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Long and Short-Term Shoreline Changes Along Mangalore Coast, India

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ABSTRACT: Eighteen kilometers long coastal stretch from the New Mangalore Port in the north to Talapadi in the south has been studied in order to understand shoreline changes and erosion/ accretion patterns that have taken place due to the natural processes and anthropogenic activities. Shoreline changes and quantification of beach erosion/accretion were made using the Survey of India topomap, multidated satellite images and beach profile surveys. During 1967-97 period, most of the beaches were accreted, except those lie just towards south of the Netravati and Gurpur river mouth in Sector III. During 1997-2001 period also, the beaches showed accretion trend, but they were subjected to severe erosion during 2001-05 in all the four sectors. The beaches in Sectors I-III are polluted due to discharges of effluents and very poor maintenance.

Key words: Beach erosion, Shoreline changes, Natural processes, Anthropogenic activities

INTRODUCTION

Mangalore is located at 12.87° N 74.88° E with the Arabian Sea in the west and the Western Ghats in the east. It is being one of the major cities on the Karnataka coast gaining economic importance due to urbanisation and industrialisation. It has an average elevation of 45 m with reference to the mean sea level (msl). The Netravati and Gurpur (N-G) rivers encircle the city by flowing around its south and north respectively and debouch into the Arabian Sea at its southern side. It is estimated that out of 290 km length of Karnataka coastline, about 80 km (27.5%) is vulnerable to severe erosion during the SW monsoon (Jayappa *et al.*, 2003). An understanding the rate of change in coastal landforms and shoreline position is important for a wide range of coastal studies, such as development of setback planning, hazard zoning, erosion-accretion patterns, regional sediment budgets and conceptual or predictive modeling of coastal morphodynamics (Sherman and Bauer, 1993; Zuzek *et al.*, 2003). The morphological and shoreline changes in this region are dependant on many factors, such as beach erosion/accretion, human interference with natural processes of longshore sediment transport and beach reclamation. Erosion control is one of the important aspects of coastal zone management and the degree of management required depends on density of population, extent of development of the region and the intensity of erosion.

Over the past few decades, remote sensing and geographical information system (GIS) techniques have led to improvements in coastal geomorphological studies. These include determination of shorelines changes (Singh, 1989, Ryu *et al.*, 2002; Yamano *et al.*, 2006); identification of relative changes among coastal units (Siddiqui, and Maajid, 2004, Jayappa *et al.*, 2006) and their integrated GIS analysis (White and El Asmar, 1999).Based on field studies and remote sensing techniques, the present study attempts to understand the long and short-term shoreline changes (from 1967 to 2005) and the processes that operate in bringing about erosion and deposition along this coastal zone. Width of the beaches has been reduced to zero at some places, due to reduction in sediment supply and anthropogenic activities such as construction of

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breakwaters and seawalls. Damming of rivers which cut off the major source of sediments for many coastal systems (Griggs, 1987; Addad and Martins-Neto, 2000) and the breakwaters, groynes and jetties reduce the normal longshore drift (Frihy, 2001). Relative sea-level change, wave energy, shape and location of beach (Pilkey and Thieler, 1992) are the other causes of erosion. Relative sea-level rise is a global problem mostly due to greenhouse effects and the subsequent melting of the Artic and Antarctic ice sheets, as well as many glaciers. Most models predict a eustatic sea-level rise of 0.5 – 2.0 meters above present sea level by the year 2100 (White, 1990).

This paper also deals with the impact of human interference on beach erosion by construction of ports, breakwaters on either side of navigation channels, seawalls, vented dams, mining, industrialisation and urbanisation. The study area comprising a total length of 18 km, extends from the New Mangalore Port (NMP) in the north to Talpadi in the south. It is divided into four sectors in order to understand the erosion/accretion patterns, shoreline changes, pollution and impact of anthropogenic activities on beach morphology. NMP to Thannirbhavi forms Sector I, Thannirbhavi to N-G River mouth is Sector II, N-G River mouth to Someshwar rock outcrop is Sector III, and Someshwar rock outcrop to Talapadi is Sector IV (Fig. 1). The beaches are fine to coarse sandy in nature with their width ranging between 20 and 230 m. Bengre, Kotepura and Ullal are the most densely populated zones in the study area. Of these, the beaches fronting the latter two have been experiencing severe erosion since the last three to four decades. However, Thannirbhavi and Someshwar beaches have gained recreational importance.

MATERIAL & METHODS

Indian Remote Sensing Satellites IRS-1C/1D LISS-III images (acquired during low-tide time) of January 1997 and December 2001, 2005 of the study area were procured and made use of in order to understand long and short-term beach morphological and shoreline changes. For this purpose, available cloud-free remote sensing data were analysed using digital image processing techniques. Beach width and shoreline changes have been carried out by comparing the Survey of India (SOI) topographic map (48 L/13) of 1967 edition with the satellite data. All the images were rectified (GCPs < 0.5 pixel) with reference to SOI topographic map and False Colour Composites (FCCs) were generated on 1:50,000 scale.

