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Mangroves of Godavari – analysis through remote sensing approach

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Abstract

The expansion of agriculture and aquaculture farms in the coastal areas has led to conversion of mangroves in the recent past. The extent of mangroves has also changed due to the erosion of mangroves along the coast and accretion near river mouths, leading to the formation of new mangrove areas. This study has been undertaken in the mangroves of the Godavari estuary, Andhra Pradesh, India to understand the changes in the extent of mangroves, namely accreted mangroves, erosion due to wave action and river water flow during floods, and changes due to forest restoration between 1986 and 2001, through remote sensing. The geomorphological changes due to river water flow in and around the mangroves have also been analysed. The changes in the vegetation due to forest restoration and natural regeneration are appreciable, while the changes in the area due to erosion and accretion are more or less equal. An analysis of the remote sensing images of 1986 and 2001 reveal that the mangroves outside the forest boundary have been converted to aquaculture. The sand spit of Hope Island has changed with time and has grown nearly 2.6 km between 1937 and 2001.

Introduction

The mangrove ecosystem is one of the most productive ecosystems. Increase in land use for agriculture and aquaculture, especially near mangroves, has led to the conversion of this important ecosystem. Mangroves are plant communities in tropical and subtropical regions, which live in inter tidal areas inundated by tides. Mangrove plants live in muddy and wet saline soils. They are trees associated with shrubs, growing both on the sheltered coast and inland, lining the bank of estuaries and rivers. They are an ecological group of evergreen plant species, belonging to different families, but possessing marked similarities in their physiological characteristics and structural adaptations. Mangrove areas are associated with high leaf production and leaf fall and rapid decomposition of the litter. Mangrove forests perform multiple ecological functions: they produce woody trees, provide habitat and detritus food for fish and shellfish and act as spawning ground for a variety of fishes, prawns and shellfishes. They harbour a variety of valuable fauna, including migratory birds. They also protect the coasts from storms and tidal waves and help in the formation of land by trapping sediments brought by the river run-off. A significant percentage of the coastal community, especially the fishermen, is traditionally dependent on mangroves for their

domestic needs such as firewood and timber, apart from collecting fishes for their livelihood. Though the mangroves provide a large amount of resources, they are being increasingly cleared for other landuse activities such as settlements, agriculture and shrimp farming.

Remote sensing is used as a tool for monitoring the changes, especially in forests, because the hilly or swampy terrain is inaccessible and vast in area. It provides relatively accurate information regarding the status of vegetation in the forest and is cost-effective and time saving. Geographic Information System (GIS) and remote sensing tools are being extensively used to understand the changes in mangrove areas, for purposes of planning and management. Mangroves have been mapped and monitored for better management through aerial photographs or satellite data, as in Florida (Ramsey and Jensen 1996), Guiana (Sery et al. 1995), Kenya (Brakel 1984), Senegal, Goa and Cauvery in India, Cilacap in Java, Thailand (Silapathong and Blasco 1992) and Ecuador (Klemas and Bartlett 1975; Terchunian et al. 1986). Remote sensing technique is a useful tool to assess and monitor the effectiveness of mangrove restoration and conservation programmes where physical monitoring is difficult (Selvam et al. 2003).

Mangrove areas are commonly characterized by rapid changes, i.e. conversion of the mangroves for other land uses such as shrimp farming, agriculture and industry. Natural changes such as accretion of new land area and erosion along the coast and rivers are also common in this ecosystem. Information about these changes is crucial for developing management policies. Remote sensing allows quantitative and qualitative assessments of ground conditions over large and inaccessible geographical areas. This study describes the changes in the mangroves and associated landuse of the Godavari estuary between 1986 and 2001.

Study area

The Godavari mangroves are located between the latitudes 16°30′ and 17° N′ and the longitudes 82°10′ and 82°25′ E in East Godavari District, Andhra Pradesh, India. The mean annual rainfall in this region is 110 cm and the annual mean temperature is 28 °C. The Godavari River is the second largest river in India, with a total catchment area of 314,685 sqkm and a total length of 1465 km. Two-thirds of the catchment flows into the Bay of Bengal. The Godavari River is connected to Kakinada Bay by two major canals, namely the Corangi and the Gaderu. There are numerous other small canals branching from these canals, supplying tidal water to the mangroves. The Godavari River flows into the sea through two mouths, one near Bhairavapalem in the north and the other near Kottapalem in the south (Figure 1).

