IRS-1C applications for coastal zone management

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IRS-1A and 1B data have been found to be useful in providing information on the extent and condition of coastal habitats, coastal processes and water quality of coastal waters. These inputs formed major elements for preparing coastal zone management plans. IRS-1C data having improved spatial resolution (5.6 m PAN data), extended spectral range (inclusion of middle infra-red band in LISS-III) and increased repetitivity (5 days for WiFS data) have opened up new vistas of applications in the coastal zone. Preliminary analysis of IRS-1C data indicates that coral reef zonation, identification of tree and shrub mangroves, seaweed/sea grass beds, improved delineation of coastal features such as fringe mangroves, mudflats, beach, dune vegetation, saline areas, etc. as well as better understanding of suspended sediment patterns are now possible. These additional information will certainly form vital remote-sensing-based input for preparing coastal zone management plans.

INDIA has a long coastline of about 7500 km including that of its island territories and comprise 60 coastal districts. Coastal zone in India assumes its importance because of the high productivity of its ecosystems, concentration of population, exploitation of renewable and non-renewable natural resources, discharge of waste effluent and municipal sewage, development of various industries and spurt in recreational activities in and around the coastal zones. A principal concern of coastal zone management is to ensure a rational development of area and judicious use of its resources which is consistent with the surrounding natural systems and environment. Thus, environmentally effective coastal zone management depends upon accurate and comprehensive scientific data on which policy decisions can be based. The major issues which require immediate attention in the context of management of coastal zone in India have been grouped in three areas[1] and are shown in Figure 1. Satellite data, especially IRS-1A, 1B and P2, because of their multispectral, synoptic and repetitive capability, have proved to be extremely useful in creating baseline inventory of coastal wetlands[2–4], coral reef[2,5–7], mangroves[8], monitoring of protected areas[9,10], selecting sites for brackish water aquaculture[11,12], detecting shoreline changes[3,13–15], studying coastal landforms[16], estimating suspended sediment concentration and assessing the impact of engineering structures on suspended sediment patterns[17]. IRS-1C data have improved spatial resolution (5.6 m PAN data), extended spectral range (inclusion of middle infrared in LISS-III) and increased repetitivity (5 days for WiFS data). This unique combination has provided additional/ new information on certain aspects of coastal habitats, coral and mangrove ecosystems, improved accuracy in delineating shoreline-changes and better understanding of the suspended sediment dynamics. The results of preliminary analysis of IRS-1C data for some of these aspects as mentioned above are described in this article.

Coastal habitats

Coastal habitats—especially wetlands, mangroves—are being cleared rapidly for urban, industrial and recreational growth as well as for aquaculture ponds. The information on loss of tidal wetlands is important as it provides a vital link in the marine energy flow through transfer of solar energy into forms which are readily usable by a wide variety of estuarine organisms[18]. The knowledge about areal extent, condition and utilization status of wetlands is vital for arriving at coastal management programmes.

IRS-1C LISS-III data of Goa coast of 8 January 1996 was analysed to study various coastal features. Many features such as mudflat, beach, fringe mangroves, creeks, dunes and dune vegetation were clearly delineated. It was observed that mangrove patches which are about 20–40 m wide and 100–150 m long and bordering creek areas are clearly distinguishable. These areas could not be detected in earlier studies. The identification of two types of mudflats, delineation of smaller creeks, distinction between beach and dunes as well as density-wise classification of dune vegetation are now possible using LISS-III data.

IRS-1C PAN data of Tuticorin area, Tamil Nadu, acquired on 6 January 1996 was merged with IRS-1B

