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**GIS, MULTI-DATE AND MULTI-SOURCE DATA FOR DETERMINING SHORELINE CHANGES:
A CASE FOR GAUTAMI GODAVARI DELTA, EAST COAST OF INDIA**

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ABSTRACT

Accretion and erosion processes in the Godavari delta south of Kakinada in Andhra Pradesh are intense as viewed from changes in the shoreline itself. This was particularly visible in the formation and growth of a 17 km long, narrow sand spit that separates Kakinada Bay from the open sea. With a view to understand the overall dynamics of shoreline changes attributable to major shifts in the River pattern and other geo-morphological events within this delta, the present study was undertaken based on crucial information furnished through British Admiralty charts that date back to 1861, Survey of India toposheets, satellite images of last 20 years and other aids. The findings revealed that the Bay-estuary areas and the 'Hope Island' emerged fairly rapidly until 1930's with an average of 15-20 ha/year caused by heavy import of sediments from the Gautami Godavari River. During the second half of last century when River Godavari shifted its course, deposition became less prominent there but the activity moved southwards. At present, the whole area is involved in an erosion phase except at Nilarevu mouth. In the paper, an attempt is made to explain these phenomena vis-à-vis the causative agencies both natural (e.g. inshore currents, littoral drift) and man-made processes such as port expansion episodes etc.

Introduction

River Godavari, the second longest in India, has its origin in the Western Ghats. After flowing through considerable distance eastward, the River divides in its lower reaches into two, and one of the distributaries namely Gautami Godavari joins the sea south of Kakinada in Andhra Pradesh where it forms a large delta. One of the main features of Gautami Godavari is that in the dry season (April-June) while its flow is almost nonexistent, during monsoon (July-September) it swells and discharges enormous sediment loads into the recipient systems. For the same reason, the accretion and erosion process in the delta are intense, as can be shown by changes in the shoreline itself. The Coringa Wildlife Sanctuary representing one of India's largest mangrove ecosystems is located here. Within a wider project focusing on the study of the degradation and resilience of these mangroves, it was necessary to understand the evolution of the whole area, knowing that the status of the mangroves depends for a large part on processes occurring not necessarily within the mangrove areas. Over the years, Godavari delta underwent massive topographical changes and remained a major theme for research (e.g. Mahadevan and Prasada Rao, 1958; Sastry, 1958; Subba Rao, 1967; Ramanadham et al., 1971a, 1971b; Reddy and Prasad, 1982). The Godavari point was originally indistinguishable from other sand bars at the mouth of the Godavari River, but floods and deforestation of the Godavari delta caused more of the river to discharge in the open sea than into Kakinada Bay. Increased sedimentation thus began to flow up the coast and deposit at Godavari Point, which has grown for the past century from south to north at the rate of about 8 miles in 100 years (La Fond, 1966). More recent studies even attempted to predict whether the Bay mouth would eventually silt bringing about a near closure of Kakinada Port (Sharma, 1996; Ramkumar, 2000). On account of these developments and keeping in view their topical value, the present study was undertaken to find out the overall dynamics of shoreline changes in this area as a result of major shifts in the River pattern and other associated events during the last 100 years or so. The hypothesis proposed by us is based on an important amount of data obtained through British Admiralty charts dating back to 1861, Survey of India toposheets, and remote sensing. The area of this study lies between Kakinada and Kotapalem.

Study area

The Bay/Mangrove/Estuary complex at Kakinada is located in East Godavari District in Andhra Pradesh (Latitude 16°35' - 17°00', Longitude 82°10' - 82°23'). River Godavari constitutes the main feature of this area. The River flows initially through a large alluvial plain and in the lower reaches culminates in a vast delta encompassing several islands and sandbars before joining the sea at Bhairavapalem. Many distributaries emanate from River Godavari and at least seven known major mouths existed for this river (Gazetteer of India, 1979). Mangroves formed important coastal vegetation of this area and Coringa was declared as Wildlife Sanctuary in 1972. An important aspect of flow characteristics of Godavari is related to Dowlaiswaram barrage, also known as Sir Arthur Cotton Barrage. Built in 1850s, the barrage controls the flow from River Godavari. Its repartition during a year shows two very different periods. The period November to June is marked by negligible freshwater. However, during July-October months coinciding with southwest monsoon, the discharge of freshwater could reach up to 15,000 m³/s. Another important seasonal feature is related to the presence of littoral currents along this coast that exhibit a complete reversal of events depending on the prevailing wind systems. These currents also largely determine the hydrographical conditions in the sea. Off Kakinada, the current direction is northerly during March-July coinciding with strong South West winds. This period is also marked by littoral drift when considerable amounts of sand are deposited on the coast (La Fond, 1966). The southerly current on the other hand is noticed from July to December when low salinity conditions prevail in the sea.