Materials and Methods

The remote sensing data was obtained from National Remote Sensing Agency (NRSA) and interpreted with the base line information derived from Survey of India (SOI) toposheets. To monitor the geomorphological and shoreline changes, baseline information from the Survey of India maps of 1937–1938 (65 L) and 1975–1976 (65 L/1, 2, 5 and 6) were used. The remote sensing data of 1986 and 2001 were mapped for wetland features such as dense mangroves, degraded mangroves, mudflat, beach, lagoon and water bodies and the changes were analysed. The classification was verified with intense ground truth survey.

As the remote sensing digital data have geographical distortions, they were geographically projected to real earth coordinates system, using Survey of India toposheets (1:50,000 scale). The ground control points like road/road intersection, road/railway line intersection, road/canal intersection and sharp bends, found both in remote sensing data and the reference toposheets, were used for rectification. The field points were collected using GARMIN hand held Global Positioning System (GPS). The satellite data obtained from National Remote Sensing Agency were used for this study (Table 1).

After the rectification process, the standard False Color Composite (FCC) image was generated with green, red and near infrared bands and enhanced through the histogram equalization method to clearly distinguish the land use and land cover features. Onscreen digitization procedure on ERDAS Imagine was carried out to delineate mangrove and associated land cover categories. The visual interpretation keys used to identify the coastal features are given in Table 2.