Shoreline detections by automatic (Ryu *et al.*, 2002; Loos and Niemann, 2002; Yamano *et al.*, 2006) and manual digitisation techniques are complicated due to presence of water saturated zones in the vicinity of the land water boundary. Several processing methods like post-classification comparison, change vector analysis and image-differencing (Gordon, 1980; Jensen and Toll, 1982; Quarmby and Cushnie, 1989; Singh, 1989; Lambin and Strahler, 1994; Lillesand and Kiefer, 2000) are followed using multi-dated remotely sensed data in order to extract the changes in shoreline positions. Vector layers were created from the above mentioned satellite data products and the topomap using ArcGIS software. Finally, progradation/recession of shoreline were measured at about 100 m interval to evaluate long-term (1967-97) and short-term (1997-2001 & 2001-05) changes (Fig.2). Rate of erosion/accretion were also calculated for all the four sectors (Fig. 3). The results obtained were verified by field checks. Sixteen beach profiles measured at four stations (one each in I & II sectors and two in III sector) using leveling method from reference points to low-waterline during low-tide time between 1980 and 2005 were selected for this study (Fig. 4). A simple instrument fabricated for this purpose by mounting a telescope and spirit level on a fixed stand was used.

RESULTS & DISCUSSION

Long and short-term shoreline changes as well as erosion/accretion patterns have been estimated by comparing topographic map of 1967 with multidated satellite images and beach profile surveys conducted between 1980 and 2005. Shoreline changes, erosion/accretion patterns and pollution aspects are discussed in this paper. Causes for beach erosion and shoreline recession are also debated.

Sector I extends for about 2 km with a pair of breakwaters in the north, on either side of the approach channel to the NMP. Rubble mound breakwaters of 570 m length constructed in late 1960's, and extended by another 200 m in 1977,

