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1-2-18/103, Mohini Mansion, Gagan Mahal Road, Domalguda
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Monitoring Morphological Changes in and around Nethravathi - Gurupur Estuary of Mangalore Coast - A Geoinformatics Approach

H. GANGADHARA BHAT[1], C. KRISHNAIAH[1], K. N. CHANDRASHEKARAPPA[2], MOHAN[3], M. V. MAVISH KUMAR[1] and A. SUMALATHA[1]

[1]Department of Marine Geology, Mangalore University, Mangalagangothri-574199
[2]Department of Applied Geology, Kuvempu University, Jnana Sahyadri, Shivamogga
[3]Department of Mines and Geology, Mangalore
***Email:** gangadharab@yahoo.com*

Abstract: Short term and long term shoreline change detection studies and coastal mapping are very critical for navigation, coastal zone management and sustainable coastal development. In the present paper an attempt has been made to understand the dynamic marine and river environments responsible for the morphological changes in and around Nethravathi-Gurupura river mouths. The Nethravathi-Gurupura river system, the largest river basin of Dakshina Kannada of southern Karnataka, was chosen for the study due to the rapid industrialization and urbanization which is taking place in this basin. The aim of this study is to analyze the present dominant environment and the impact of human activity on the coast. The satellite images and aerial photographs obtained through remote sensing techniques provide synoptic, multispectral and multi temporal information, which can be used effectively for mapping, monitoring and understanding these changes. Analysis of the changes (1910-2009 period) has been carried out using multi temporal satellite images and multidated topographic maps. The results obtained based on the multi dated data study show that the Bengre spit, north of the northern breakwater experiences accretion, while the Ullal coast, south of the southern breakwater generally experiences erosion. Accretion areas are located near coastal structures especially near the breakwaters, since they block along the shore sediment transport. Added to this, the two ships drowned in the near shore waters off Bengre spit about 2 years back, act as temporary breakwater, and this has resulted in a convex beach near Bengre. The study has indicated that the multi temporal satellite images can be used for coastal change detection analysis and the accuracy could be increased by using high spatial resolution images. The integration of the information derived from the remotely sensed data with the field data in a GIS environment has helped in suggesting suitable management plans for the coastal environment.

Keywords: *morphological changes, remote sensing, GIS, topographical maps, aerial photographs, multi temporal satellite images*

Introduction:

The Nethravathi is a major river of southern Karnataka coast, which originates in the Western Ghats and flow for about 148 km before discharging the water to the Arabian sea near Mangalore. It is joined by another river Gurupura, which also originates in the Western Ghats. These two rivers have a common estuary near Mangalore. The mouths of these rivers are subjected to modifications from time to time. The river Nethravathi flows almost at right angles to the coast, whereas river Gurupura flows parallel to the coast for a considerable distance before joining the Arabian Sea (Fig.1). The significant morphological changes occurring in and around the estuaries can be monitored by using multidated Topographical maps, satellite images and aerial photographs. The analysis of the multispectral satellite images provide ample information, which can be effectively used to monitor the significant morphological changes occurring in the estuaries/in the near vicinity of the estuaries. The New Mangalore Port (NMPT) is just 10km north of Nethravathi –Gurupura (N-G) estuary, whereas the fishing port is situated in the near vicinity of the estuary.

