

Coastal Land Use/Land Cover and Shoreline Studies for Dakshina Kannada Coast, Karnataka, India

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Abstract Coastal zone is highly dynamic in nature and undergoes rapid change. It plays an important role in the livelihood of 55 million people along Indian coast. The critical issue faced by the coastline includes coastal erosion, Sea Level Rise (SLR), urbanization, industrialization, and resource management. 23% of Indian coastline is facing coastal erosion and this problem is relatively severe in Dakshina Kannada, making it a critical stretch. As per NOAA report prediction, global SLR is of the order of 0.5–2 m over the next century which ultimately cause extensive loss of low lying coastal areas. The present study is carried out with a view to identify the coastal vulnerability sites along 40 km stretch of Mangalore coast, starting from Talapady in South to Mulky in North. Both conventional and remotely sensed data, coupled with field data were employed to identify critical erosion zones, over a period of 16 years. ERDAS Imagine (2014) software was used to analyze the satellite data to prepare Land Use/Land Cover map. This can be employed in identifying area of land submergence, in case of coastal inundation and to develop ICZMP for Mangalore Coast.

Introduction

Coastal zone plays an important role in the economic, social, and cultural sectors of all the countries. They are vital components of the local ecosystems and are generally densely populated. About 23% of the world's populations are estimated to live within 100 m of sea level and 100 km from a coast (Nicholls and Small 2002).

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However, shorelines are highly dynamic in nature, which depend on a number of intricately linked complex processes like tectonic movements and climatic changes which are difficult to predict accurately. Impulsive change in shoreline and submergence of low lying areas due to sea level rise are the solemn issues that have to be addressed. Indian coastline of about 7516 km is under threat due to global warming and related human interventions. Remote sensing data products provide synoptic and repetitive view of the earth in various spatial, spectral, temporal and radiometric resolutions. Hence, it can be used in monitoring coastal areas on a temporal scale.

Remote sensing provides a platform for rapid delineation of the coastlines at relatively low cost. A detailed quantification of shoreline change can be obtained through repeated observations over the time. The earliest coastline can be obtained from maps dating back to the late 1800s. The long-term shoreline changes can be developed using topographic maps. Aerial photographs for developing shoreline change were popularized since 1920s (Anders and Byrnes 1991). The Geographic Information System (GIS) has been adopted worldwide to elude reliable shoreline change over the years. The digitized shorelines can be used as an input to Digital Shoreline Analysis System (DSAS), an extension to ArcGIS, for calculating shoreline change rate. DSAS computes rate of change statistics from multiple historic shoreline positions residing in a GIS. Karnataka coast has one major port and ten minor ports and is one of the most indented areas with a number of river mouths, bays, spits, sand dunes, lagoons, creeks, cliffs, and long beaches. This clearly unveils the problems associated with this coast. A numerous researchers have studied this coast either as a complete stretch or by considering a particular river mouth. Dakshina Kannada coast has two crucial river mouths namely Netravathi–Gurpur river mouth (with breakwater) and Mulky–Pavanje river mouth (without breakwater), which makes the stretch ideal for studying the effect of breakwater on coastal erosion. The studies on long- and short-term shoreline changes along Mangalore coast shows the impact of construction of seawalls in shifting erosion from one place to another and of breakwaters acting as barriers for littoral drift (Raghavan et al. 2001; Kumar and Jayappa 2009; Gumageri and Dwarakish 2011; Kankara et al. 2014; Hegde and Akshaya 2015).

Knowledge of the distribution of land use and land cover is essential for planning and management activities (Chauhan and Nayak 2005). The global environment change can reflect in LU/LC changes. SLR can occur as a result of storms, tsunami or global sea level change due to global warming. Inundation of coastal low lying areas is a direct outcome of sea level rise. This could lead to great economic and habitat losses, as both human constructions and wildlife habitats would be submerged. Hence, it is primary to quantify the perils associated with the SLR to guide decision maker in future coastal infrastructure development. Land Use/Land Cover (LU/LC) of the coastal area and its dynamics have to be

considered in prior to contemplating the Sea Level Rise (SLR) owing to inundation losses. Murali (2014), Murali and Kumar (2015) have examined the implications of SLR on LU/LC classes of coastal zones of Orissa and Cochin respectively. Effect had been studied on the major LU/LC classes like Agriculture, Built-up, Water body, etc., by preparing inundation maps. They are useful in assessing the extent of SLR and potential impact on inundation. LU/LC map generated with conventional maximum likelihood classifier is merged with Digital Elevation Model for quantifying inundation. They considered the SLR of 1 and 2 m to calculate the habitat loss. Dwarakish et al. (2009) had done an extensive study along the Udupi coast of Karnataka, by calculating Coastal Vulnerability Index (CVI) along the coast and by preparing LU/LC map and inundation map of the study area.