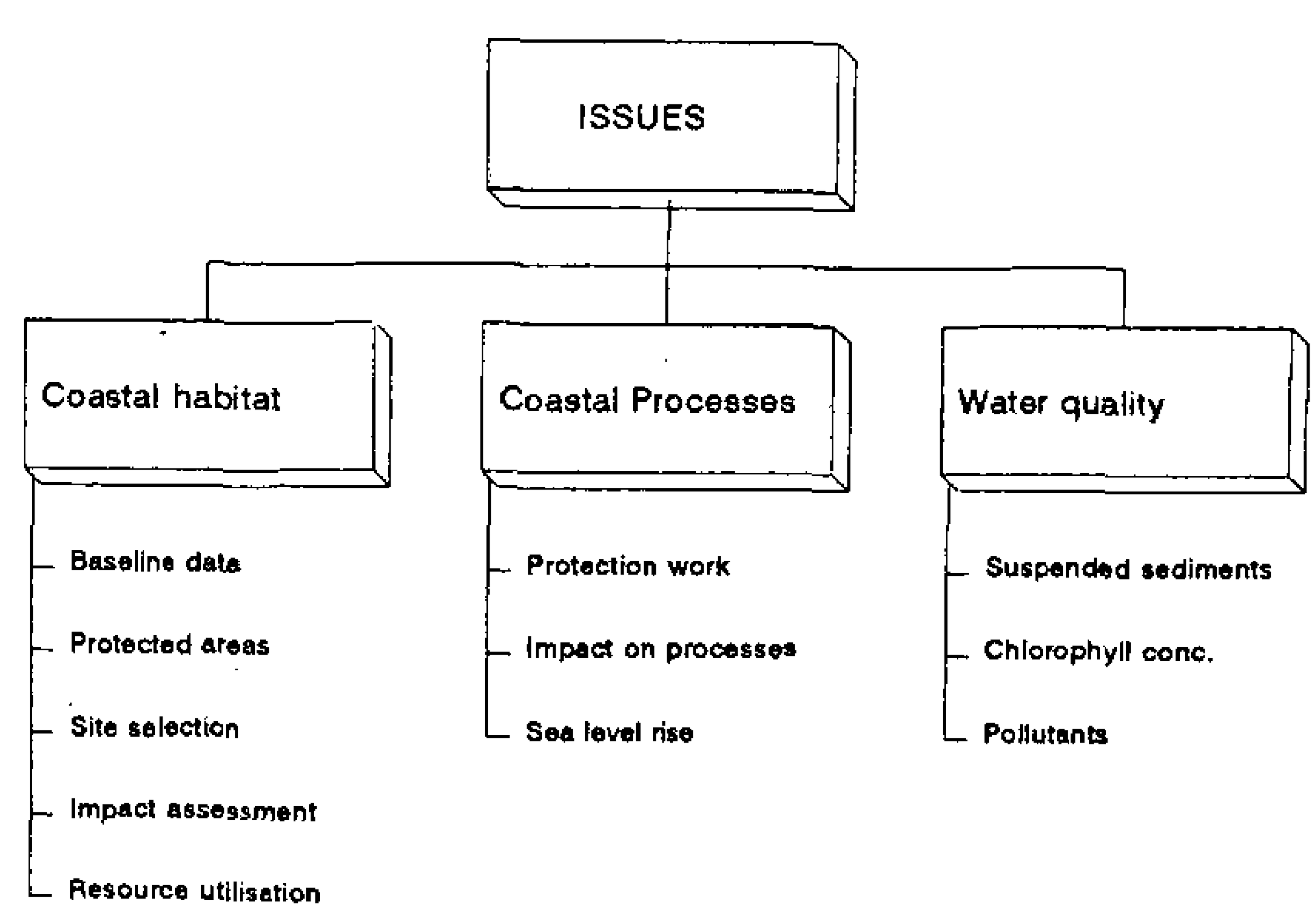

Figure 1. Coastal zone management issues in India.

LISS-II data of 15 April 1996, thus using better spatial resolution of PAN data and multispectral capability of LISS-II data (infrared, red and green bands) for discrimination of various coastal features. LISS-II data was registered with PAN data using well distributed control points (rms error ~ 4 m). Cubic spline resampling technique was used to resample 36 m resolution LISS-II data to 5.8 m PAN resolution. Intensity, hue and saturation (IHS) transformation was done on the resampled LISS-II bands. Further, intensity information of LISS-II was replaced by PAN data and IHS to red-green-blue (RGB) inverse transformation was performed. The resultant output is thus a merged false colour composite (FCC) of IRS LISS-II and PAN data (Figure 2).

It was observed that this product gives improved accuracy in boundary delineation of tidal flat, beach, dunes, categorization of reclaimed area, delineation of jetty, built-up area, etc. Built-up areas such as roads, railways, canals, salt pans, industrial buildings, godowns, etc. were distinctly visible. The reclamation is being done by depositing fly ash from the thermal power plant. The comparison between PAN, LISS-II and merged product is given in Table 1. Some of the effluent discharge points of fertilizer and other industries are visible in PAN data. This product is extremely useful in providing detailed information on 1 : 25,000 scale or larger about reclamation and construction activities – which are required for regulating these activities in the coastal regulation zone (the area between high tide line and low tide line and 500 m from high tide line).