Data used and Methodology

During the study, data on shoreline changes have been extracted from different sources: IRS-1C LISS3 image of 1999, LANDSAT 5 TM image of 1993, LANDSAT 2 MSS image of 1977. They have been first geo-referenced in UTM projection, based on ground control points obtained with a GPS. Then, the extraction of the shoreline was performed based on unsupervised classifications using the ISODATA algorithm of Erdas Imagine software. With ground truth it was possible to identify the shoreline as corresponding to high tide. Other sources of information were the toposheet of 1941 and six Admiralty Charts dating between 1861 and 1929. While it was not possible to consider all available Admiralty charts in the GIS analysis (for reasons of accuracy), only two of

them (years 1893 and 1929) with useful data were selected. The maps were scanned, vectorised using Arc Info software and geo-referenced based on 1999 and 1993 satellite images, through the best available common control points. At the end, six vector layers were obtained containing shoreline and the main river course for years 1893, 1929, 1941, 1977, 1993 and 1999. Overlay techniques then followed. The six layers generated have been overlaid using logical operations such as addition and multiplication. For example, areas of coastal erosion or accretion could be estimated using multi-temporal coastline maps. For the purpose of this study, the analysis was focused on 4 select zones that best described the overall trends for the whole area. These included 1) area around Kakinada Harbour, 2) mangrove areas of Kakinada bay, 3) Hope Island (sand spit) and 4) the coast around Nilarevu mouth.

Results

Changes in the main River course

Figure 1 shows two major shifts in its main course for River Godavari since the construction of Dowlaiswaram barrage in 1850, same time the sand spit began to form. Until 1930, Godavari was flowing northwards into Gaderu opening into Kakinada bay. Between 1930 and 1970 its course, however, shifted gradually southwards through Nilarevu channel. Since the 70s and until now, Godavari is flowing eastwards.

Harbour area

The harbour area (Figs. 2a & 2b) has been subject to a process of continuous sedimentation for several decades now (1893 and 1993). Over the years, the land area increased by about 5 ha per year on an average, with an exception between 1929 and 1941 when the increase was up to 25 ha per year. There was considerable accretion along the shore and the result was that two new harbours were built, one in the 70s and the other in early 90s. A wave-breaker was built in 1994-'95. The consequence since this date has been erosion just north of the first Harbour (built in the 70s) at the rate of about 6 ha/year.

Estuary area

Between years 1893 and 1941, Kakinada Bay and adjoining swamps were directly under the influence of heavy loads of sediment derived from Gautami Godavari and this was evident by the very rapid extension of land into the bay up to 35 ha/year (Fig. 3). From this date, that corresponds to the first shift of the river course, the rate at which sedimentation took place decreased (average of 10 ha/year). In the 1990s, there was a marked acceleration attributable to the construction of a wave-breaker and erosion in the harbour area. Accretion remains active in the western part of the bay when the eastern part is slowly eroded. It is noteworthy that in July-September a clockwise circulation is set up in Kakinada Bay, caused by the southerly current (Ramasarma, 1965), leading to a movement of sediments in that direction.

Hope Island

The Hope Island (sand spit) appeared to have had a similar evolution (Fig.4). It increased prominently up to 1940s but slowed down subsequently. This is probably suggestive that the sand spit would eventually stop its progression.

Nilarevu mouth

The region at Nilarevu, south of the mangrove area, reveals somewhat different dynamics that can be summarised in 3 phases, corresponding to the 3 river directions (Figs. 5a & 5b). In each case, the area at the river mouth underwent rapid accretion (hook shape) culminating in the formation of a bay. However, following a change in the river course, the shoreline along some pockets was eroded.