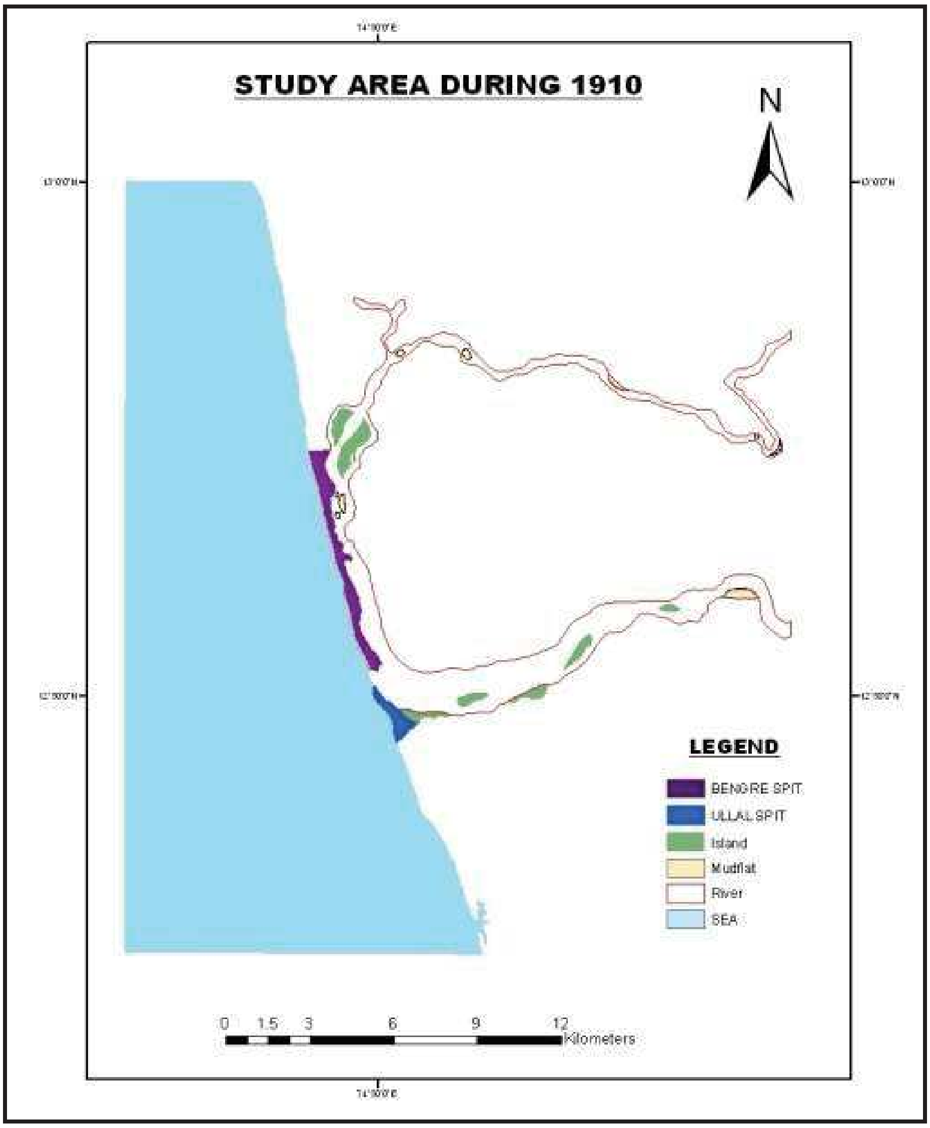

Figure 1: *Nethravathi - Gurupura Estuary during 1910*

The Ullal spit is located on the southern side and the Bengre spit is located on the northern side of the N-G estuary. In the present paper an attempt has been made to understand the morphological changes and the causes for the changes through an integrated approach of remote sensing and GIS. The tremendous technological advancement in the field of remote sensing has made this tool as the best and most popular technique to detect shoreline changes due to synoptic, multispectral imaging, repetitive data coverage and high spatial resolution capability. Mangalore coast is experiencing constant changes mainly due to natural processes and human activities. Important changes are taking place in the area, due to human development that has irreversibly altered the physical features and has shaped the morphology of the estuary. In order to detect the changes in the configuration of the coastline and morphological changes in and around the estuaries, data obtained from topographical maps, aerial photographs and satellite images of different dates have been used.

The google images available in the public domain pertaining to the period 2004-2009 were also used, since they provide ample information on various coastal landforms, because of their high spatial resolution. Remote sensing techniques have the capability to map the shoreline and offer the potential of updating the maps frequently. Number of researchers have carried out shoreline change detection studies using coarse and fine resolution satellite images; small and large scale aerial photographs (Davis, 1976; Leatherman, 1983; Bird, 1984; Dolan., 1984; Nayak and Sahai, 1985; Prabhakara Rao et al., 1985; Ramasamy, 1992; Gangadhara Bhat, and Subrahmanya, 1992; Gangadhara Bhat, 1995; Gunashekara, 1996; Chen and Rau, 1998; Yang et al., 1999; Raghavan et al., 2001; Zhu, 2001; Gatsis et al., 2001; Skilodimou et al., 2002; Byrnes et al., 2003; Frihy et al., 1998; Chalabi et al., 2006 and Kumar et al., 2010). To get accurate information on the status of eroding and accreting beaches, it is necessary to use high spatial resolution satellite images of the order of 5 to 1m. Some of the present satellites like Cartosat, IKONOS and Orbview are capable of providing images at 2.5m, 1m and less than a meter resolution, offer the capability to resolve relatively small changes in the shoreline position. The main advantage of these satellite images are: they are capable of identifying the coastal landforms with better accuracy.