Coral reef ecosystem

Coral reefs are being destroyed by siltation, logging, mining and pollution. Sedimentation of reefs reduces live coral and species diversity and fish biomass is affected. The knowledge about various zones and their conditions will help to plan preventive and conservative measures to protect this fragile ecosystem.

IRS PAN and LISS-II merged product, as described in the earlier section, was also evaluated for coral reef zonation. The merged product for Van and Koswari reefs, located 7–10 km northeast off Tuticorin coast, was analysed using unsupervised K-mean clustering algorithm. The comparison of PAN, LISS-II and merged product is given in Table 2. It was possible to delineate four categories of reef based on depth (between ~ 1 and 20 m), beach and terrestrial vegetation (Figure 3 *a, b*).

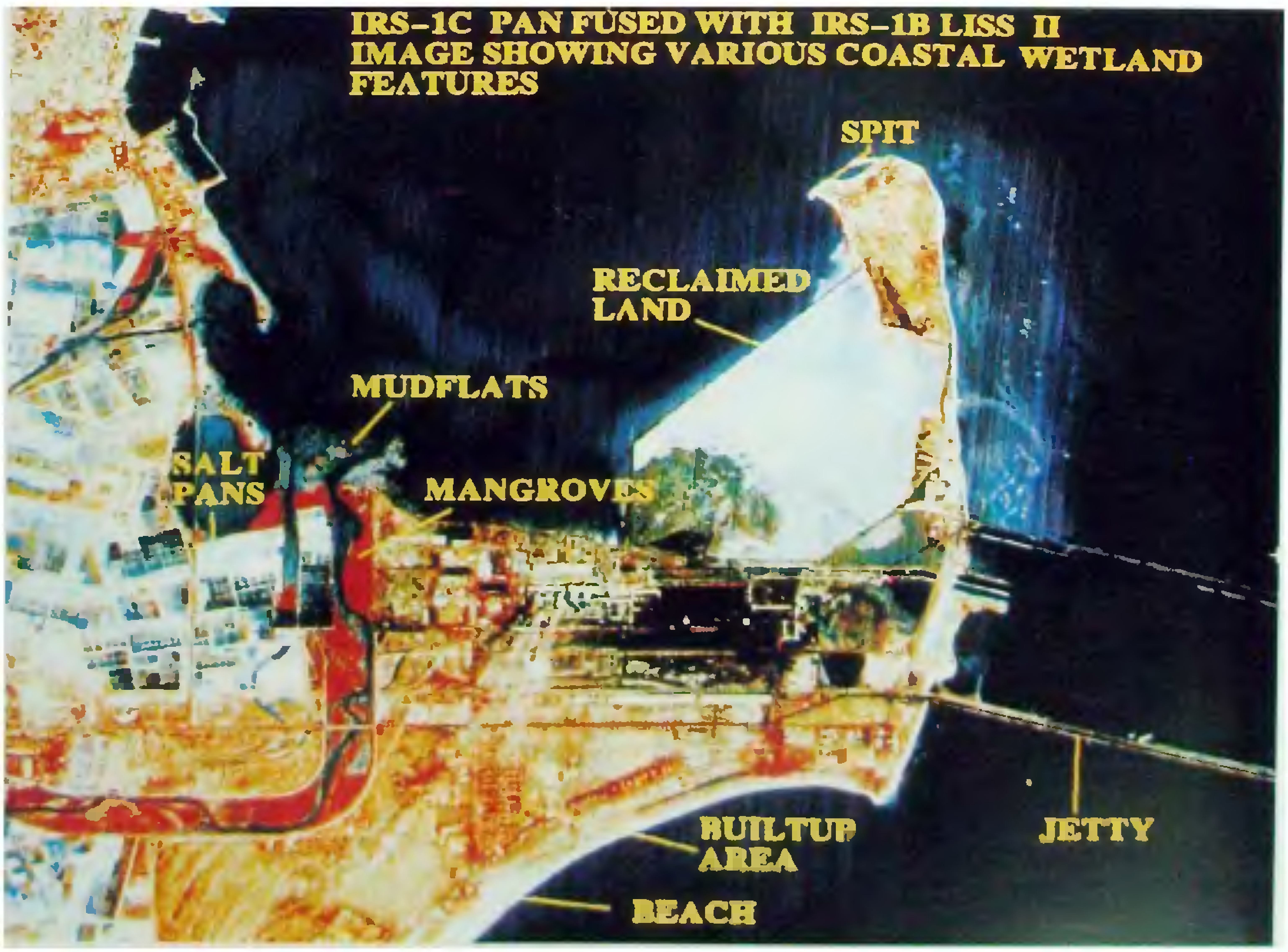

Figure 2. False colour composite of merged PAN and LISS-II data of Tuticorin area.