Discussion

The frequent and often marked changes in the River main course are due mainly to 1) the absence of relief in this alluvial area, 2) the pre-existence of many former channels, more or less filled by sediments, 3) the very high flow variations depending on the season, and 4) the frequency of cyclonic events. Gautami Godavari is

progressively filled every year by sediments deposited in the riverbed and the elevation becomes higher each time. Then during a flood, the river course can change and use a former channel. This process explains the rounded shape of the whole alluvial area.

Comparing different data sources is a basic step to show an evolution. Each kind of data has its specific treatment problems: for toposheets, it is mainly geo-referencing and the difficulty to find places that did not change during the years; satellite images - it is identification of objects, particularly when the image is not recent and that no ground data are available to confirm them. In the present case, the geo-referencing proved difficult precisely because the coastal area was very dynamic. The man-built channels were preferred therefore as an alternate source. The identification of the shoreline was not problematic because water and land have very different spectral signatures. However, one problem was the time of satellite overpass: the tide was not exactly similar at the three dates, especially lower for 1993. This bias can lead to an overestimation of the extent of land areas.

The general dynamics shows a constant increase of the land area even when silting in most area slowed down. This is particularly evident in the case of the harbour area and Kakinada bay. The Southern shore is stable: accretion and erosion are in equilibrium. A sand hook is being created near the major mouth of Gautami, which is gradually changing into bay-like. The latter is then slowly being filled and also eroded by the littoral currents. In this perspective, the sand bar and the Kakinada bay are normal features of sedimentation. Their extraordinary development is due to their position at the Northern end of the alluvial area that protects them against currents moving from South.

The impact of human activities, decadal and recent, proved important for this region. Firstly, the construction of a barrage at Dowlaiswaram is acting as a bulwark for sediments brought by the Godavari River. This explains the general slow down of siltation. In the Kakinada bay, accretion and erosion processes appeared largely accountable to the construction of a new harbour and wave-breaker. These developments, which are of recent origin, tend to modify the direction and strength of littoral currents and thereby keep the Bay open, though erosion still takes place in some pockets.

Conclusions

Multi-source studies are a necessary step to understand ecosystem functioning, highlight major trends and try predicting future events. Satellite images last 30 years can be a very valuable source of information in this regard, but have to be processed correctly. Their integration into a GIS allows a comparison with other data such as toposheets. In the case of Godavari delta, the application of GIS yielded valuable information on deposition and erosion processes in a time scale of 150 years. Based on the findings, it was possible to underline the main processes responsible for physical changes that took place in this area last several decades. The study should now help understand better the ongoing events that could affect mangroves and the near shore environment in the Godavari delta.