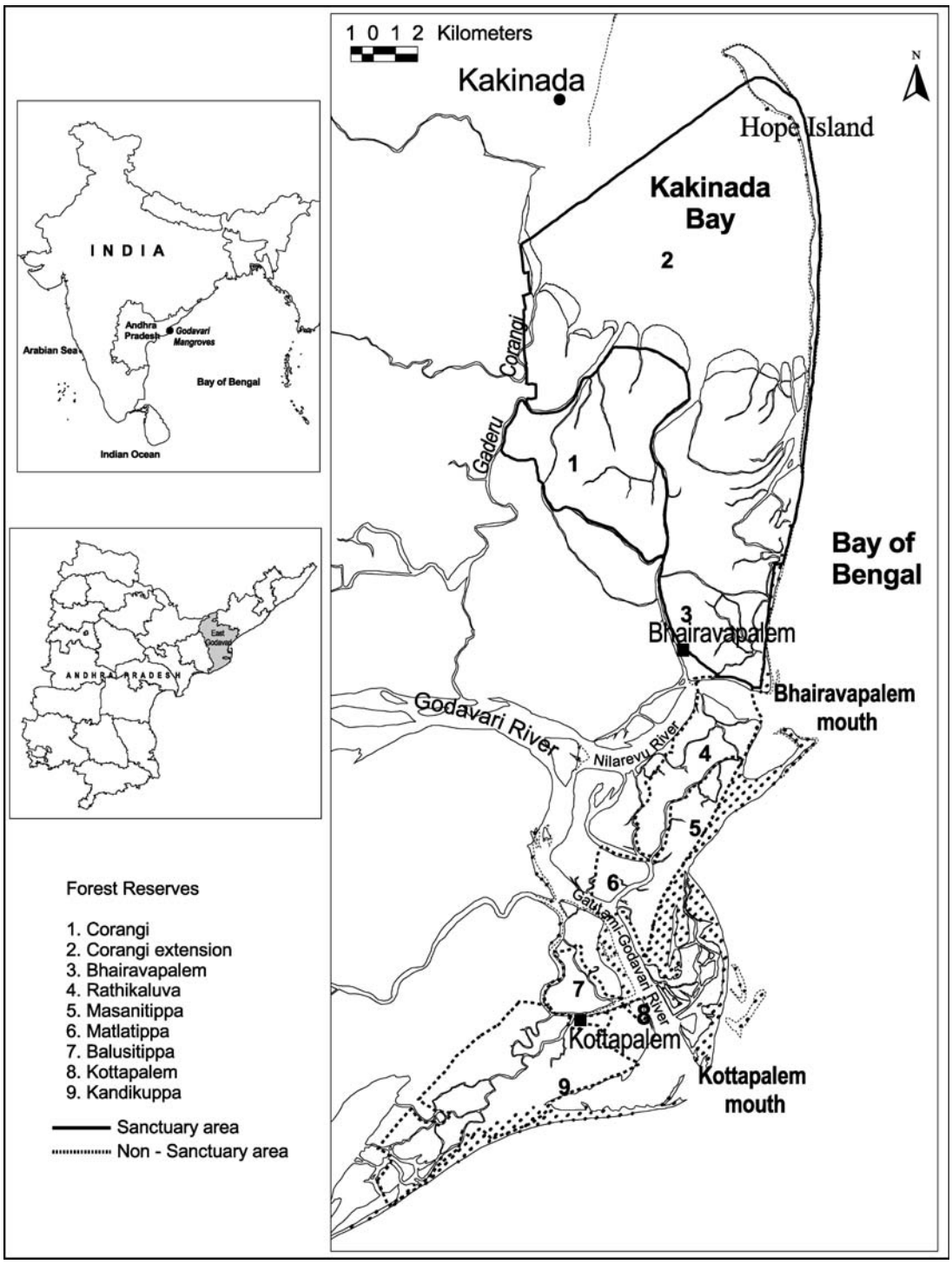

Figure 1. Study area – Godavari mangrove wetland, India.

Ground verification of 72 points was done for the land used and land cover classes. The number of verification points of each class was decided, based on its area coverage and also the longevity towards its correctness, based on ground knowledge. The error matrix of the

Table 1. Details of data used in this study.

Year	Data	Purpose
1937	Survey of India Toposheet (1:2,50,000)	Shoreline changes
1975	Survey of India Toposheet (1:50,000)	Base data, shoreline and geomorphological changes
1986	Landsat 5 TM	Mangroves mapping and monitoring
1998	IRS 1C LISS III	Mangroves mapping and monitoring
2001	IRS 1D LISS III	Mangroves mapping and monitoring

ground verification of 2001 data is given in Table 3.

Results and discussion

Changes in mangrove area due to restoration

The Godavari mangroves occupy an area of about 33,150 ha in the deltaic region of the Godavari River, which includes large areas of water bodies. The digital data (2001) shows that dense mangroves occupy only 16,406 ha; degraded mangroves occupy 3355 ha; mudflats and water bodies cover the rest of the area (Table 4). The interpretation of the satellite data and the ground truth information revealed that the density of mangrove cover is more on the northern side (Coringa Wild Life Sanctuary) of the Godavari River than on the southern side (non-sanctuary area). This may be due to the fact that the northern areas receive fresh water for a prolonged period from agricultural run-off. The agriculture run-off through the creeks of Corangi and Gaderu canals brings dissolved nutrients such as nitrates and phosphates to the mangroves. This area is also protected from high velocity winds and high-energy water currents by the sand spit which is about 18 km long. The mangrove vegetation found in the periphery near the villages is degraded due to anthropogenic pressures. The restoration of mangrove vegetation in the degraded area is

Table 2. Identification of coastal features.