Sea grass beds and live coral zones were identified visually. The live coral areas, as small as 50 m^2 were identified. This is extremely useful to monitor condition of individual coral knoll/reef patch and it may be possible to identify coral bleaching, whenever it occurs. The sea grass bed, only 15–20 m wide, was clearly mapped. This will help in estimating total sea grass/seaweed resources available in an area.

A coral pinnacle (~ 2 km^2), north–northeast of Okha in the Gulf of Kachchh was studied using LISS-III data (Figure 3 *c*). It was possible to delineate, for the first time, sea grass/sea weeds bed separately, reef flat and sand cay on a coral pinnacle. This will give improved understanding of coral reef ecology and geomorphology.

Mangrove ecosystem

Mangroves are important as they help in the production of detritus, organic matter and recycling of nutrients and thus enrich the coastal waters and support benthic population of sea. They prevent soil erosion, act as buffer for mainland from storms and thus protect coast from erosion. Above all they provide feeding, spawning and nursery grounds to many organisms apart from a vast range of direct and indirect products, benefits and services to the human-being.

IRS-1C LISS-III data of 1 February 1996 of northwest Gulf of Kachchh were analysed to identify various features related to mangrove ecosystem. Use of middle infrared was attempted essentially to distinguish tree and shrub mangroves. The combination of red, infrared and middle infrared bands helped in distinguishing tree mangroves, *Rhizophora* spp. and shrub mangroves *Avicennia* spp. (Figure 4 *a*, *b* and *c*). This distinction was possible because of the different spectral properties of canopies of two types of mangroves produced by a combination of individual vegetative components, effects of plant growth, density and height. This new information is extremely useful for biodiversity studies. This combination also helped in distinguishing between i) sandy area, salt pan and saline area, ii) high tide, intertidal and subtidal mudflats, and iii) terrestrial vegetation, mangroves and dune vegetation. The delineation of small sand bodies (smallest is of size 0.25 ha), which demarcated past position of shoreline, provided vital clues in understanding the growth patterns of this coast.

Table 1. Comparison of IRS PAN, LISS-II and merged (PAN + LISS-II) data for the Tuticorin coast, Tamil Nadu

Category	PAN data	LISS-II	Merged FCC
Tidal flats	Distinct	Indistinct	Distinct
Beach	Distinct with sharp boundary	Indistinct boundary	Distinct sharp boundary
Spit	Clearly demarcated	—	Clearly demarcated
Mangroves	—	Demarcated	Demarcated
Reclaimed area	Distinct two categories	One category	Distinct two categories
Salt pans	Distinct	Distinct	Distinct
Jetty	Clear with precise details	Detection possible	Clear with precise details
Built up area	Clearly demarcated	—	Clearly demarcated
Smoke plume	Clear with direction	—	Clear with direction

Suspended sediment dynamics

In India, in many major bays, estuaries, and seas, a large proportion of pollutants comes not from coastal sources such as dumping, industrial and municipal discharge (point source) but from watershed (non-point source). Among the many upstream activities known to degrade water quality in coastal areas major ones are logging, agriculture, dam building for power and irrigation, urbanization, etc. It is necessary to connect upstream polluting activities with coastal pollution. Suspended sediments which are readily recognized on images affect navigation, fisheries, aquatic life and recreational potential of sea resorts. They also carry absorbed chemicals. The present satellites, IRS-1A, 1B, P2, Landsat and SPOT, allow measurement of turbidity or suspended sediments especially in coastal area. However, these measurements cannot be used operationally because of their poor temporal resolution. WiFS data having 5-days repetitivity have overcome this lacunae, to a certain extent.