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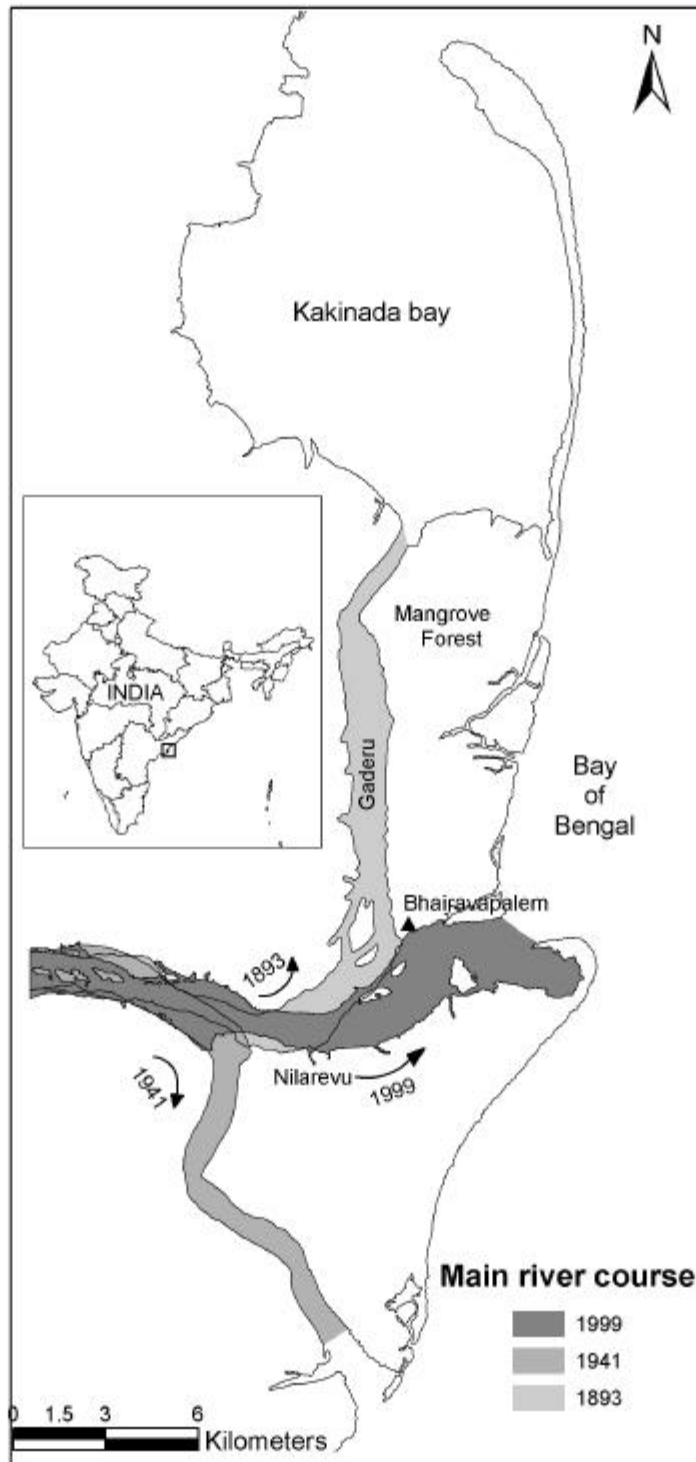


fig-1, Migration of main Godavari river course between 1893 to 1999
 Insert : Study area location map