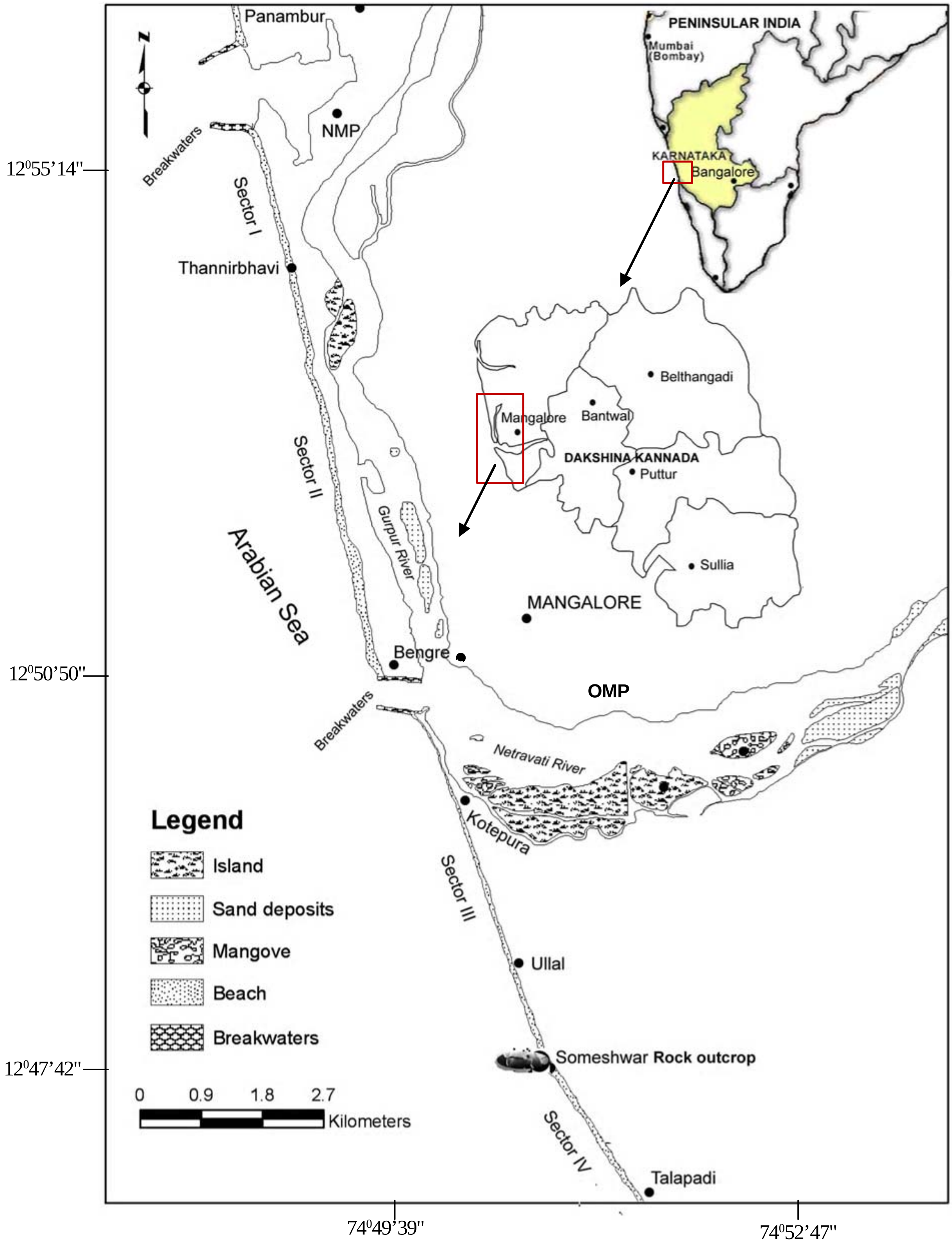

Fig. 1. Map showing the location of the study area

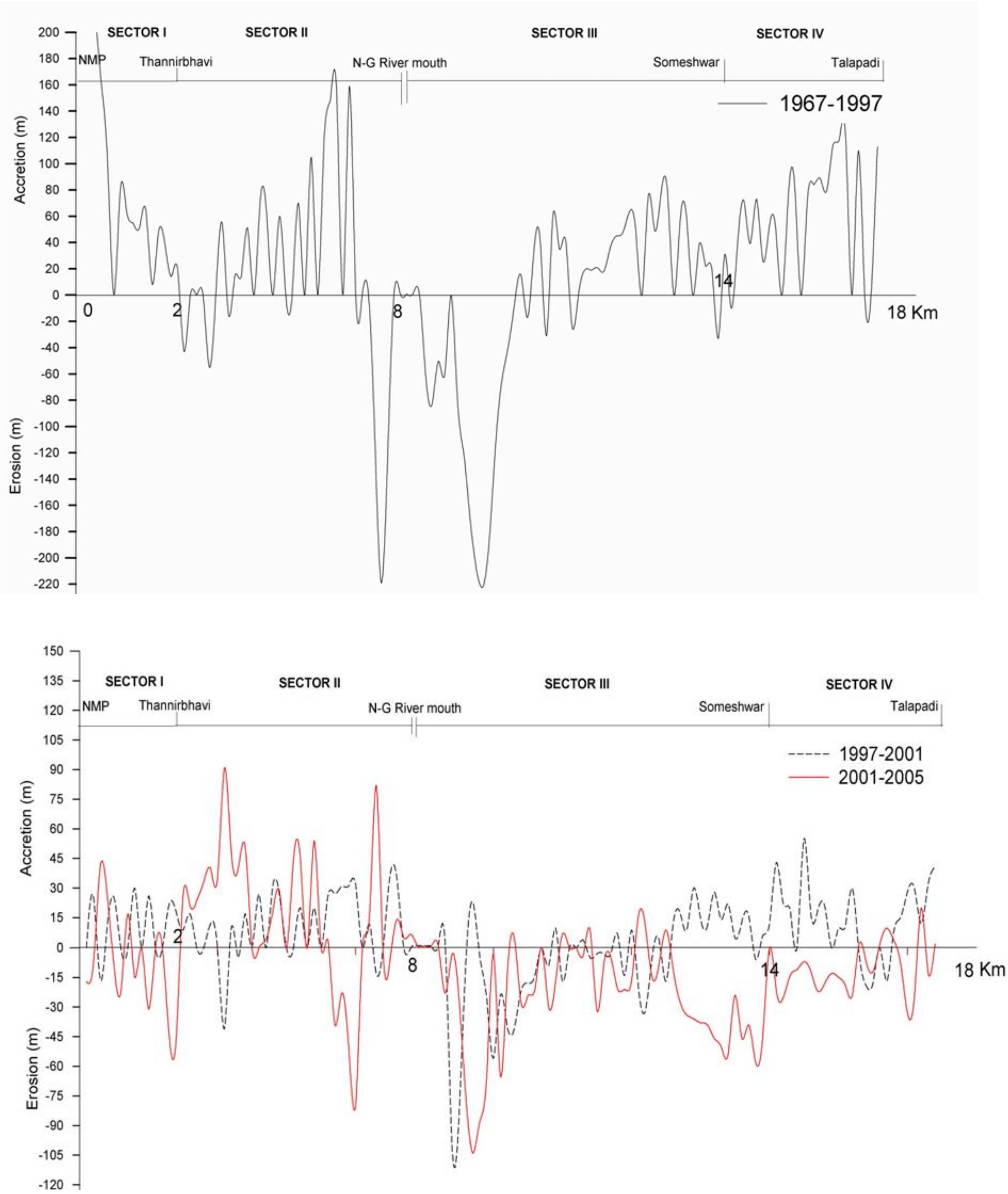

Fig. 2. Long-term (1967-1997) and short-term (1997-2001 & 2001-2005) changes in accretion and erosion patterns in all the four sectors

has resulted in slight building up of beach face on either side of the approach channel and seaward shifting of shoreline (Jayappa *et al.*, 2003). The shoreline of this sector was prograded by 10-80 m and the net accretion was about 30 acres during 1967-97. It further prograded by 10-30 m except recession of ~10 m at few places and about 10 acres of beach area was developed during 1997-2001. However, during 2001-05 periods, the shoreline further prograded by ~10-30 m at some places and receded by 20-60 m at other places. The net erosion was about 3 acres during this period (Figs. 2 & 3). Beach and near shore profiles measured during 1984-85 at Thannirbhavi