Area	Colour	Shape and size	Texture	Association
Wetland without vegetation				
Mudflat with water	Dark bluish gray to brownish gray	Irregular	Smooth	Estuaries, inland wetland and coastal wetlands
Mudflat without water	Medium gray to bluish gray	Irregular	Smooth	Estuaries, inland wetland and coastal wetlands
Sandy mudflat	Very light yellowish gray	Irregular	Smooth to moderately rough	River beds
Tidal flats	Dark gray or bluish gray	The shape of the river bank or coast	Smooth	River course or coastline near the reach of tidal water
Saline area	Pure white to bluish white	Patchy or irregular	Smooth	Coastal or river course or mudflat
Salt pan	Pure white when dried or black when filled with water	Regular rectangular or square	Smooth	Coastal area
Aquaculture	Dark blue or black	Regular rectangular	Smooth	Just outside the forest reserve boundary
Water bodies				
Deep or clear water	Dark blue/black	–	Smooth	–
Shallow water	Light blue/cyan	–	Smooth	–
Turbid water	Grayish blue or greenish blue	–	Smooth	–
Vegetated wetland area				
Dense Mangrove	Bright red	–	Smooth	Estuary and backwater
Sparse and dwarf mangrove	Pinkish red to brownish red	–	Moderately rough to smooth	Estuary and backwater
Marshy vegetation	Dark to light brownish red	–	Moderately rough to smooth	Along with mudflat and wetland

Table 3. Error matrix of ground truth verification points of classified map of Godavari mangroves.

Classified	Actual								
	Dense Mangrove	Sparse Mangrove	Degraded area	Sand	Mudflat/tidal flat	Coastal plantation	Aqua-culture	Salt pan	Total
Dense Mangrove	10	0	0	0	0	0	0	0	10
Sparse Mangrove	0	18	0	0	0	0	0	0	18
Degraded area	0	3	12	0	0	0	0	0	15
Sand	0	0	0	3	0	0	0	0	3
Mudflat/Tidal flat	0	0	0	0	5	0	0	0	5
Coastal plantation	0	0	0	0	0	8	0	0	8
Aquaculture	0	0	0	0	0	0	8	2	10
Salt pan	0	0	0	0	0	0	0	3	3
Total	10	21	12	3	5	8	8	5	72

Table 4. Mangrove and nearby landuse areas (ha) in 1986 and 2001.

Description	Area in ha.	
	1986	2001
Dense mangroves	16,038	16,406
Degraded area	5708	3355
Shrimp farms	–	7310
Salt pan	1868	685

Table 5. Changes in mangrove vegetation between 1986 and 2001.

Description	Changes in area between 1986 and 2001 (ha)
Restoration of mangroves	594
Natural regeneration in the degraded areas	2318
Natural regeneration in the accreted areas	586
Total increase	3498
Degradation due to Aquaculture/Salt pans	658
Erosion	806
Degradation due to other causes – coupe felling, grazing and felling	1666
Total loss	3130
Net increase	368

clearly noticed in the 2001 remote sensing data (Figure 2). The degraded area of 5708 ha, seen in 1986, was reduced to 3355 ha in 2001 (Table 4). This reduction was due to the restoration of degraded mangroves by the Forest Department, the Government of Andhra Pradesh and the mangrove restoration programme of M.S. Swaminathan Research Foundation. Selvam et al. (2003) studied the impact of the mangrove rehabilitation programme in Pichavaram, using remote sensing, in which the mangrove cover was seen to have increased from 325 ha to 618 ha and the degraded area reduced from 375 ha to 60 ha between 1986 and 2002. The earlier system of coup felling was found to be one of the causes for the degradation of the mangroves while the geographically elevated area, formed by sediment deposition during floods along the rivers and canals, was another.

Changes due to accretion and erosion

The increase in the extent of mangroves due to newly accreted areas was about 586 ha between 1986 and 2001 (Table 5). The accretion was due to sedimentation of alluvium from the runoff in the Godavari River through the Corangi and Gaderu canals. Erosion reduced the mangroves by 806 ha in the same period. Mangrove vegetation along the southern bank of the Nilarevu River has been eroded due to floods during the southwest monsoons. The river had become wider in 2001 than it was in 1986. In 1986 the river span was about 1.2 km while in 2001 it had become 2.6 km due to erosion. The mangroves along the coast on the northern side of the Kottapalem River mouth have also been eroded; the small mangrove islands seen in the 1986 image are not seen in the 2001 image.