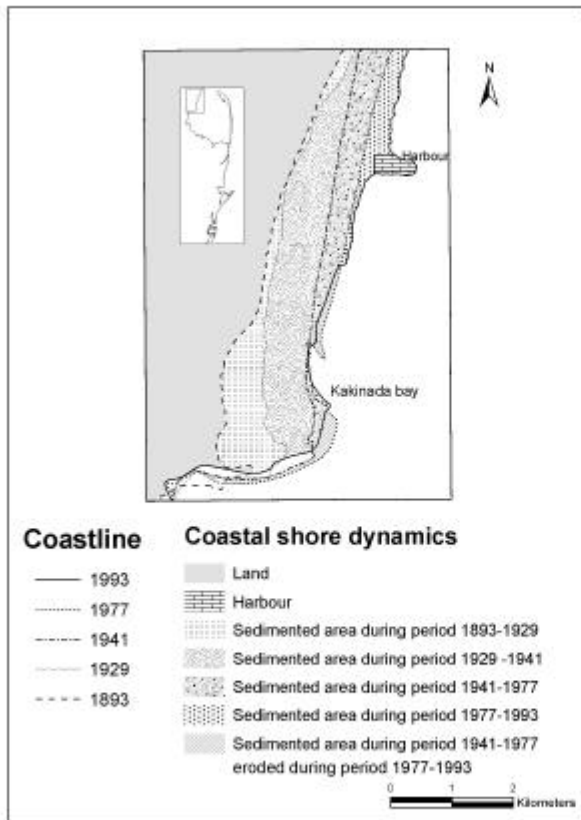


fig-2a, Harbour area evolution between 1893 and 1993

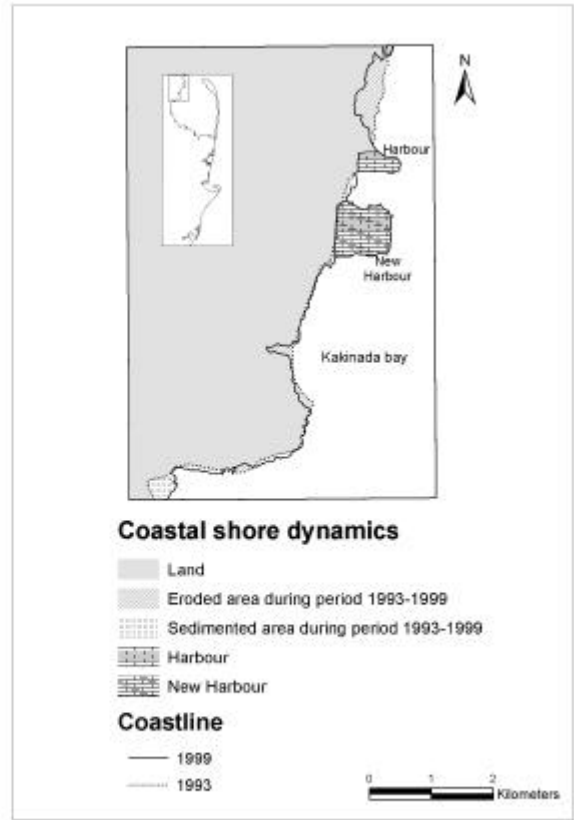


fig-2b, Harbour area evolution between 1993 and 1999

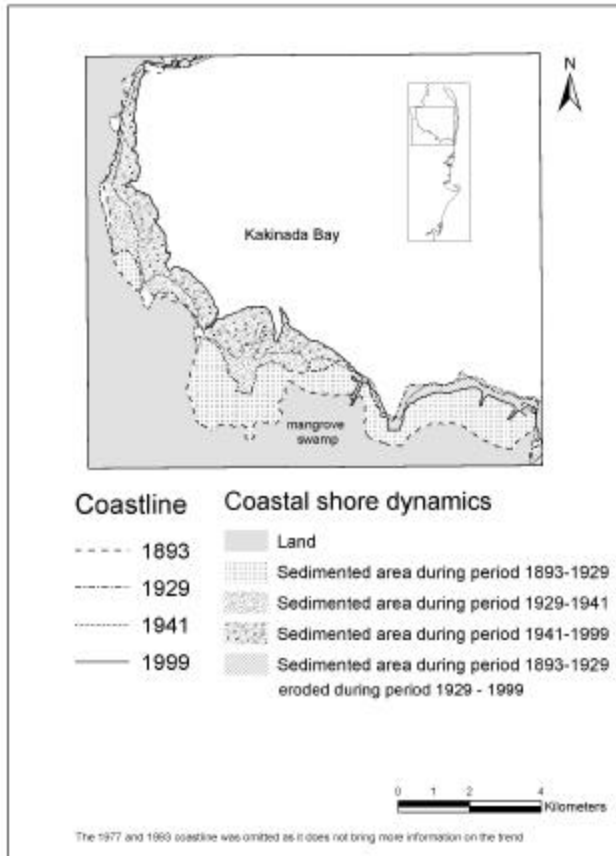


fig-3. Estuary area evolution between 1893 and 1999

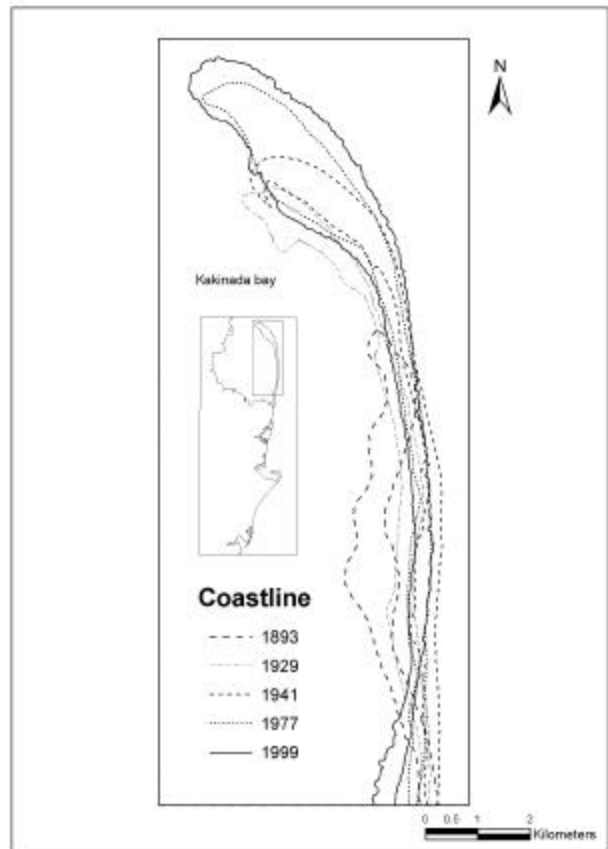


