

# Quantitative Estimation of Coastal Changes along Selected Locations of Karnataka, India: A GIS and Remote Sensing Approach

P. Vinayaraj, Glejin Johnson, G. Udhaba Dora, C. Sajiv Philip, V. Sanil Kumar, R. Gowthaman

*Ocean Engineering Division, National Institute of Oceanography*

*(Council of Scientific & Industrial Research), India*

*E-mail: sanil@nio.org*

*Received May 29, 2011; revised July 8, 2011; accepted August 29, 2011*

## Abstract

Qualitative and quantitative studies on changes of coastal geomorphology and shoreline of Karnataka, India have 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. Significant morphological changes in landforms like spit, channel Island, coastal plain, tidal flat, lateritic plain, alluvial plain and sand bar within and adjacent to estuarine river mouths of Kali, Sharavathi, Kollur-Chakkara—Haladi and Udyavara Rivers are observed. The study indicates that gradual erosion is observed at i) Karwar spit along the northern side of the Kali river mouth, ii) the spit at the southern side of the Sharavathi river mouth and iii) at some regions of Kundapur.

**Keywords:** Coastal Geomorphology, Shoreline, Coastal zone, Erosion, Accretion, Beach

## 1. Introduction

Coastal zone is the transition area between land and ocean [1] and is an area of complex, dynamic and delicate environment. External factors influencing the coastal zone are the sediment supply by the rivers and coastal processes. Shoreline is one of the most rapidly changing landforms of the coastal zone. Geomorphic processes such as erosion, deposition, sedimentation, periodic storms, flooding and sea level changes are continuously modifying the shoreline. The accurate mapping of shoreline is therefore very important for planning conservation measures such as protection of human life, property and natural environment [2]. The coastal zone is receiving an increasing attention because of the pressure of increasing population and industrial developments. Erosion is also caused by shifting of river mouth and spits [3]. Protection of natural resources, the loss of habitats, severe coastal erosion, sedimentation in ports and harbors and municipal and industrial pollution are major concerns for coastal zone managers [4].

Remote sensing technology had been used commonly to map the shoreline and offers the potential of updating maps frequently [5]. Satellite Remote Sensing (RS) tech-

nique has proved its utility in all fields of earth science studies including the study of coastal processes, because of the repetitive, synoptic and multispectral coverage of the satellites. Satellite imageries are useful tools for detecting the coastal morphology changes. RS data can be used to evaluate the coastal processes like erosion/accretion and shoreline changes. Geographic Information System (GIS) is designed to work with data referenced by spatial/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. Remote sensing satellites images have been effectively used for monitoring shoreline changes of different locations [6-8]. In this paper an attempt has been made to study the shoreline changes in terms of accretion, erosion and geomorphology using IRS-1D, IRS-P6, toposheets data and GIS technique along Karnataka coast, west coast of India.