The vegetation in the accreted areas near the mouth of the Corangi River and the Gaderu River in the Kakinada Bay is distinct. *Porteresia coarctata* is found along with seedlings of

Avicennia alba and *Sonneratia apetala* Pure stands of *Avicennia alba* are seen near the Kakinada Bay. Next to this, towards the land, is *Sonneratia apetala*. From here onwards, the vegetation is found to be mixed, with small patches of pure stands of *Excoecaria agallocha*, *Aegiceras corniculatum*, *Lumnitzera racemosa* and *Avicennia marina*. *Suaeda maritima* and *S. nudiflora* are seen in the degraded areas. *Rhizophora apiculata* and *R. mucronata* are found along the creeks on the seaward side.

Loss of mangrove forests due to aquaculture farms

Analysis of the remote sensing data of 2001 reveals that an area of 658 ha of mangrove vegetation has been converted into aquaculture farms outside the forest reserve boundary (Table 5). The rapid growth in shrimp farming, which began in the Godavari delta during the early 1990s, has resulted in landuse conversion of agricultural fields and mangrove vegetation into shrimp farms. These shrimp farms are located in the revenue lands and in the private lands abutting the mangroves. In East Godavari district alone the area of shrimp farms has increased from 2006 ha in 1989 to 19,239 ha in 1999. About 14% of the aquaculture farms have been constructed on mangrove lands outside the forest reserves. The rate of conversion of mangroves into shrimp ponds between 1997 and 1999 increased substantially, suggesting that suitable fallow/agriculture lands are not available along the coast (Andhra Pradesh Remote Sensing Application Centre (APRSAC) 1999).

Geomorphology and shoreline changes

The base maps of Survey of India toposheets of 1937–1938, 1975–1976 and the remote sensing data of 1986 and 2001 were used to assess the changes in the shoreline. Appreciable changes are seen in both the sanctuary and non-sanctuary areas. Erosion of the coastline can be seen along the Bay of Bengal on the northern side of the Godavari River, i.e., from the Godavari River mouth to the tip of Hope Island. Elongation and enlargement of Hope Island in the north and northwest directions is also seen. The length of the sand spit was 15.6 km during 1937–1938 and in 2001 it was 18.2 km (Figure 3; Table 6). There has been a shift in the sand bar towards the west, which can be seen in the 2001 image, which has resulted in the loss of mangrove vegetation. The river course has also changed much near the mouth. The small sand spit on the southern side of the Nilarevu River mouth has also grown significantly as seen in the map of 2001 (Figure 2). The river discharge into the sea, which was towards the east in 1986, has shifted towards the northeast in 2001.

Reddy and Prasad (1982) studied the geomorphological changes of Kakinada Bay, the sand spit and mangrove waterways of Coringa River. The initial formation of a small sand spit dates back to 1864, which extended to a length of about 16 km by 1968. The survey charts during the period 1848 and 1971 revealed that till 1889 the river discharged a major portion of water directly into Kakinada Bay. From 1893 to 1929 the river discharge took place through the Godavari in the south (Kottapalem mouth). At present, the discharge is mainly through the mouth near Bhairavapalem on the northern side (Ranga Rao et al. 2003). The ground verification of the satellite images of 1986, 1996 and 2001 also confirm that the discharge through the mouth near Bhairavapalem is very high. The southern part of Kakinada Bay is very shallow, with a depth of less than 2 m. The Corangi mangrove region, including the creeks and channels, is also found to be shallow near the Bay, with depths varying between 1 and 3 m. During low tide, large areas of mud flats are exposed in Kakinada Bay.

Conclusion

The Godavari mangroves and the coastline have undergone drastic changes within a short period of about 60 years due to both natural and

Table 6. Increase in the length of Hope Island spit.