Materials and Methods:

In the present study, Survey of India topographical maps (1:50,000 scale) surveyed during 1910, 1967 and 1980; Indian Remote Sensing Satellite Images (IRS-1D- LISS-III) of 1999 and 2005 and Google images of 2006, 2007, 2008 and 2009 have been used (Table 1) to get the required information on various coastal landforms and coastal processes. The salient features of some of the satellite images are represented in Table 2. Survey of India topographical maps and the satellite images were georeferenced using ERDAS IMAGINE 8.7 software. The shoreline maps in the vector format were extracted from the multidated data products and based on the GIS integration techniques, significant morphological changes are observed. Extensive field work has also been carried out using GPS to locate the exact positions of various coastal landforms. Both visual and digital analysis of the satellite data has been carried out. The vector layer extracted from the Google images of 2005 and 2006 in true colour mode provided enormous information on various coastal landforms. During the 1970s to 1990s coarse resolution satellite images were analysed using various recognition elements criteria to differentiate the earth surface features because of their coarse spatial resolution. Technological advancement in the field of spatial, spectral and radiometric resolution has now permitted to identify the minute details of the landforms very clearly.

Table 1: *Data Products Used in the Present Study*

Sl. No.	Data Products	Scale	Year
1	Survey of India topographical map	1:63,360	1910
2	Survey of India topographical map	1:50,000	1967
3	Survey of India topographical map	1:25,000	1980
4	Aerial photographs	1:50,000	1979
5	IRS-1B-LISS-II Sensor	1:50,000	1998, 2000
6	Google images	1:25,000	2005

Table 2: *Specification of IRS-1D and Google Images*

Satellite	Sensor	Spectral bands	Spatial Resolution
IRs – 1D	LISS - III	1 - 520-590nm(Green) 2 – 620-680nm (Red) 3 – 770-860nm (Near IR) 4 – 1550 -1700nm(SWIR)	23.5 m
	PAN	500 – 750 nm	5.8 m
	WIFS	620-680 nm (Red) 770-860 nm (NIR)	188 m
Goggle Image details: *True colour images; Satellite: Mainly IKONOS;* ***Spatial Resolution:*** *About 4m (Multispcetral); 1m (Panchromatic)*			

Results and Discussion:

The significant morphological changes noticed in and around the estuaries of N-G estuary and along the beaches of Ullal and Bengre during different periods are discussed below.

1910-1967:

During 1910 period, the main road connecting Mangalore and Kasaragod was passing through Ullal spit. There was a ferry connecting Old Mangalore port and Ullal spit. There were no shoals present in the river mouth of the two rivers, clearly indicates siltation was less during that period.

During 1980s:

Both Bengre and Ullal spit experienced significant morphological changes from 1967 to 1980 period. Bengre spit, which was very narrow at its tip got widened and started growing towards the estuarine mouth. The Ullal spit at its tip got curved and was showing boat hook shaped bend. There were number of stabilized islands noticed along the course of Nethravathi and Gurupur rivers near the river mouth. The river mouth gradually shifted towards north during this period.

During 2000:

The breakwaters at the tip of N-G estuary were constructed during the early nineties. Subsequent to this, the Bengre spit got widened and stabilized. Where as Ullal spit got eroded at its tip and middle portion.

2004 onwards:

Bengre spit was not showing remarkable changes, whereas Ullal spit show remarkable changes. The breakwater started collapsing and it got destroyed at its tip and middle part. Furthermore, the spit at its tip started protruding towards the estuarine mouth.