This study is focused on understanding the shoreline changes of Dakshina Kannada coast over the years 1997–2013. Also, LU/LC classification has been done through various methods.

Study Area

For this study, a 40 km coastal stretch of Dakshina Kannada Coast starting from Thalapady in South to Mulki-Pavanje river mouth in North is considered. It lies between $12^{\circ} 45' 50''$ and $13^{\circ} 05' 00''$ North Latitude and $74^{\circ} 46' 30''$ and $74^{\circ} 52' 48''$ East Longitude. The length of the coastline is about 40 km and is oriented about the NNW–SSE direction. This stretch is characterized by the presence of two estuaries formed by Nethravathi and Gurupur rivers on southern side and Mulki and Pavanje rivers on Northern side. The New Mangalore Port is located along this coast with two breakwaters in the harbor. The establishment of this port has lead to rapid urbanization and industrialization along this coast. Fisheries, tourism and agriculture form other main economic activities of this coast. This implies the importance of studying coastal characteristics of this coast. The study area is depicted in Fig. 1.

Data Used

The data used in this study with their specific purposes are listed in Table 1.

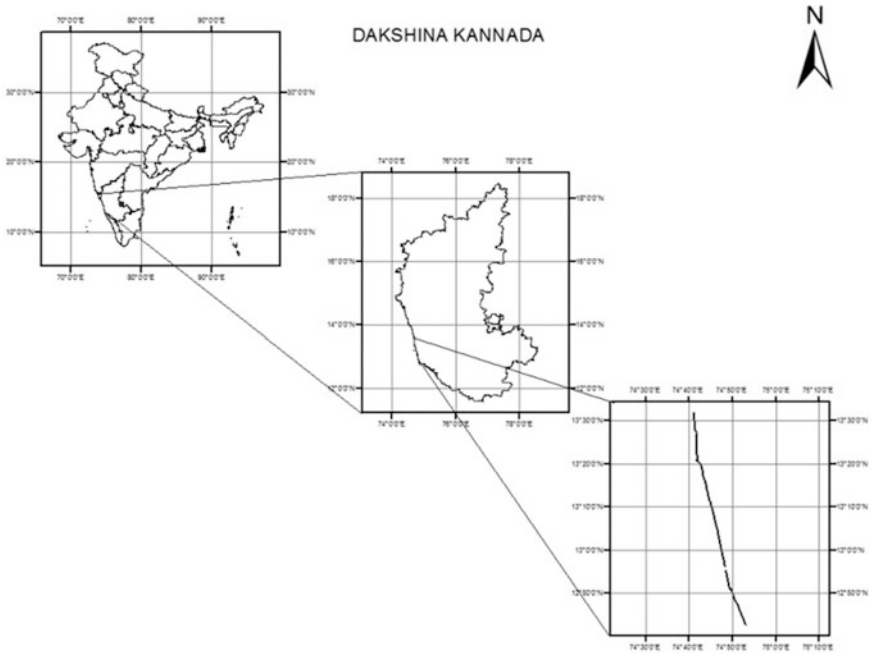


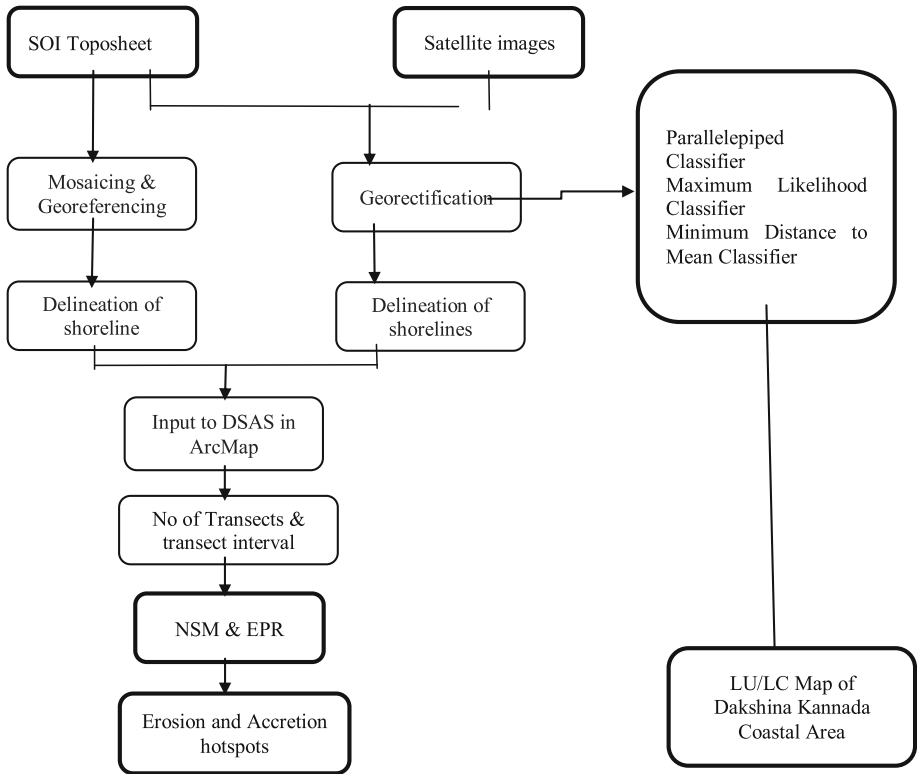
Fig. 1 Location Map of the Study Area

Table 1 Details of data used for the study

S. No.	Type of data	Source	Year	Purpose
1	Toposheet (1:50,000)	Survey of India (SOI)	1987	To prepare base map
2	IRS—1D LISS III (23.5 m resolution)	NRSC	1997	Shoreline extraction
3	IRS—1D LISS III (23.5 m resolution)	NRSC	2001	Shoreline extraction
4	IRS—1D LISS III (23.5 m resolution)	NRSC	2005	Shoreline extraction
5	IRS—P6 LISS III (23.5 m resolution)	NRSC	2013	Shoreline extraction and to prepare LU/LC map

Methodology

General Methodology



- DSAS Digital Shoreline Analysis System
- NSM Net Shoreline Movement
- EPR End Point Rate

Shoreline Configuration

The mapping of shorelines was done using Arc GIS software. Initially the digital satellite images were geo-referenced to geographic coordinate system and then projected to UTM. Locating and delineating water bodies with remote sensing data are done most easily in Near Infra Red (NIR) wavelengths (0.7–1 μm), because of