Year	Length of Hope Island spit (km)
1937–1938	15.60
1975–1976	16.33
1986	16.93
1996	17.75
1998	18.00
2001	18.20

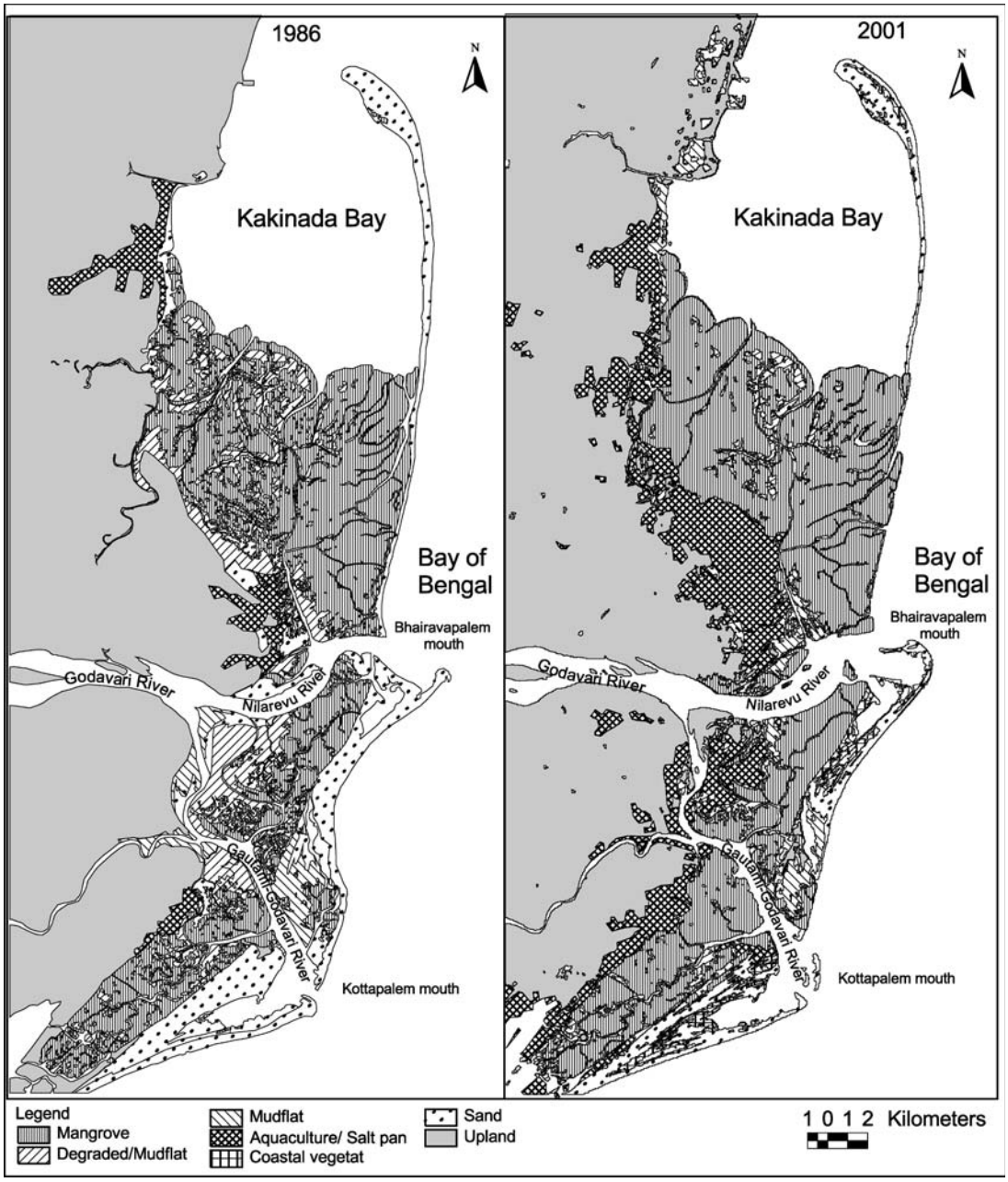

Figure 2. Maps showing changes in the area of mangroves between 1986 and 2001.

anthropogenic causes. On the one hand, it shows a positive impact on mangrove vegetation as seen by the increase in the mangrove cover in accreted areas, as also restoration and conservation activities. On the other hand, the mangroves facing the sea have vanished due to coastal erosion. The overall change in the mangrove area is not very much, since the area of accreted and restored mangroves is almost equal to the area of degradation, landuse conversion and erosion. But the drastic change in the island spit needs to be studied in detail for the management of mangroves and other coastal developmental activities.