## Study Area

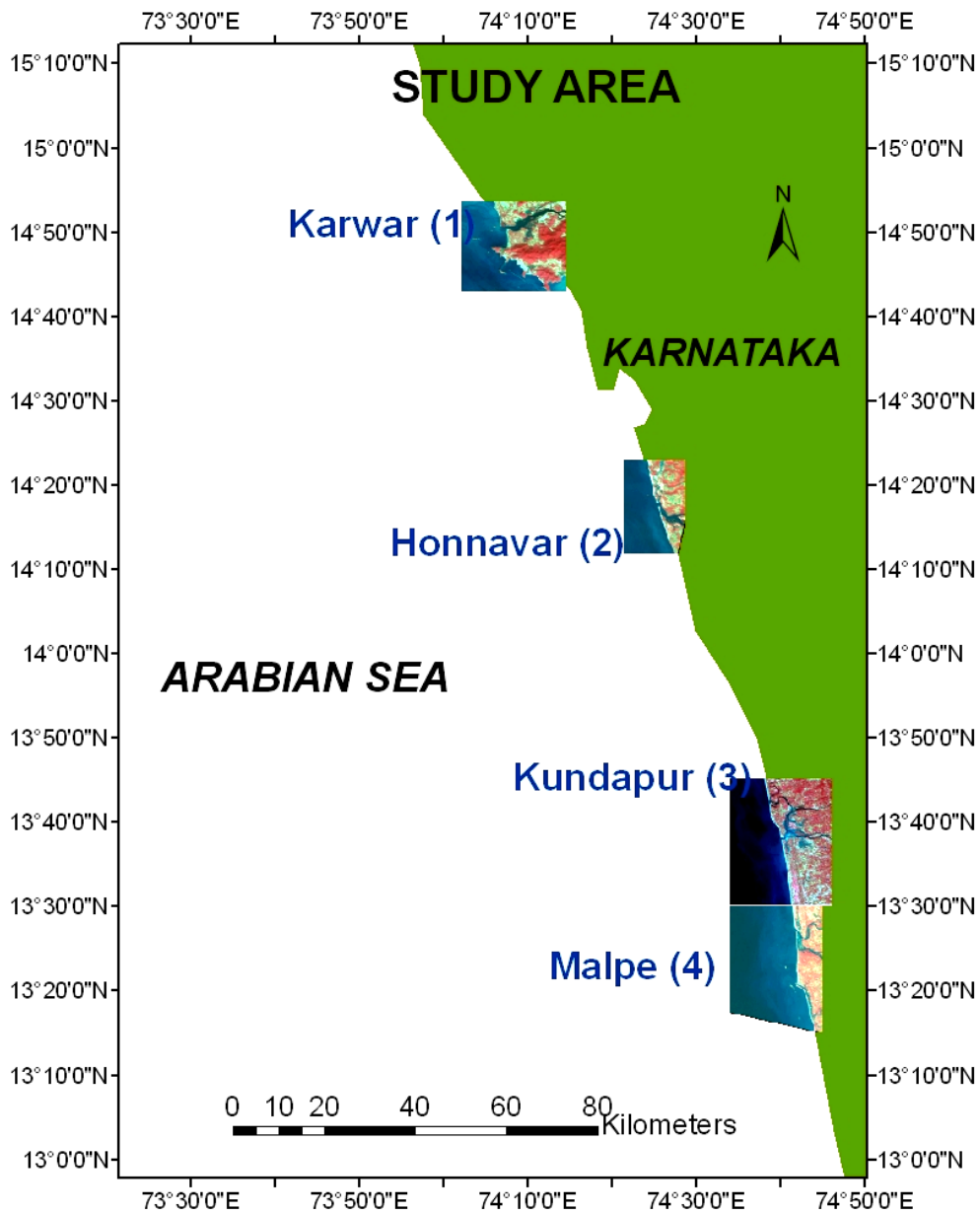
Karnataka coastline extends over a length of 280 Km intercepted with a number of rivers joining the Arabian Sea. Areas near the river mouths along the coastline of Karnataka State suffer permanent erosion due to natural shifting

and migration of the river mouths [9]. The present study focused at four regions; Karwar, Honnavar, Kundapur and

Malpe. **Table 1** and **Figure 1** present the location of beaches under study on either side of the river mouth.

**Table 1. Location data of the study area.**

Stations	Starting Point	Ending Point	Distance (Km)
Karwar (1)	14°52'0"N 74°6'0"E	14°48'0"N 74°8'0"E	7.316
Honnavar (2)	14°20'0"N 74°23'30"E	14°14'30"N 74°26'30"E	10.002
Kundapur (3)	13°40'0"N 74°38'30"E	13°36'0"N 74°42'0"E	7.644
Malpe (4)	13°22'0"N 74°40'30"E	13°15'0"N 74°44'0"E	14.383



**Figure 1. Location map of the study area.**

**Karwar (station 1):** Karwar is one of the major fishing zones in Karnataka. The Kali River flows through Karwar which is also a prominent tourist destination. The entire city of Karwar is situated on beach ridges formed due to the influence of Kali River and Arabian Sea confluence during the past [10]. The study area covers 7.316 Km and it covers north and south of the river mouth.

**Honnavar (station 2):** Shoreline covers 10.002 Km and it lies on the banks of the river Sharavathi, forming an estuary in the central west coast of India. Honnavar is characterized by the presence of coastal alluvial soil, spit, lateritic plain and tidal flat.

**Kundapur (station 3):** Study area at this station covers 7.644 Km and is situated on the confluence of Kollur-Chakkara and Haladi rivers and Arabian Sea. Rocky beaches, lateritic plain, alluvial plain, tidal flat and Channel Islands are the characteristics of Kundapur.