its absorption property (Lillesand and Kiefer 1994). Therefore, NIR band was considered for shoreline mapping. For the periods 1997–2013, High Tide Line (HTL) was used to represent shoreline. The tidal range and the distance between HTL and LTL (Low Tide Line) being low for Mangalore coast, the error of mapping HTL to represent shoreline for a LISS III image will be negligible. For the digitized shoreline, the rate of change analysis was carried out using Digital Shoreline Analysis System (DSAS) developed by United States Geological Survey. For this, after creating baselines, transects were developed at an interval of 50 m. For the interpretation of shoreline changes, Linear Regression Rate Method (LRR) and End Point Rate Method (EPR) were used. LRR was determined by fitting a least squares regression line to all the comparable shore points of different periods for a particular transect. EPR indicates basically the horizontal displacement rate of shoreline. This was calculated by dividing the distance of horizontal shoreline movement by the time elapsed between the earliest and latest measurements. The positive LRR and EPR represent the rate of accretion and a negative value for the rate of erosion.

LU/LC Mapping

The satellite image data for year 2013 had been used for developing land use/land cover maps of the area. After images were geo-referenced and geometrically rectified, Image classification and interpretation was performed using ERDAS Imagine 2014. For the classification with level I, seven LU/LC classes, i.e., barren land, built-up land, sandy area, forest land, sea water, river water and other vegetations were classified. For supervised classification, total of 210 training sites were made by demarcating a polygon or an area of interest for all the seven land use and land cover types. Many different strategies can be used to classify land use or land cover categories in remotely sensed images. The study used three different methods namely, the Maximum Likelihood algorithm, Minimum Distance to Mean algorithm, and Parallelepiped algorithm for classification. Maximum Likelihood Classification (MLC) represents the most established approach, which assumes a normal gaussian data distribution of multivariate data with pixels allocated to the most likely output class, or a posterior probability of membership and dimensions equal to the number of bands in the original image (Richards and Jia 2006).