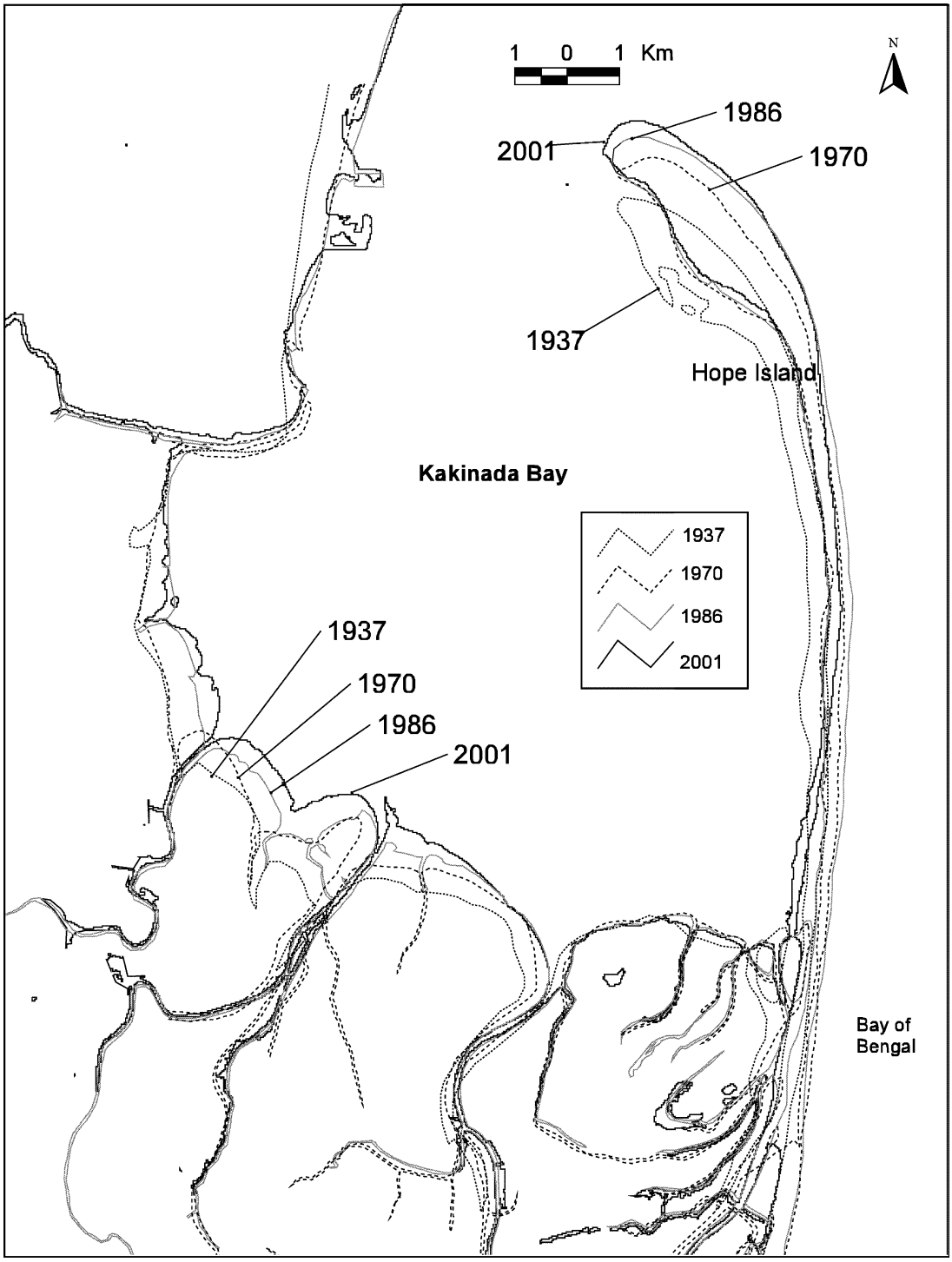

Figure 3. Map showing the shoreline changes in Kakinada Bay and Hope Island.

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