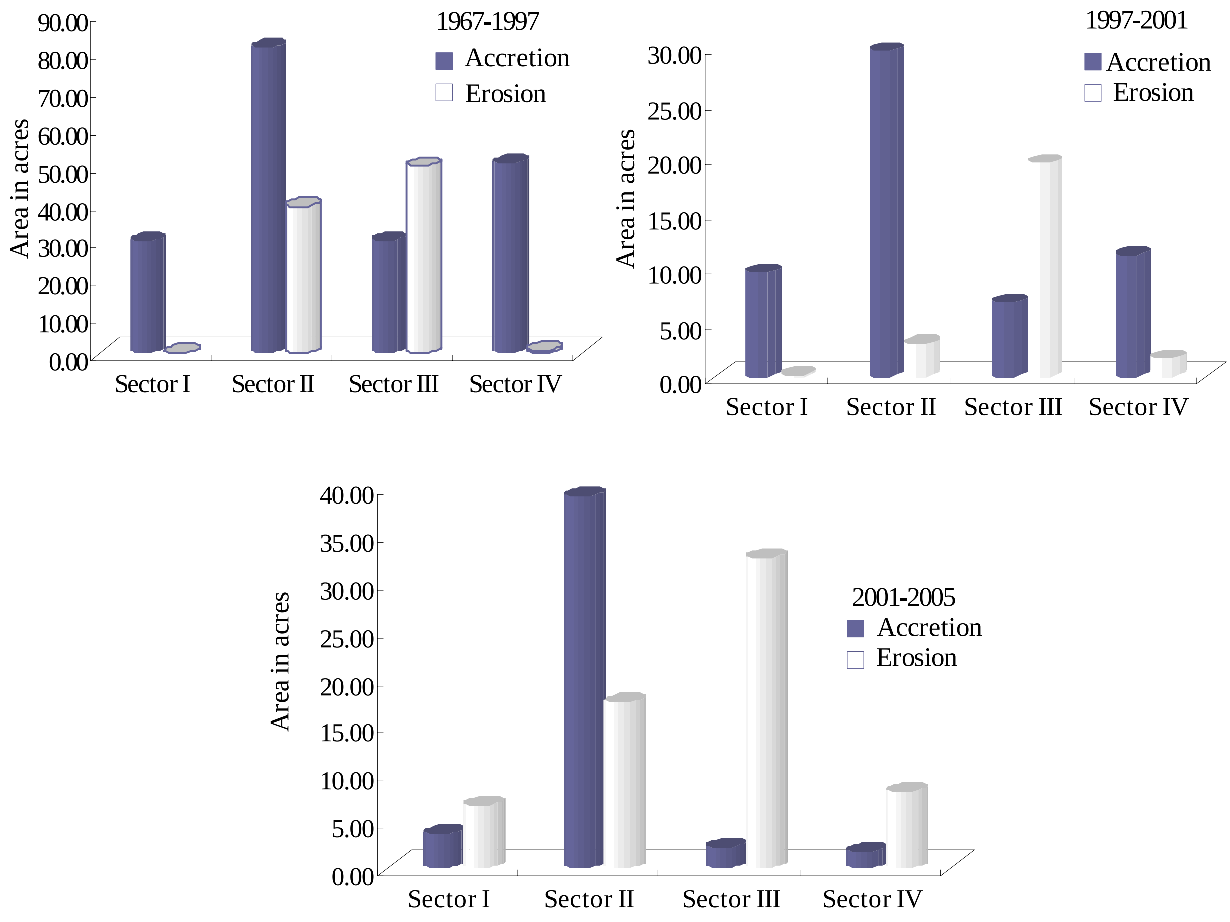

Fig. 3. Bar diagram showing rate of changes in areal extent of beaches during the last 38 years

do not show much variation except seasonal movement of sediment in onshore-offshore directions. However, due to replenishment of this beach in January 2000 width and height of the beach increased by about 100 m and 1 m respectively (Fig. 4a). Overall, this sector accreted except minor erosion in the southern portion during 2001-05.

Daily, about 15,000-40,000 m^3 and 7,200-13,000 m^3 of effluents are discharged to this sector from the Kuduremukh Iron Ore Company Ltd. (KIOCL) and Mangalore Chemical Fertilizers (MCF) respectively. The main effluents released by MCF are ammonia, smaller quantities of chromium and vanadium, while, KIOCL releases non-recoverable particulate metals with high pH value (Bhat and Bhatta, 1999-2001). In addition to these, municipality solid and liquid wastes released to these beaches are also playing a major role in polluting the beach and coastal waters of this sector.