This method takes advantage of the probability of a pixel being a member of an information class in its decision making. The decision rule in the minimum distance to mean algorithm is based on the relativity among the spectral distances between the pixel in question and the center (mean) of all information classes that have been derived from the training samples. The parallelepiped algorithm assigns a pixel into one of the predefined information classes in terms of its value in relation to the DN range of each class in the same band. After supervised classification, accuracy assessment was carried out. It is the most important aspect to assess the reliability of map. No image classification is said to be complete unless its accuracy has been

assessed. To determine the accuracy of the classification, a random sample of 50 pixels for each method is selected on the classified image and their class identity is compared with the ground reference data. Based on the results of accuracy assessment, best classification algorithm was identified and its results were utilized for the process of identifying sea level inundation.

Results and Discussion

Analysis of Shoreline Change

The Dakshina Kannada coast has undergone various changes in the last decade. The shoreline obtained for the various years are represented in the Fig. 4. From the analysis, EPR and LRR are obtained for the period of 2001–2013. The variation of EPR and LRR for each transects length along the shoreline is displayed in Figs. 2 and 3. The range of EPR and LRR for the coast obtained is shown in Table 2. These parameters can be considered to define the coastal management zones in future.

The entire beach shows both accretion and erosion along the coast. The open beach shows erosion during 1997–2001 and an accretion during 2001–2005 and further erosion in the period 2005–2013. Near the Nethravathi–Gurupur river

Fig. 2 LRR variation of shoreline change for 1997–2013

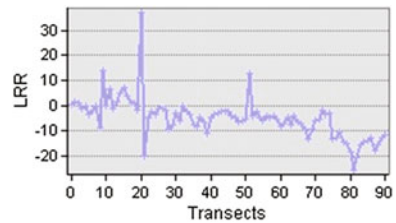


Fig. 3 EPR variation of shoreline change for 1997–2013

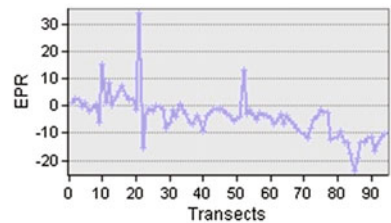


Table 2 LRR and EPR rates during the period 1997–2013

	LRR (m/year)	EPR (m/year)
Maximum	32.23	30.92
Average	-4.93	-3.79
Minimum	-25.63	-23.68

mouth, Bengre spit shows an accretion while Ullal has undergone erosion during the period. Similarly, Mulki spit showed an accretion during the period 1997–2013. On the other hand, Pavanje spit had been under erosion during this period. Slight deposition characteristics have been seen near the New Mangalore Port Breakwaters during this period (Fig. 4).