The comparison of the maps (Fig. 2 and 3) generated based on 1967-80 period shows that the southern spit lengthened towards north for about 250m, whereas the northern spit shortened and shifted about 250m towards north. Comparison of the maps (Fig. 3 and 4) of 1987-2000 period shows that during 2000, the river mouth width was 130m and the southern spit shifted about 500m towards north where as the northern spit shortened by 500m. Maps of 2000-2006 period (Fig. 5 and 6) shows the shifting nature of the spit and the southern spit is shortened by 100m and the northern spit shifted about 140m towards south. The Ullal spit during 1910-12 period was extended in the NNW-SSE direction and was curved at the tip. During the subsequent years it gradually got eroded and during 1967 it was shortened in its length, but got widened. In the years 1978 it was further narrowed and started shifting towards east i.e. towards the river mouth. Subsequent to the construction of breakwaters at the tip of Ullal and Bengre, Ullal spit has subjected to severe erosion. The comparison of the naval hydrographic charts of 1910 and 1967 also show the deepening of the near shore near Ullal beach. The breakwaters (Fig. 7 and 8) and sea walls constructed during late 1990s are under the attack of high energetic waves during southwest monsoon season and are collapsing each year (Fig. 9 and 10). The Bengre spit was very narrow during 1910 period got widened during the subsequent years. During 1967 it was about 2km wide and the construction of the breakwater at the tip of the Bengre spit has resulted in the widening of Bengre beach. The satellite images of the subsequent years show that the Bengre spit not only got stabilized, it is also showing the accretion trend. A ship was marooned at the near shore waters of Bengre are acting as a parallel breakwater, due to this the Bengre spit at Thannirbhavi showing a convexity (Fig.11A&B). The Ullal breakwater which was stable upto 2004, started eroding /collapsing during 2005. It got collapsed further during 2006 and at present (2010) it is severely damaged at its tip and central portion (Fig. 10).

Compared to Gurupur river, Nethravathi is a major river system of the area and occupies a catchment area of about 3300km^2. When there is a heavy precipitation in the catchment's area during peak monsoon season, the Nethravathi river is flowing with enormous volume of water. The river at its lower reaches running at right angles to the coast for a considerable distance. When the monsoon strikes this coast, from south west direction, the high energetic waves generated from these winds attack the beaches. On one side, the high energetic waves and the other side, there is a high volume of water entering in to the sea during heavy downpour. These create enormous pressure on the Ullal spit. This creates pore pressure. Similar observations were made by Ravindra and Krishna Rao, (1987). The result is erosion of the Ullal spit from the sea side as well as from the riverine side. The effect of this kind of activity is negligible on Bengre spit, because Gurupur river is flowing parallel to the coast for a considerable distance. The estuarine mouth is dynamic one and thus undergoing modifications due to the tidal influence and riverine discharge. The southern tip of the Bengre spit and northern tip of Ullal spit show considerable changes from time to time and the significant morphological changes are clearly evident on the maps generated based on the multidated data products. Mining of sand from the estuaries, river courses and construction of check dams in the upper reaches of the river courses have reduced the sediment supply to the nearshore areas of N-G estuary, which is the major reason for erosion of Ullal spit. John and Cheryan (1974) reported the accretion of Ullal barrier spit from 1905 to 1968 and erosion of the Bengre spit during the same period. Based on the survey conducted during 1974 and 1978 period, Reddy et al., (1982) indicated the continuation of eroding trend for Bengre and a period of stability for Ullal spit. Subsequent to the construction of sea wall, near the tips of the spits in 1984 , the Bengre spit has not only been stabilized, it started accreting and during the same period Ullal spit is being continuously eroded (Subrahmanya et al., 1989). According to Kunte and Wagle (1991) the predominance of southerly littoral drift is responsible for the growth of spits in Mangalore coast.