Thannirbhavi to the N-G river mouth measuring about 6 km length forms Sector II. The southern tip of this sector ends with a pair of breakwaters on either side of approach channel to the Old Mangalore Port (OMP). To prevent beach erosion, half a km length of seawall was constructed on an experimental basis at the Bengre tip in 1984-85. After this, the beach not only became stable but also started growing. Beach sediment volume changes estimated on annual basis reveals that about 45 m^3 of sediment per meter length of beach was added annually during 1985-86 (Jayappa and Subrahmanya, 1989). In order to prevent boat capsizing and littoral drift entering into the N-G estuary, breakwaters were constructed in early 1990s on either side of the approach channel to the OMP. Subsequently, accumulation of sediment and seaward shifting of shoreline continued on the Bengre side, and severe erosion began at the Kotepura beach. The shoreline of this sector was prograded by about

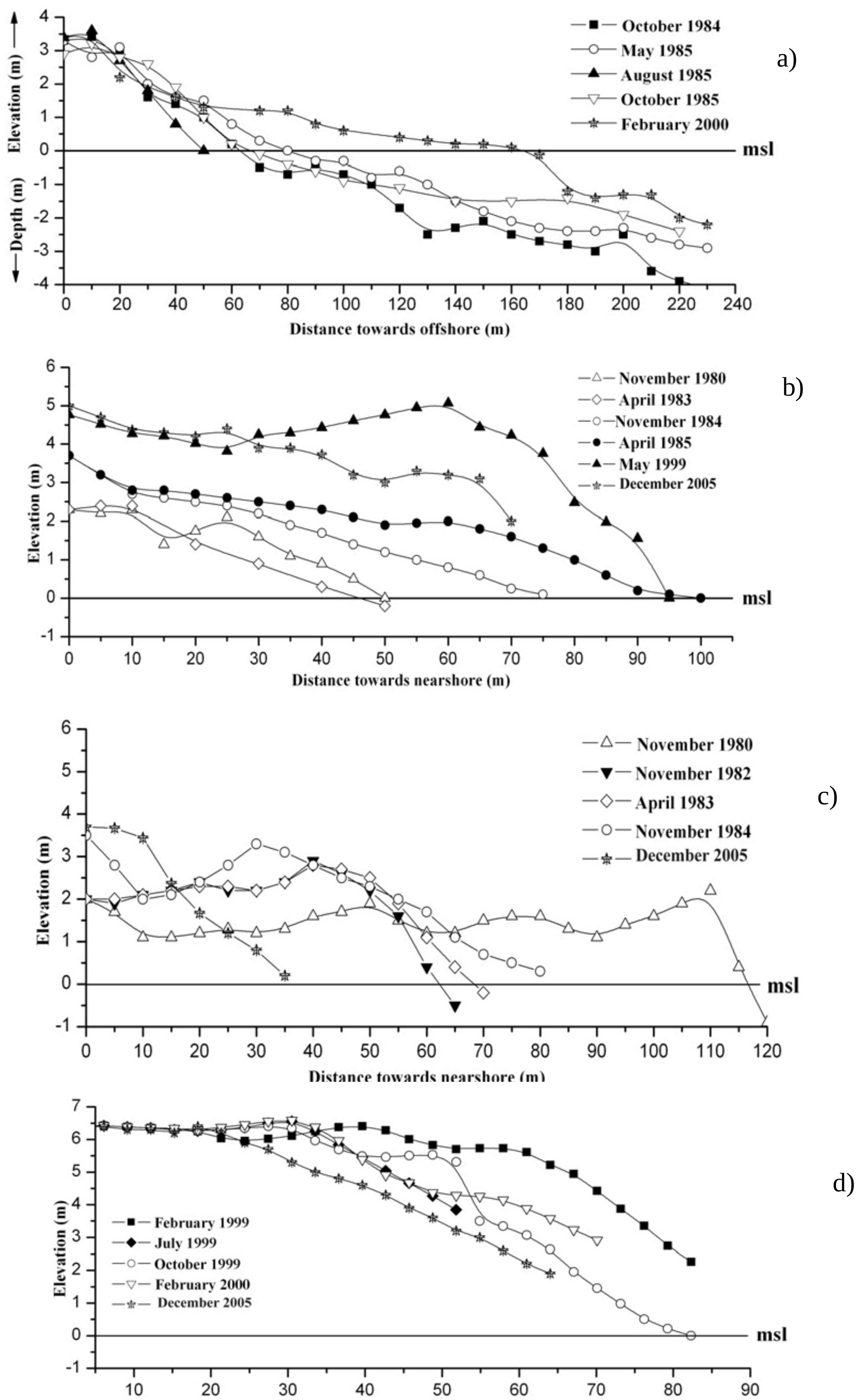

Fig. 4. Beach and nearshore profiles of Thannirbhavi (a). Beach profiles of Bengre (b); Kotepura (c); and Ullal (d)