SHORELINE CHANGE DETECTION MAPPING 1997-2013

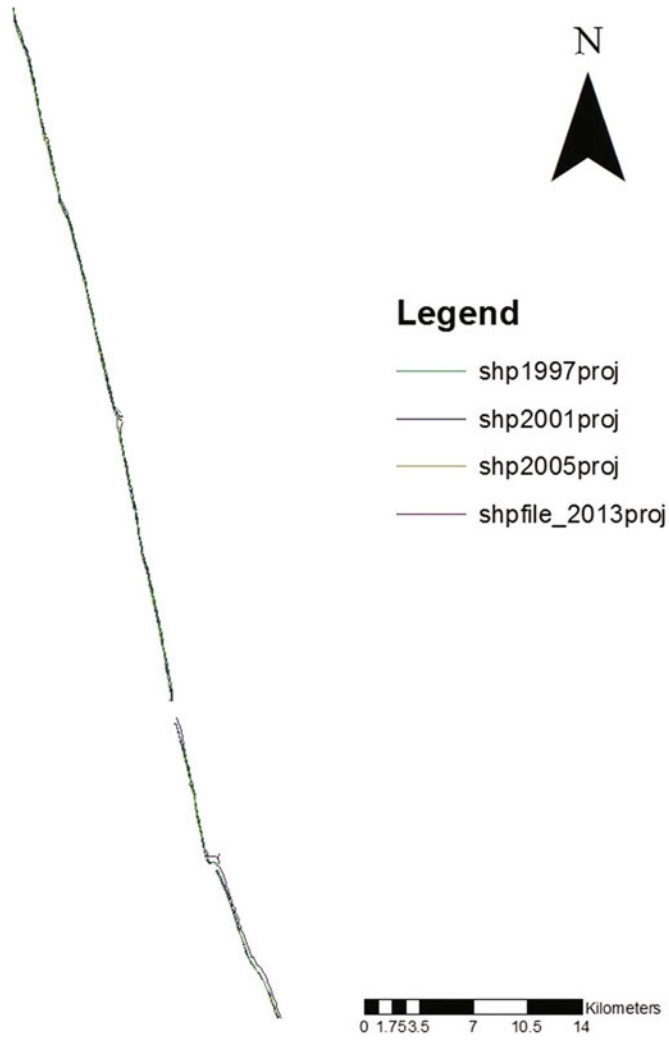


Fig. 4 Shoreline Dynamics During 1997-2013

Land Use Land Cover

The LU/LC classification was done for an area of 800 km². The classification was carried out by using three different methods: Maximum Likelihood Algorithm, Minimum Distance to Mean Algorithm, and Parallelepiped Algorithm and the classified area of different LU/LC classes is shown in Figs. 5, 6 and 7. The land use distribution of this area is shown in Table 3. The accuracy of the classified maps