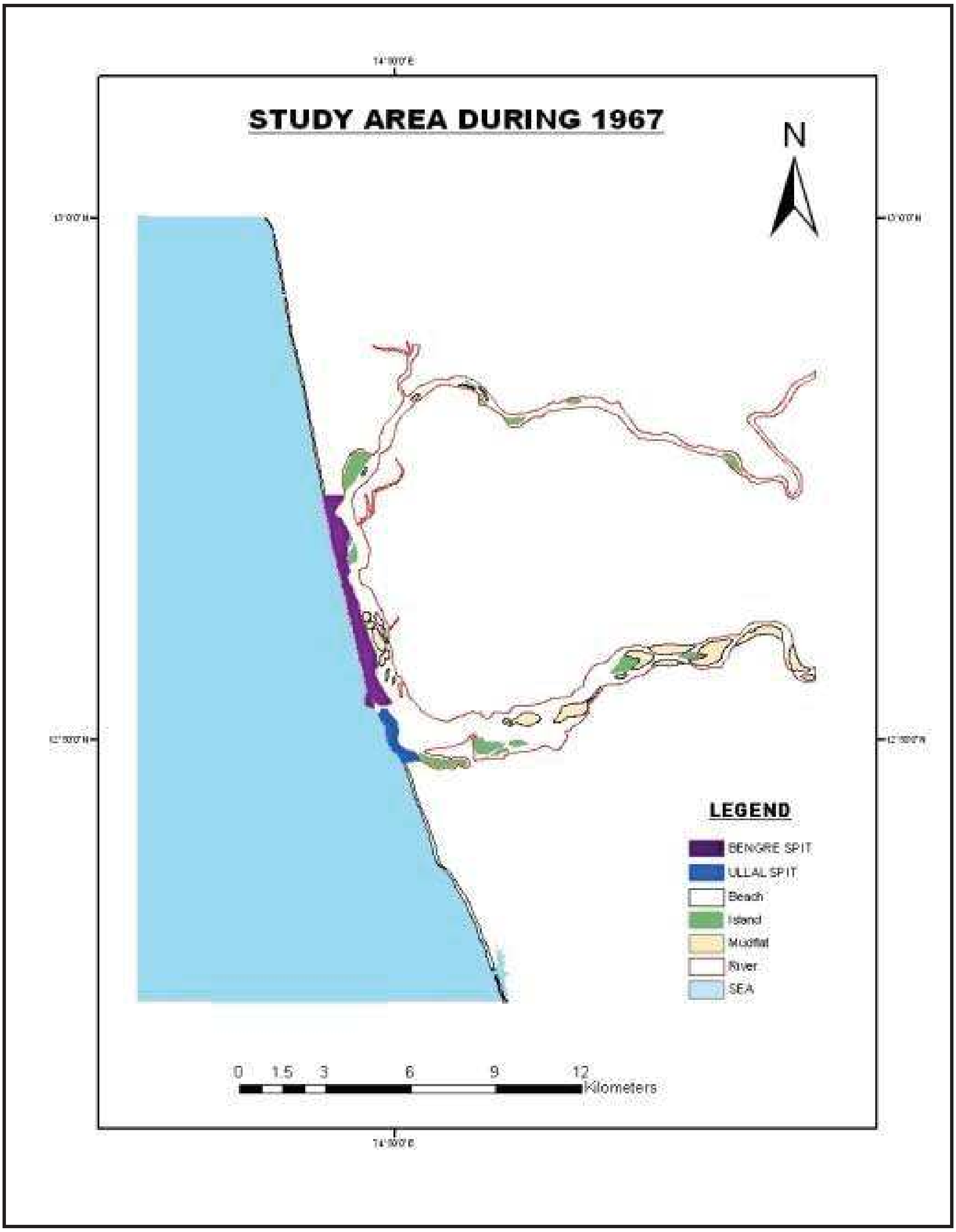

Figure 2: *Nethravathi - Gurupura Estuary during 1967*

Figure 3: *Nethravahti - Gurupura Estuary during 1980. Curvilinear Shape of the Ullal Spit is Clearly Seen.*