**Malpe (station 4):** Shoreline covers 14.383 Km and it lies at the confluence of Udyavara river and Arabian Sea. Malpe is the largest fishing harbour in Karnataka. Rocky islands and barrier spit are the major characteristics of Malpe.

## 2. Data and Methods

### 2.1. Data Source

IRS-1D and IRS-P6, LISS-III (cloud free) satellite image of 26 Feb 1998 0547 hrs and 09 Jan 2008 0539 hrs, path 096 and row 062 covering the area between 74.1079° E and 74.728° E longitude and 14.87° N and 13.2608° N latitude was used for the study. IRS-1D and IRS-P6 are two among the series of Indian Remote Sensing satellites. Characteristics of both IRS-1D and IRS-P6 satellites are presented in **Table 2**.

### 2.2. Data Processing

Topomaps were scanned and opened in ERADAS IMAGINE 8.5 environment. Base maps were generated based on the Survey of India topographical maps surveyed in the year of 1973 for Kundapur, 1977 for Malpe, 1980 for Honnavar and 1981 for Karwar, registered by giving corner points after projecting into geographic projection with Modified Everest as the datum. IRS (LISS-III) imageries of 1998 and 2008 were Geo-registered with the base map using more than 25 corresponding Ground Control Points (GCPs) like bridges, road crossing and other permanent significant features, using survey of India toposheets [11].

Geo-registration is a process of stabilizing the relationship between map and the known real world coordinates. Re-sampling in each case was performed using cubic

interpolation technique to keep the spatial distortions at minimum. Accuracy of the geo-correction is tested by swiping one image above the other and confirmed by field check. The geocorrected data is entered to the ArcGIS environment for digitization of shoreline. High waterline shown in the satellite imageries (1998 and 2008) and topographic sheets for all the four stations are digitized as line feature. Shorelines representing different years of a same station are presented by overlaying together. Quantification of erosion/accretion rate is done by digitization as polygon features using ArcGIS.

Coastal process are not uniform with respect to time and it is difficult to compare two scenes taken at different time because of the non-uniform tides of coastal area *i.e.*, if it is low tide in one scene, it may be high tide in other one. So there is chance of error in estimation of erosion/accretion [10]. For minimizing the error, the data during similar tidal phase is considered in the present study.

Geomorphologic features like alluvial plain, tidal flat, sandbar, spit, rocky beaches and Channel Island are denoted on the imageries and plotted as geomorphologic maps for each station in different years.

## 3. Results and Discussion

The quantitative estimation of morphological changes along the shoreline and estuarine mouth of Karwar, Honnavar, Kundapur and Malpe are discussed below. The tide variation between the satellite imageries of 1998 and 2008 for the path/row-096-062 (Karwar and Honnavar) is negligible but path/row 097-063 (Kundapur and Malpe) shows 65 cm change in the tide between two data.

**Table 2. Satellite data characteristics.**

Satellite	Sensors	Spectral bands(Microns)	Resolution (m)
IRS-1D	PAN	0.50 - 0.75	5.2 to 5.8
	LISS-III	0.52 - 0.59 (B2), 0.62 - 0.68 (B3), 0.77 - 0.86 (B4), 1.55 - 1.70 (B5)	21.2 to 23.5 (V & IR)
		WiFS	0.62 - 0.68 (Visible)
IRS-P6	LISS-IV	0.52 - 0.59 (Green (Band 2)) 0.62 - 0.68 (Red (Band 3)) 0.76 - 0.86 (NIR (Band 4))	5.8
	LISS-III	0.52 - 0.59 (B2), 0.62 - 0.68 (B3), 0.77 - 0.86 (B4), 1.55 - 1.70 (B5)	23.5 (V & IR)
AWiFS		0.52 - 0.59, 0.62 - 0.68, 0.77 - 0.86, 1.55 - 1.70	58

The erosion and accretion map of Karwar during the period of 1981 to 1998 (**Figure 2**) shows considerable erosion of around 1.459 Km<sup>2</sup> at the northern side of the Kali River along the shoreline. Net erosion during this period is 0.467 Km<sup>2</sup> and net accretion is 0.290 Km<sup>2</sup>. The width of the river mouth has increased from 250 to 800 m without any significant change in the position of the river mouth, this is because of the erosion took place at the both banks of the river mouth. During the period from 1998 to 2008, at Karwar, erosion has occurred along the shoreline from the river mouth to the northern side to a length of around 3.75 Km (**Figure 2**). It is also observed that the Kali River mouth has shifted slightly around 125 m towards north, with net erosion of 0.397 Km<sup>2</sup> and accretion of 0.102 Km<sup>2</sup> occurred during this period. The study indicates that an area of 0.405 Km<sup>2</sup> was eroded during the last 27 years (1981-2008) from the spit mouth, which is the most vulnerable location at station 1.