LAND USE / LAND COVER MAP - MAXIMUM LIKELIHOOD METHOD

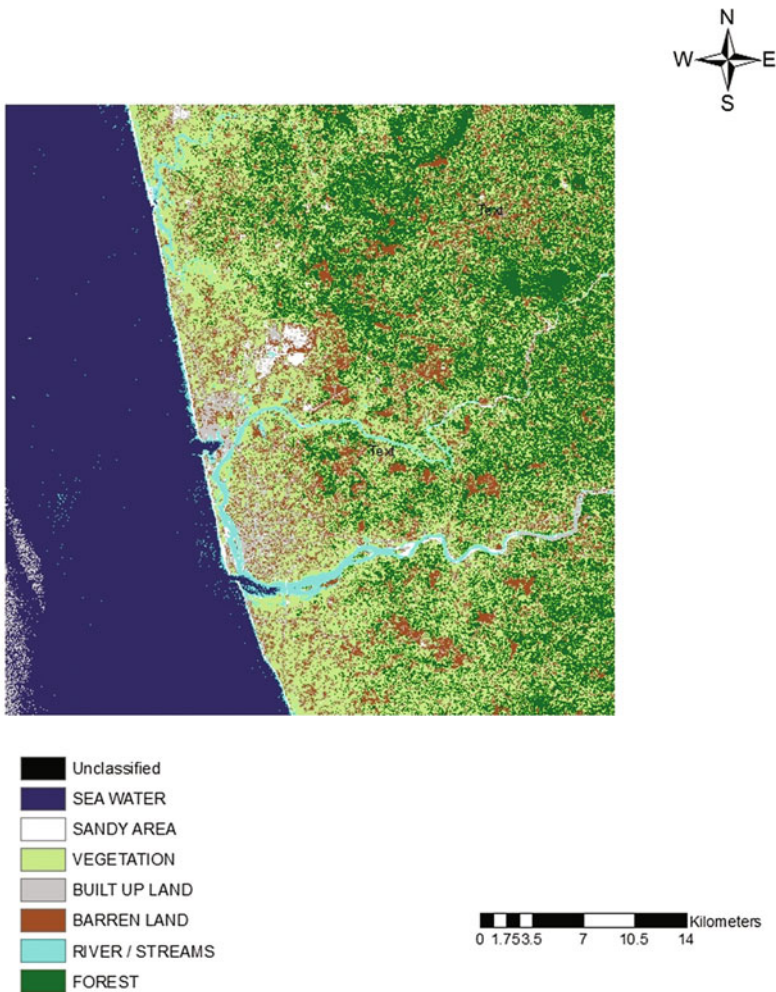


Fig. 5 LU/LC map—maximum likelihood method

LAND USE / LAND COVER - MINIMUM DISTANCE TO MEAN METHOD

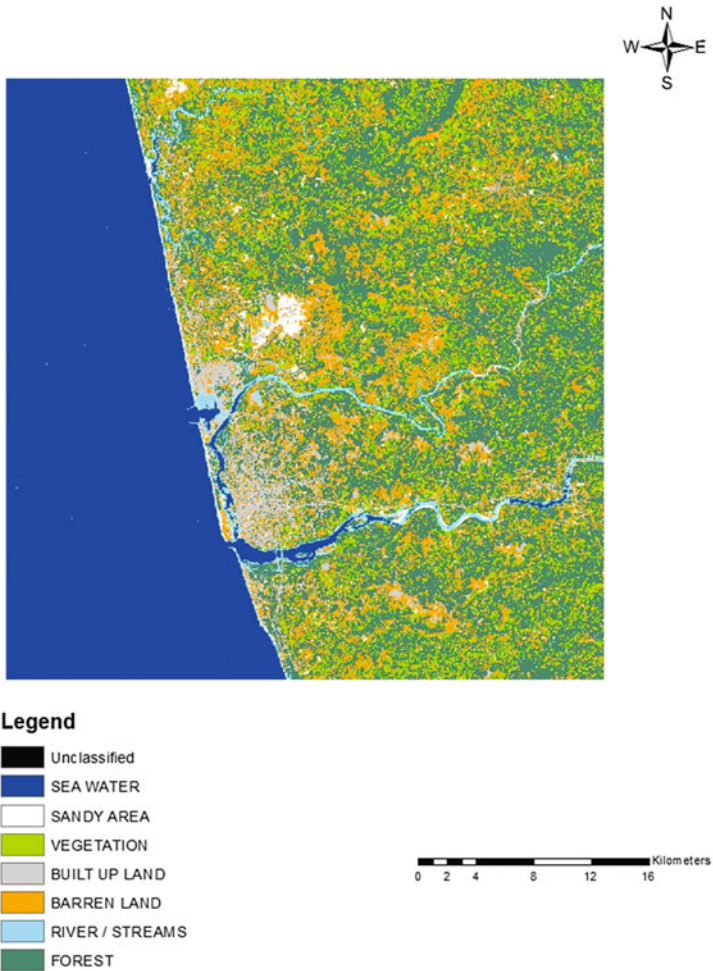
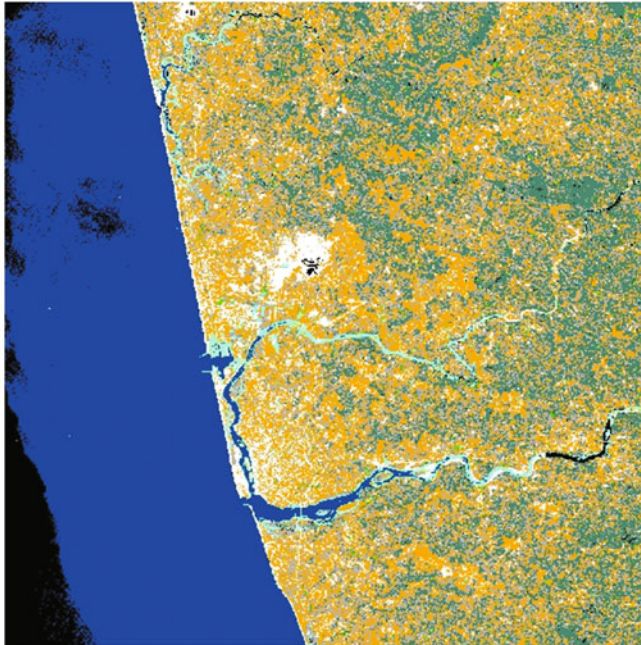


Fig. 6 LULC map—minimum distance to mean method

was analyzed by estimating overall accuracy. The result of accuracy assessment is as given in Table 4.

The study shows that more accuracy can be obtained through Maximum Likelihood Method than other two. The other two shows an overestimate of forest and barren land.

LAND USE / LAND COVER - PARALLELOPIPED



Legend

-  Unclassified
-  SEA WATER
-  SANDY AREA
-  VEGETATION
-  BUILT UP LAND
-  BARREN LAND
-  RIVER / STREAMS
-  FOREST



Fig. 7 LU/LC map—parallelopped method

However, the result shows a lower accuracy for vegetation (80%) than other classes. This is due to the combination of omission and commission errors particularly mixing with forest class. Lower producer’s accuracy was also observed for wetlands due to the omission and misclassification to agriculture than to water.

Table 3 Extent of land use/land cover

Class	Area (km ²)
Vegetation	538.77
Forest	354.3
Built-up land	464.9
Barren land	154.9

Table 4 Accuracy assessment of different types of classifier

Type	Accuracy (%)
Maximum likelihood	86
Minimum distance to mean	78
Parallelepiped	74

Conclusions

The study was focused on the coastline variation that had occurred over the years 1997–2013. The shoreline showed mostly an eroding trend throughout the period. The Ullal spit has undergone erosion during the period while Bengre spit has been growing. Similar characteristics have been shown in Mulki–Pavanje spit as well. The land use/land cover study through various methods show that maximum likelihood method gives a more accurate result with an accuracy of 83%. The reliability of these classification methods can be increased by considering more ground control points. Ultimately, these results can be used to prepare coastal inundation mapping which helps in developing coastal management plans.

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