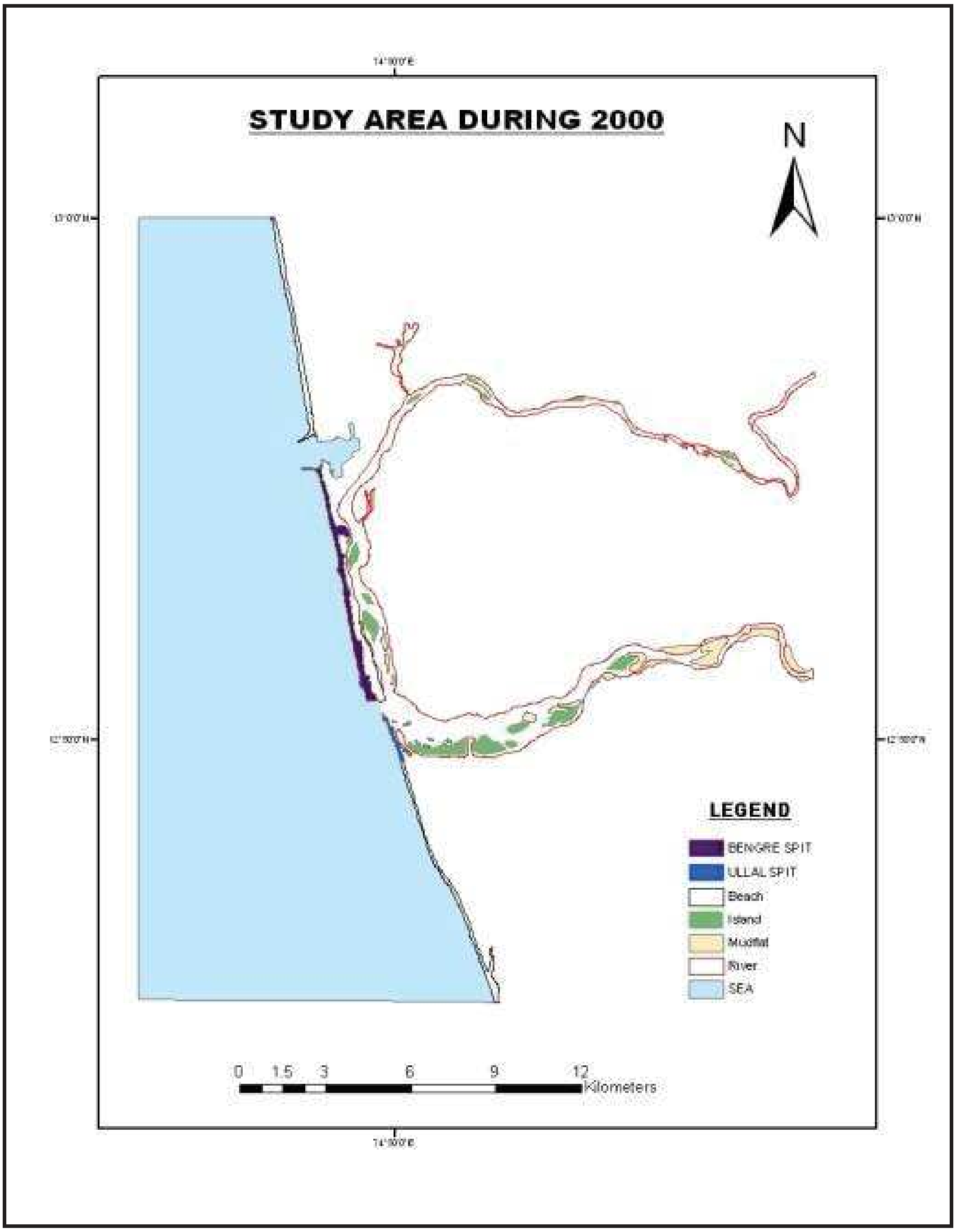

Figure 4: *Nethravahti - Gurupura Estuary during 2000*

Figure 5: *Nethravathi - Gurupura Estuary during 2004*

Figure 6: *Nethravahti - Gurupura Estuary during 2007. Siltation and Sand Bars are Noticed on the Southern Side of the Estuary (Courtesy: Google Earth)*

Figure 7: *Nethravathi-Gurupura Estuary during 2007. The Ullal Breakwater was very Stable during that Period.*

Figure 8: *Nethravathii-Gurupura Estuary during 2009, the Breakwater Started Collapsing.*

Figure 9: *Ullala Breakwater during 2004*

Figure 10: *Ullal Breakwater during 2010. The Breakwater Severely Damaged.*

Figure 11A:

Figure 11B:

Figure 11 - A & B: *Part of the Bengre Spit as Viewed by Google Images (2006). The Drowned Ship on the Western Side of the Bengre Spit is acting as a Breakwater, due to this, the Bengre Spit showing Accretional Trend.*

Based on the beach profiling study Jayappa (1996) also made similar kind of observations. According to Reddy et al., (1978, 1982) the predominance of southerly drift of the coastal currents during major part of the year could be responsible for the growth of Bengre spit. Overall, the study area experiences accretion, except at few stretches where the erosion is more than the accretion. An evaluation of depositional and erosional landforms of coastal Zone of Mangalore indicates that the area covered by depositional features marginally exceed those under erosion. The presence of paleo beach ridges in the northern sector (near Panambur), presence of river terraces on either sides of the river banks of Nethavathi river, presence of oyster shells above the present high tide line near Suratkal (Subrahmanya, 1996b), presence of paleo-tidal flats around Nethravathi- Gurupur estuary, the shallowing of the near shore zone to the north of Mangalore (Gangadhara Bhat and Subrahmanya, 2000), all these point to emergence of land in this sector. Tide gauge records of Mangalore area which indicate a relative fall in sea-level of about 1mm/year substantiate this inference.

Conclusions:

The multidated data products study indicated the growth and migration of barrier spits and erosion and accretion of beaches, which in some areas are situated adjacent to coastal engineering structures. On the whole there is predominance of the depositional landforms like the barrier beaches, spits, paleo tidal flats and beach ridges. This clearly demonstrates that the southern Karnataka coast is an accretion coast. In addition to the alongshore littoral drift, the ongoing up warp along the Mulki-Pulicat lake axis is contributing to continuous modification of the shoreline.

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