The Sharavathi River mouth has shifted significantly (almost 1220 m) towards north during the period between 1980 and 1998 (**Figure 3**). Northern side of the river mouth is affected by erosion and the southern side shows accretion. Net erosion and accretion of the station 2 (Honnavar) is 0.465 Km<sup>2</sup> and 0.631 Km<sup>2</sup> respectively. Most of the shoreline which lies along the southern part

of the river mouth shows accretion. The width of the river mouth at Honnavar increased from 125 to 600 m during the ten year period from 1998 to 2008 because of the erosion at both edge of river mouth. Sediments from the tip of the spit on the southern side of river mouth, around 0.184 Km<sup>2</sup> areas washed off by erosion. Net erosion and accretion are measured as 0.383 Km<sup>2</sup> and 0.770 Km<sup>2</sup>. Study shows that during the last ten years (1998 - 2008) comparatively erosion is more than the accretion. Pavinkurve beach near the Basavarajadurg Island shows considerable erosion of 0.107 Km<sup>2</sup>.

Erosion and accretion map of Kundapur during 1973 to 1998, shows that river mouth has shifted around 270 m towards south (**Figure 4**). Erosion observed on the southern side of river mouth for almost 1.146 Km along the shoreline. Net erosion and accretion of the area is 0.170 Km<sup>2</sup> and 0.326 Km<sup>2</sup> respectively. River mouth width decreased from 200 to 100 m. Almost 2614 m along the shoreline of Gangoli beach grows seaward due to accretion. The width of the river mouth is considerably varying from 200 to 360 m during the last ten years from 1998 to 2008 because of the erosion of both side of the river mouth. An area 0.108 Km<sup>2</sup> of the entire shoreline of the station 3 got eroded. The net accretion of the area is around 0.127 Km<sup>2</sup>.

