar, Sujeet, Panini, Atreya have helped us a lot on programming part and in handling a complicated data set with intelligence.

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