10-120 m at some places and receded by 60-200 m at other places with a net accretion of ~42 acres during 1967-97 periods. The shoreline was further prograded by 10-45 m except recession of 5-40 m at few places during 1997-2001. The net accretion during this period was about 26 acres. During 2001-05 period, the shoreline further prograded by ~10-80 m with net accretion of ~22 acres. At one stretch (~ a km north of the northern breakwater), it receded by 10-80 m (Figs. 2 & 3). Profiles of the Bengre beach clearly indicate that it was narrow (~50 m) in 1980-83 period, but increased by 25-50 m in 1984-85 and the shoreline reached up to the proximal end of the breakwater. Between April 1985 and December 2005 period, the beach has grown vertically by 2.5-3.0 m (Fig. 4b). Solid waste brought by the rivers and oil pollutants released due to ship breaking are brought back to this beach by waves and currents (Plate 1). These pollutants are noticed during almost all the field surveys on this sector.

Sector III extends from the N-G river mouth to Someshwar for about 5.5 km with a breakwater at its northern tip. Severely eroding beaches - Kotepura and Ullal - lie in this sector. During 1967-97, the shoreline receded in the northern portion by about 20-220 m and the beach area eroded by an order of ~50 acres. Whereas, the shoreline in the southern part of this sector prograded by 10-80 m and the beach area accreted by an order of ~30 acres. The shoreline was further prograded by 10-60 m in the southern part and receded by 10-100 m in the northern part (Kotepura) with net erosion of ~12 acres during 1997-2001. However, during 2001-05, severe erosion and shoreline recession of 30-100 m was continued in this sector excepting progradation of 5-20 m at two locations in the north and four locations in the south. The net erosion was about 30 acres during this period, which is more than double compared to 1997-2001 period (Figs. 2 & 3).

The width of the Kotepura beach was ~120 m during November 1980, reduced to 70 m during 1982-84 period and further reduced to <40 m in December 2005 (Fig. 4c). Therefore, totally ~80 m width of this beach is eroded in the last 25 years. Further south at Ullal, there is no much change in beach morphology, but is subjected to erosion during the SW monsoon and attained original profile during fair weather seasons (Fig. 4d). Profiles of Bengre and Kotepura show progradation on the updrift side (at Bengre) and erosion on the

Plate 1. Loss of beach and property at Kotepura due to impact of storm waves

downdrift side (at Kotepura) of breakwaters. To save the beaches of this sector, about 4 km cumulative length of seawalls were constructed but they failed to serve the purpose with which they were constructed. Every year 5-10 houses are being collapsed during the SW monsoon (Plate 2). In the last 10 years, quite a few small-scale industries and buildings have been constructed along the Ullal spit (Plate 3).The concentration of industries and disposal of their effluents and municipal drains to estuaries, rivers or nearshore waters cause water pollution. The haphazard dumping of fish-wastes near fish landing centers, processing of fish catch and large number of ice factories also cause water pollution. About 39 percent of the total fish catch is subjected to curing, canning, and 16 percent used for fishmeal, manure and oil extraction.The N-G estuaries are considerably affected by the discharge of sewage from the Mangalore city.

Plate 2. Solid waste pollution at Bengre beach

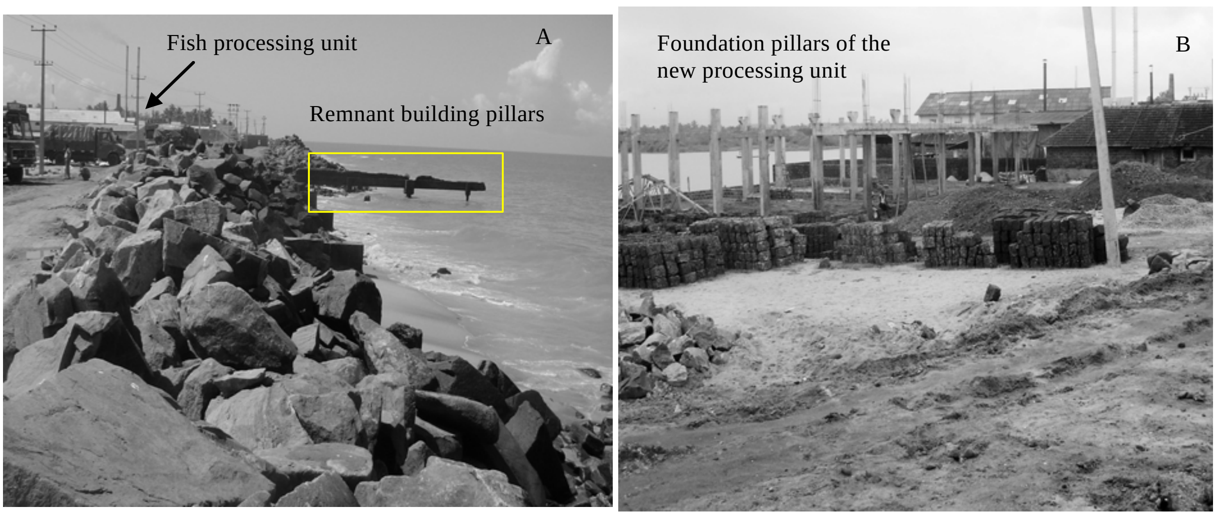

Plate 3. Establishment of fish processing unit and new building construction at the Ullal spit