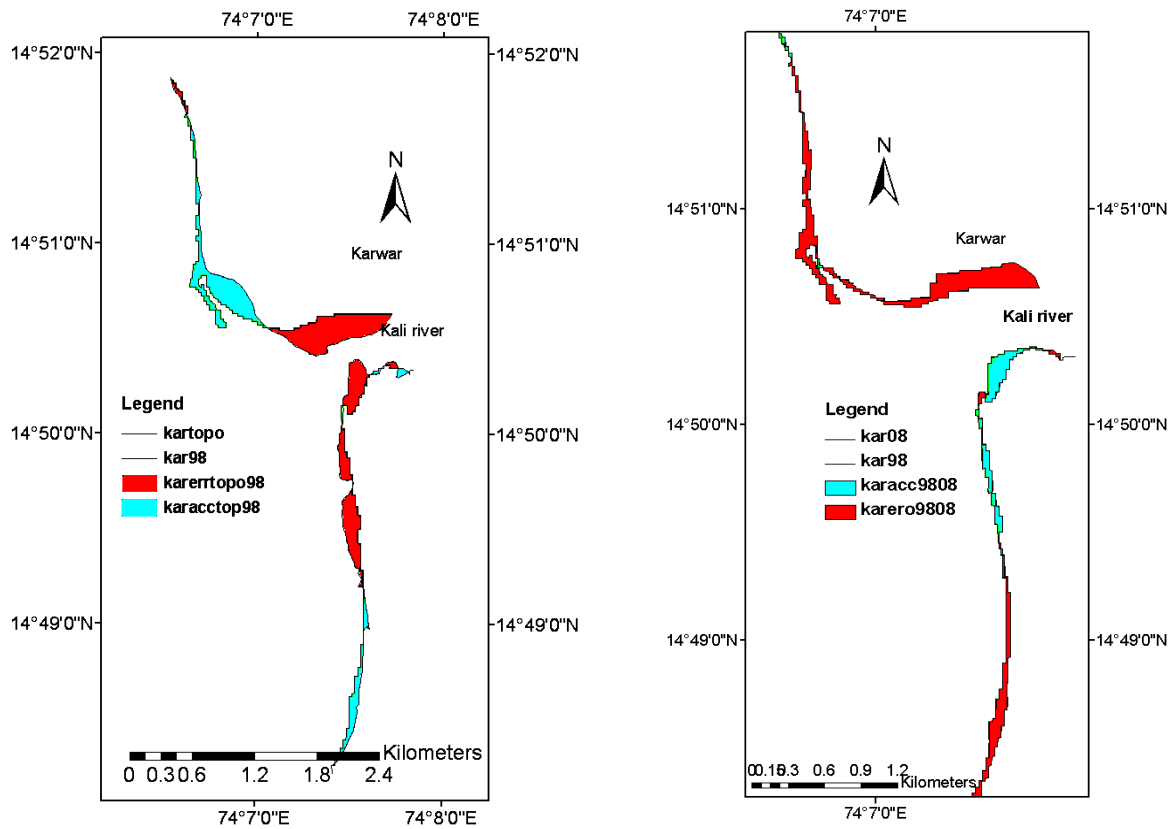


Figure 2. Erosion/accretion at Karwar during 1981-1998 and during 1998-2008.

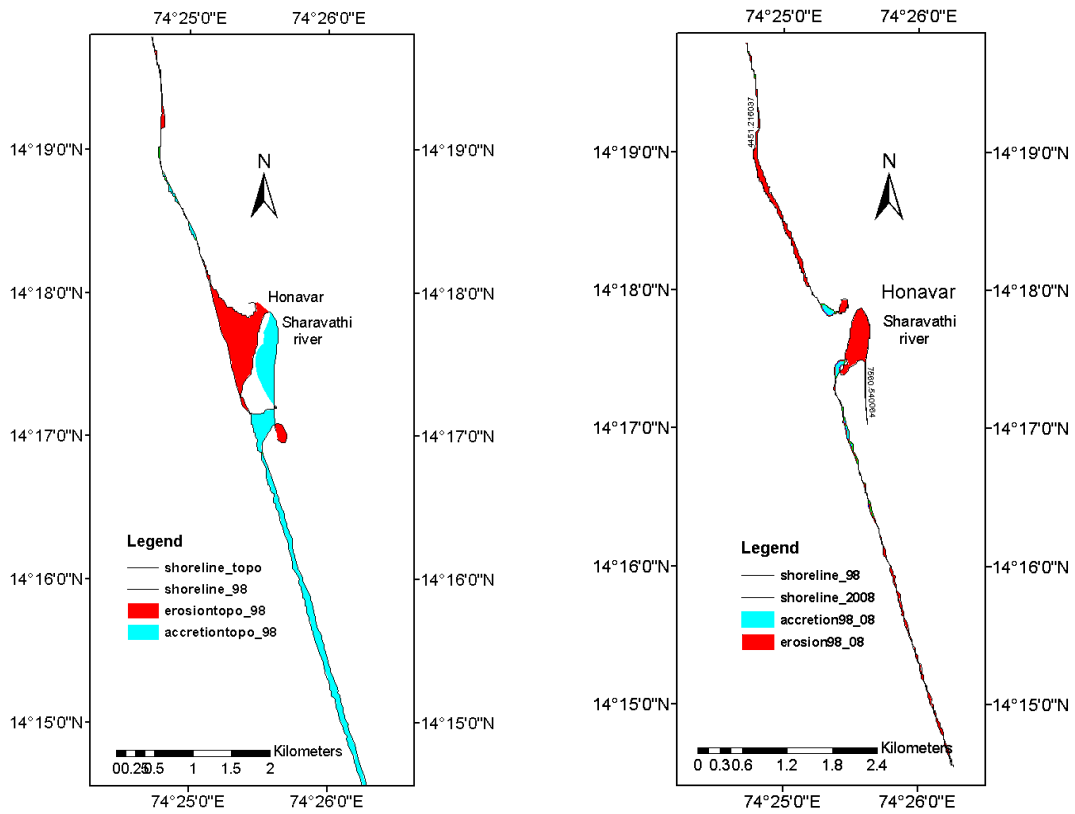


Figure 3. Erosion/accretion at Honnavar during 1979-1998 and during 1998-2008.