fig-4. Coastline changes in Hope Island between 1893 and 1999

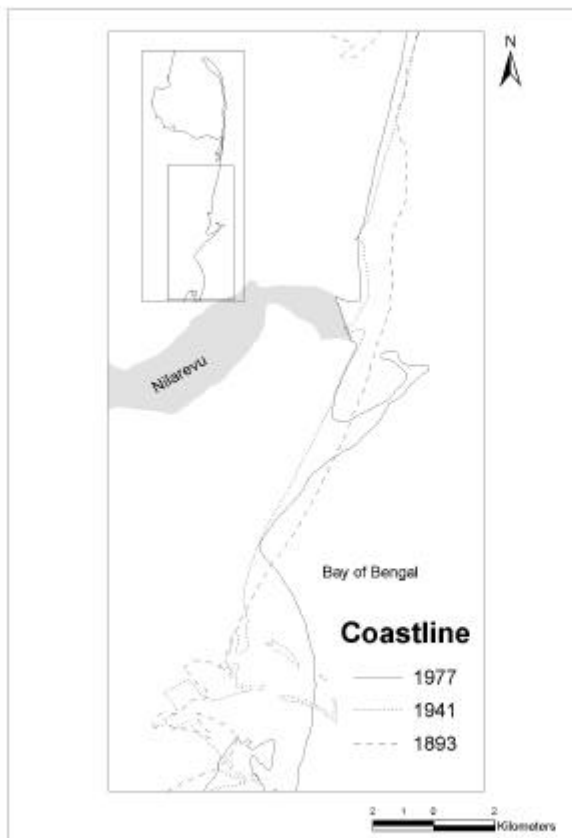


fig-5a, Coastline changes near Nilarevu river mouth between 1893 and 1977

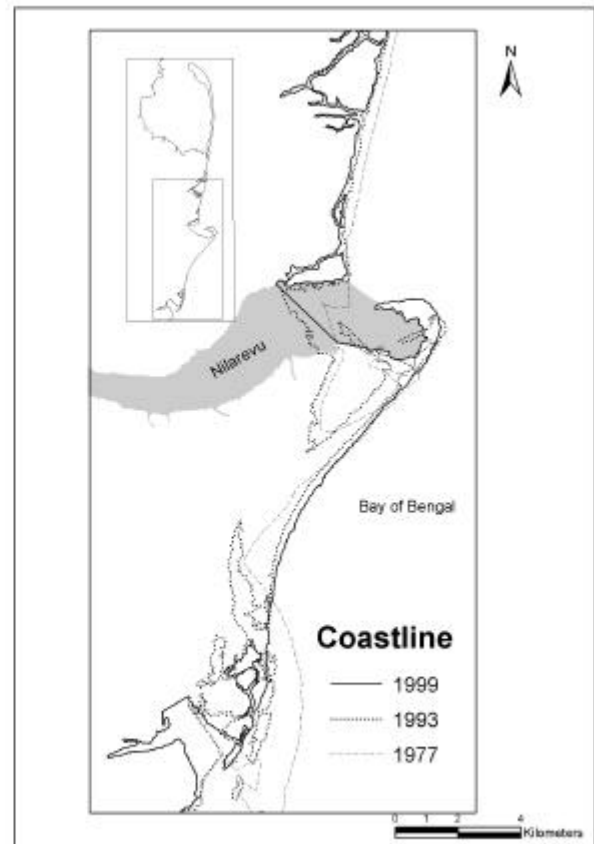


fig-5b, Coastline changes near Nilarevu river mouth between 1977 and 1999

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