Beaches from the Someshwar to Talapadi with a total length of about 3.5 km constitute Sector IV. The beaches of this sector are open and relatively stable in nature. The shoreline has prograded by 30-140 m but the rate of progradation has increased from north to south. The net area accreted has been estimated to be ~50 acres during 1967-97 periods. Between 1997 and 2001, the shoreline further prograded by ~20-60 m except receding by ~25 m in the middle portion with net accretion of ~10 acres. However, during 2001-05, this sector also prone to severe erosion and shoreline is receded almost everywhere by ~20-30 m, except prograding at two locations in the northern part by ~10-20 m with net erosion of ~6 acres (Figs.2 &3). Towards south of the Someshwar rock outcrop (Fig.1). monthly fluctuations in erosion/accretion pattern and occurrence of rip currents were noticed (Hariharan *et al.,* 1978).

Both the natural and anthropogenic activities are responsible for erosion of this coast.The natural causes include waves, littoral currents, storms, tidal currents, offshore relief and sea-level changes. Erosion/accretion is a cyclic phenomenon, which is normal along this coast. Width of the beaches is reduced greatly during July/August when minimum sediment storage is noticed on the beaches. The beaches attain maximum width during April/May when maximum sediment is stored on them. Although large-scale erosion is found in all the sectors during the SW monsoon, the lost sand is regained after the monsoon. However, this kind of balance is not found in the Kotepura and Ullal beaches of sector III. In addition to these, relative decrease in the annual average rainfall and sediment discharge, which have direct and indirect impact on shoreline changes. Annually the N-G Rivers deliver 12,015 Mm^3 and 2,822 Mm^3 of water and 1.47 Mm^3 and 0.105 Mm^3 tonnes of sediment respectively into the sea (Karnataka Irrigation Dept.,1986). Compiling the last 9 years (1997-2005), it has been found that during 1997, '98 and '99 the rainfall was close to normal and reduced gradually by about 200 mm during 2000 and 2001. Whereas, during 2001-05, it was much below (~600 mm) the normal in all the taluks of this district (Fig.5). Decrease in rainfall has been attributed to reduction of sediment input to the beaches.

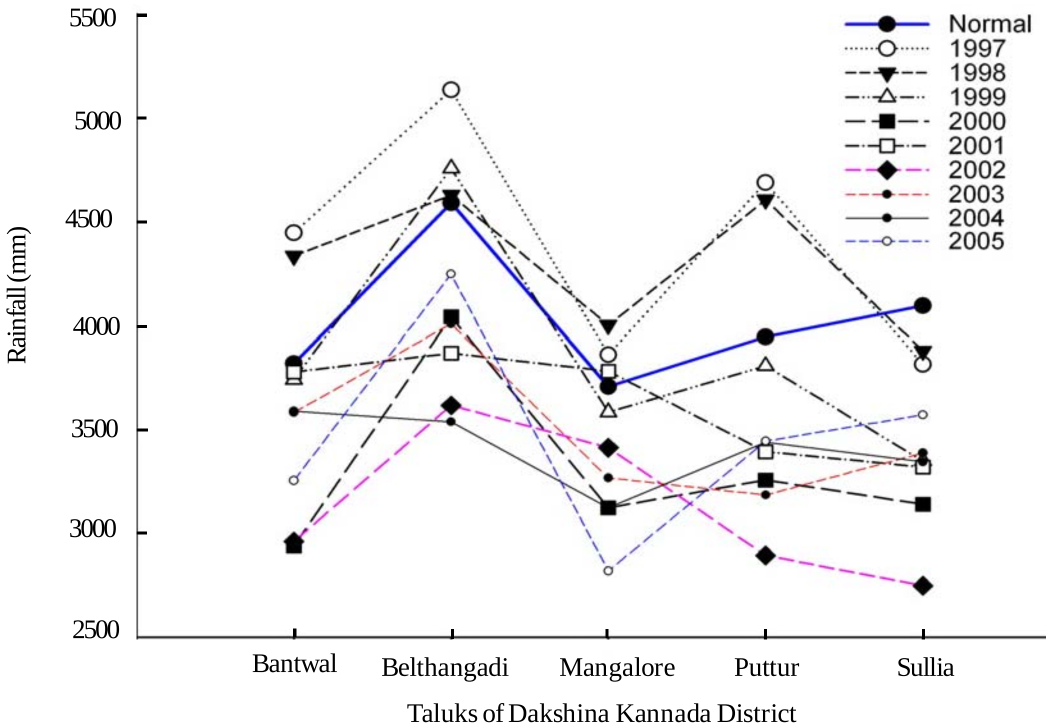

Fig. 5. Showing variation in the annual average rainfall for last 10 years (Source. Dakshina Kannada at a glance, 2006–2007)