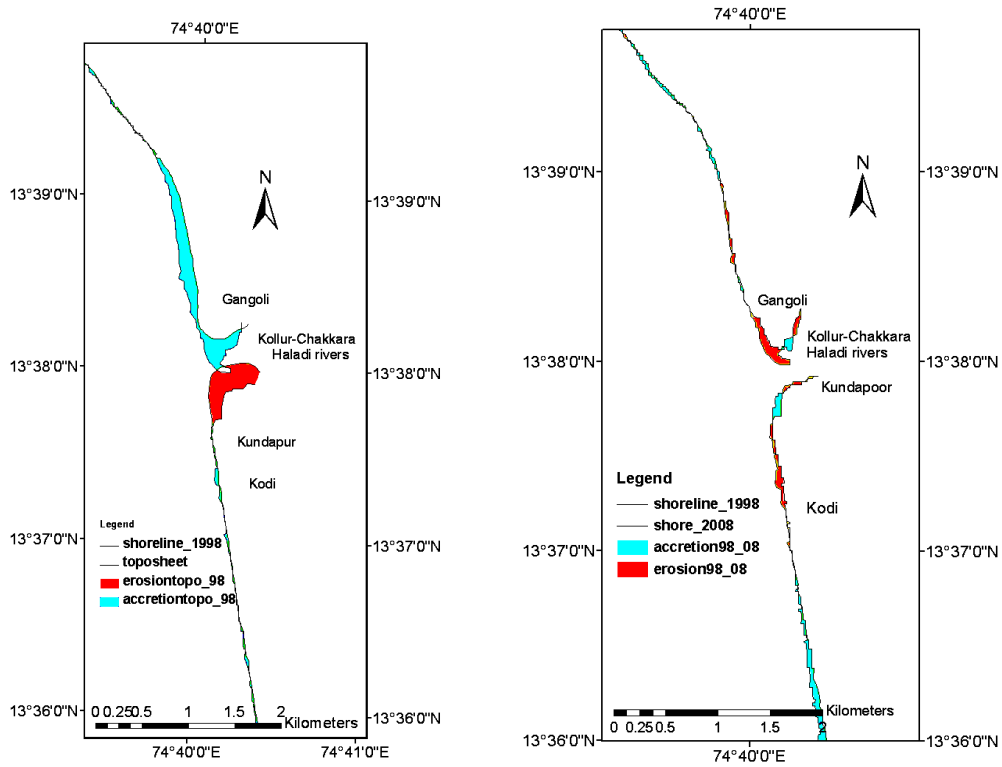


Figure 4. Erosion/accretion at Kundapur during 1973 - 1998 and during 1998 – 2008.

Morphological changes near the Udyavara river estuary during the period from 1977 to 1998 (**Figure 5**) shows that width of the mouth has been decreased due to accretion on both sides of the river mouth from 200 to 100 m. The tip of the barrier spit lies on the southern side of the river mouth grows gradually towards north-west direction, during 1977 to 1998 it has grown around 0.104 Km<sup>2</sup>. Net erosion and accretion of the area is 0.615 Km<sup>2</sup> and 0.192 Km<sup>2</sup> respectively. Study shows that, shoreline erosion is occurring along the locations at Tenkadiyur and Pangala to an extent of 1.372 and 4.636 Km respectively. During 1977 to 1998 an area of 0.113 and 0.368 Km<sup>2</sup> were eroded from Tenkadiyur and Pangala respectively.

During 1998 to 2008, the width of the river mouth at Malpe reduced marginally from 260 to 224 m. The tip of the barrier spit continued to grow towards north-west,

both side of the river mouth shows accretion. Only on the southern side of the river mouth, the spit got deposited around 0.035 Km<sup>2</sup>. Study indicates that very small area is affected by erosion and most of the beach showed depositional characteristics. Net erosion of the area is 0.026 Km<sup>2</sup> and the net accretion of the area is 0.355 Km<sup>2</sup>. GIS and Remote Sensing approach study have been done by Dwarakish *et al.* [12] along the Malpe coastal region.

**Karwar (1981-2008):** The quantity measurement of the area covered by each geomorphology classes such as tidal flat, spit, Marine Island, sandy beach, creek, coastal plain, Channel Island and alluvial plain. Spit shows gradual decrease in the area. Among the various land form features spit shows the gradual decrease in area, 0.214 Km<sup>2</sup> area got eroded from the mouth of the river Kali (**Table 3**). Slight increase observed in the area of coastal plain and alluvial plain. Creek has lost 1.028 Km<sup>2</sup>.

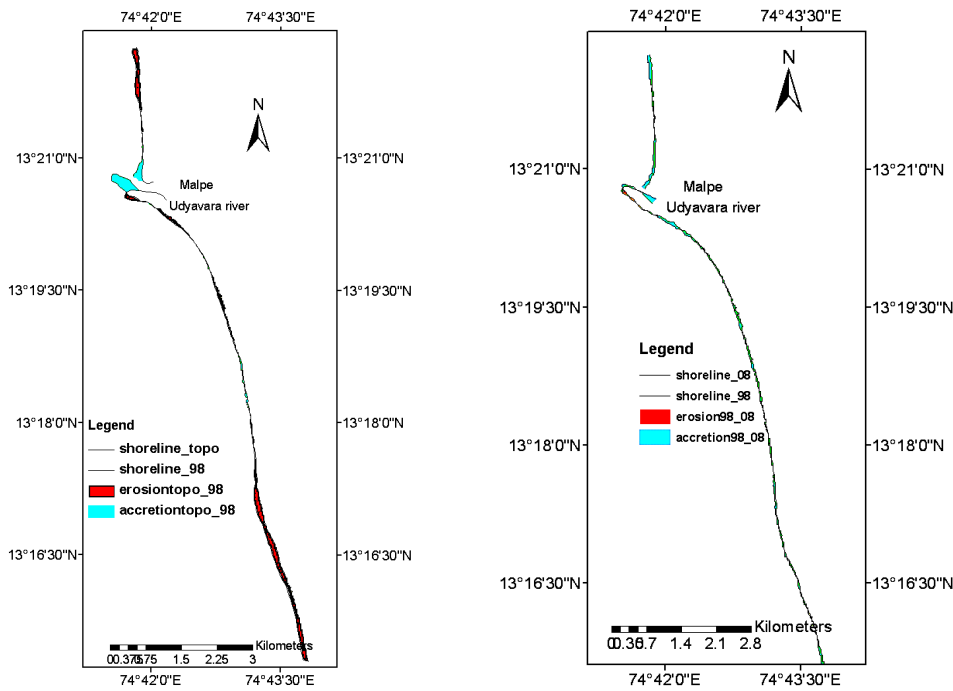


Figure 5. Erosion/accretion at Malpe during 1977-1998 and during 1998-2008.

Table 3. Geomorphologic changes at Karwar.

Class	Area (Km <sup>2</sup> ) 1981	Area (Km <sup>2</sup> ) 1998	Area (Km <sup>2</sup> ) 2008	Change in area (Km <sup>2</sup> ) 1981-1998	Change in area (Km <sup>2</sup> ) 1998-2008
tidal flat	3.397	4.333	4.272	0.936	-0.061
spit	0.814	0.729	0.601	-0.085	-0.128
marine island	0.187	0.187	0.187	0	0
sandy beach	0.505	0.622	0.513	0.117	-0.109
creek	2.490	1.959	1.462	-0.531	-0.497
coastal plain	0.694	0.707	0.771	0.013	0.064
channel island	0.165	0.242	0.261	0.077	0.019
alluvial plain	16.187	16.389	17.091	0.202	0.702

**Honnavar (1980-2008):** In the case of tidal flat, it is observed that 1.189 Km<sup>2</sup> area got reduced during the period 1980 to 1998 and an area of 0.542 Km<sup>2</sup> increased during 1998 to 2008. The spit which lies on the southern side of the Sharavathi river grows 0.370 Km<sup>2</sup> towards north (**Table 4**). Geomorphology of this area shows the presence and gradual decrease in the area of sand bars and creek. Marine Island and Lateritic plain do not show any observable change at the location. Coastal plain covers the maximum area of Honnavar region, coastal plain increase the area from 1980 to 1998 and after that it shows decreasing trend. In the case of Channel Island, it is showing an increasing trend in area from 1980 to 2008.