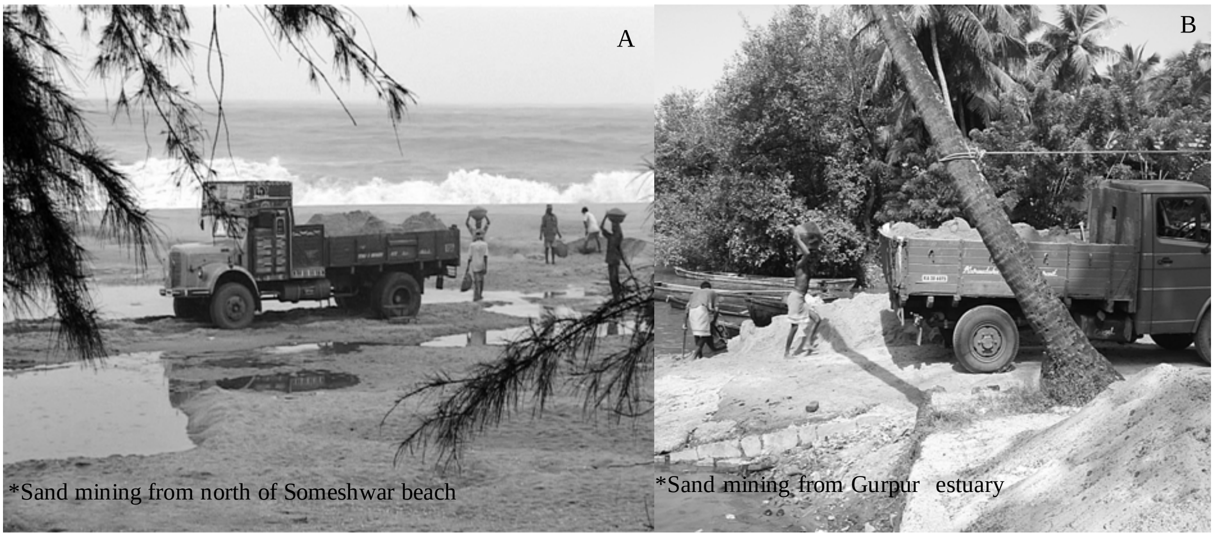

Plate 4. Illegal sand mining directly from the beach at Someshwar (A) and Gurpur estuary (B)

Anthropogenic activities like construction of port and harbour, sand and clay mining, construction of vented dams are also responsible for erosion, reduction in width of beaches and receding of shoreline in the study area. Substantial increase in the quantity of sand mining has lead to accelerated erosion of the coast in recent years. About 10^5 tonnes/year of silica sand and 3 M tonnes/year of clay were mined from the riverbanks and alluvial plains (Coastal Zone Management, 2003). Sand is dredged both legally and illegally from beaches, estuaries and in the upstream for various developmental activities. Illegal sand mining at the Someshwar beach (Plate 4A), from the N-G estuaries and in the upstream (Plate 4B) is going on. This direct loss of material affects the dynamic equilibrium of the beaches and leads to erosion. Vented dams have been constructed at Tumbe, Joyikallu and other places across the N-G Rivers to provide water for industries, drinking and irrigation purposes and ground water recharge in the Dakshina Kannada district. Due to construction of these dams, a major portion of sediment is withheld during the fag end of monsoon and post-monsoon seasons and sediment supply has been drastically reduced. In addition to these, deforestation, urbanization and infrastructure development have created major impact on coastal environments by accelerating erosion rates and effecting changes in sediment inputs. Construction of seawalls has resulted in shifting of erosion sites from one place to another, whereas, breakwaters have been acting as barriers for littoral drift.

CONCLUSIONS

The study reveals that the shoreline has prograded by 10 to 120 m and receded by 10-260 m. The net accretion of sector “I” is about 29 and 10 acres between 1967-97 and 1997-2001 respectively. However, during 2001-05 net erosion was about 3 acres. The maximum progradation is found from the Thannirbhavi to Bengre (Sector II) and recession from the Kotepura to Ullal of Sector III where the beaches are subjected to continuous erosion since 1997. In the southern part of sector III (Someshwar beach), accretion is noticed during 2001-2005. The beaches of sector IV have prograded between 1967 and 2001 but they are receded during 2001-2005 period. Width of beaches has reduced to minimum during the month of July/August and increased to maximum during the month of April/May. Based on variation in beach width and slope on either side of the approach channel to the NMP and OMP, it is inferred that movement of sand from north to south is more than that from south to north. Construction of seawalls has resulted in shifting of erosion sites from one place to another, whereas, breakwaters have been acting as barriers for littoral drift. Sand and clay mining, construction of vented dams and decline in rainfall are the three main factors responsible for decline in sediment supply and beach erosion. The beaches in Sectors I-III are polluted due to discharges of effluents from industries, oil and municipality solid wastes and ship breaking. Regulation of sand mining from the coastal zone and discharges of effluents without treatment is essential.

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