**Kundapur (1973-2008):** Rocky beach, sand bar and alluvial plane are the characteristics of Kundapur morphology. The area which covered by the tidal flat, decreased during 1973 to 1998 but 0.967 Km<sup>2</sup> area added during 1998 to 2008. Sand bar diminishes by an area of 0.227 Km<sup>2</sup>

from 1973 to 1998, but after that it shows increasing trend from 1998 to 2008 (**Table 5**). No change can be detected in rocky beaches, marine Island and alluvial plain. It is detected that the coastal plain and channel Island gradually increases its area during 1973 to 1998. From 1998 to 2008, coastal plain area increased by 0.159 Km<sup>2</sup>, but Channel Island shows a slight reduction in area from 1998 to 2008. Jayappa et al., [13] studied the area through remote sensing.

**Malpe (1977-2008):** It is noticed that most of the study area of Malpe is covered by coastal plain, it shows some changes in the area too. Barrier spit on the southern side of the river mouth detected as increasing during 1998 to 2008 and decrease in area of 0.190 Km<sup>2</sup> from 1977 to 1998 (**Table 6**). Area covered by creek reduced during the study period. Overall sand bar quantity increased during the study period. It is observed that the Channel Island of 0.055 Km<sup>2</sup> diminished.

**Table 4. Geomorphologic changes at honnavar.**

Class	Area Km <sup>2</sup> 1979	Area Km <sup>2</sup> 1998	Area Km <sup>2</sup> 2008	Change in area Km <sup>2</sup> 1979-1998	Change in area Km <sup>2</sup> 1998-2008
tidal flat	2.085	0.896	1.438	-1.189	0.542
spit	1.515	1.886	1.819	0.371	-0.067
sandy beach	0.955	0.945	1.020	-0.01	0.075
sand bar	0.023	0.083	0.040	0.060	-0.043
marine island	0.202	0.164	0.166	-0.038	0.002
lateritic plain	16.956	16.956	16.956	0	0
creek	1.135	0.592	0.576	-0.543	-0.016
coastal plain	11.728	12.004	11.325	0.276	-0.679
channel island	0.995	1.166	1.272	0.171	0.106

**Table 5. Geomorphologic changes at Kundapura.**

Class	Area (Km <sup>2</sup> ) 1973	Area (Km <sup>2</sup> ) 1998	Area (Km <sup>2</sup> ) 2008	Change in area (Km <sup>2</sup> ) 1979-1998	Change in area (Km <sup>2</sup> ) 1998-2008
tidal flat	2.581	2.050	3.018	-0.531	0.968
sand bar	0.296	0.069	1.083	-0.227	1.014
sandy beach	0.637	0.703	0.676	0.066	-0.027
rocky beach	0.027	0.027	0.027	0	0
marine island	0.052	0.052	0.052	0	0
lateritic plain	2.805	2.805	2.805	0	0
coastal plain	10.363	10.823	11.018	0.460	0.195
channel island	3.512	4.140	4.105	0.628	-0.035
alluvial plain	0.743	0.743	0.743	0	0

**Table 6. Geomorphologic changes at malpe.**

Class	Area (Km <sup>2</sup> ) 1977	Area (Km <sup>2</sup> ) 1998	Area Km <sup>2</sup> 2008	Change in area Km <sup>2</sup> 1979-1998	Change in area Km <sup>2</sup> 1998-2008
sandy beach	1.123	0.978	1.267	-0.145	0.289
sand bar	0.307	0.204	0.362	-0.103	0.158
marine island	0.555	0.555	0.555	0	0
creek	0.689	0.420	0.320	-0.269	-0.100
coastal plain	23.318	23.168	23.440	-0.150	0.272
channel island	0.340	0.246	0.285	-0.094	0.039
barrier spit	1.002	0.812	0.938	-0.190	0.126

#### 4. Conclusions

This study investigates the coastal erosion and deposition at four stations (Karwar, Honnavar, Kundapur, and Malpe) covering a period of almost thirty years along the Karnataka, west coast of India. Both erosion and deposition are observed at all the four stations. 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 of Devbag (north of Kali River), at Pavinakurve (north of Sharavathi River) and at Kundapur. 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.

#### 5. Acknowledgements

We thank Integrated Coastal and Marine Area Management Project Directorate (ICMAM PD), Ministry of Earth Sciences, New Delhi for funding the project. Director, National Institute of Oceanography, Goa and Project Director, ICMAM PD, Chennai for the encouragement provided to carry out the study. This is NIO contribution 4995.

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