WiFS data of Hooghly estuary of 24 January 1996 and 31 January 1996 were analysed to study suspended sediment patterns. These two images were corresponding to high and low-tide time respectively (Figure 5). It is seen that during high-tide, large amount of sediments are in suspension compared to low-tide time, essentially due to high turbulence prevalent during high tide. During ebb tide, the sediments were concentrated in an alternate high and low concentrations. This also indicates that the flood and ebb currents follow different paths. It is necessary to analyse more images belonging to different tidal conditions to understand the effect of tides on the

Table 2. Comparison of IRS PAN, LISS-II and merged (PAN + LISS-II) data for the coral reef areas, Gulf of Mannar, Tamil Nadu

Category	PAN data	LISS-II	Merged FCC
Reef extent	Distinct	Distinct	Distinct
Live coral zones	Demarcated	—	Demarcated
Coral reef zones based on depth	4 zones	2 zones	4 zones
Seagrass beds	—	Demarcated	Demarcated
Vegetation	Clearly demarcated with sharp boundary	Demarcated	Clearly demarcated with sharp boundary

Figure 3 *a–c*. *a*, Classified image of Koswari reef, Gulf of Mannar, Tamil Nadu; *b*, Classified image of Van reef, Gulf of Mannar, Tamil Nadu; *c*, IRS-1C LISS-III FCC of Changri reef.

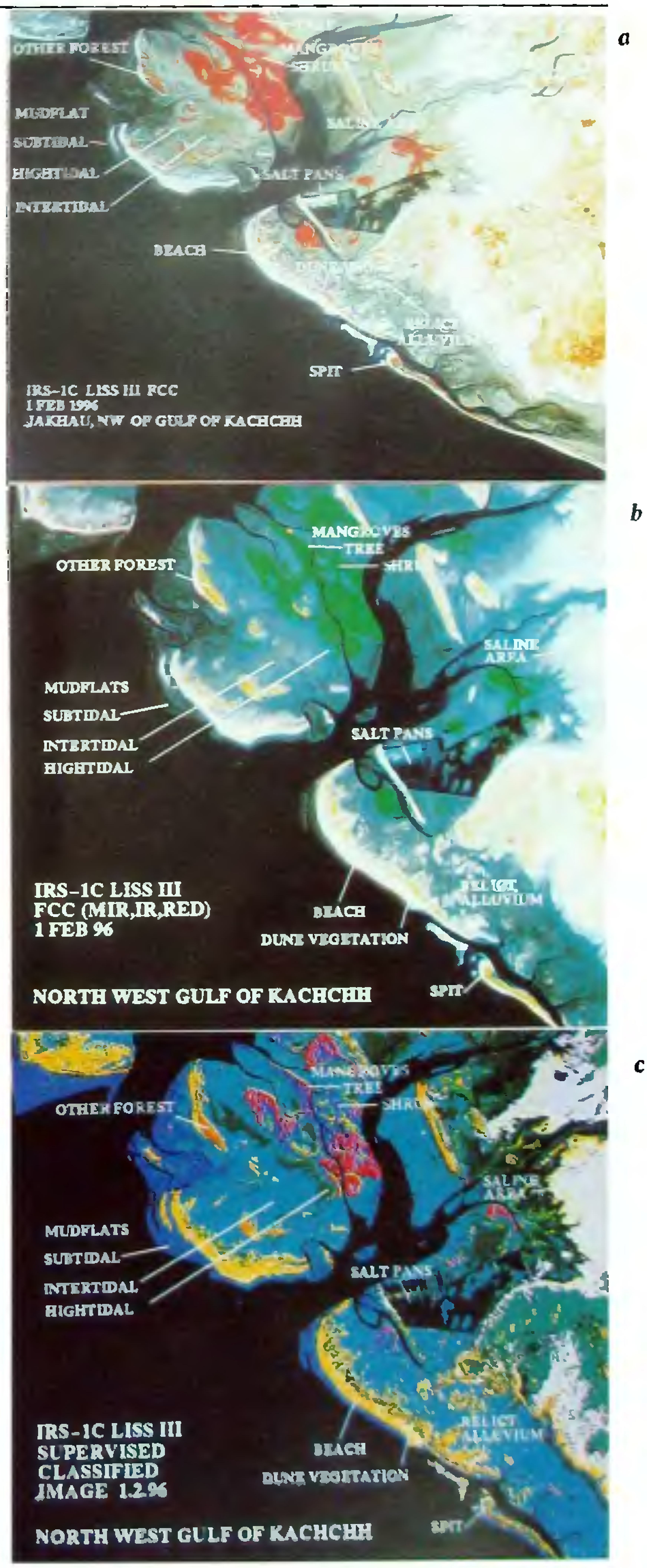

Figure 4 *a–c*. *a*, FCC (infrared, red, green) of mangrove ecosystem area in the northwest Gulf of Kachchh; *b*, FCC (middle infrared, infrared, red) of mangrove ecosystem area in the northwest Gulf of Kachchh; *c*, Classified (maximum likelyhood) image of mangrove ecosystem area in the northwest Gulf of Kachchh.

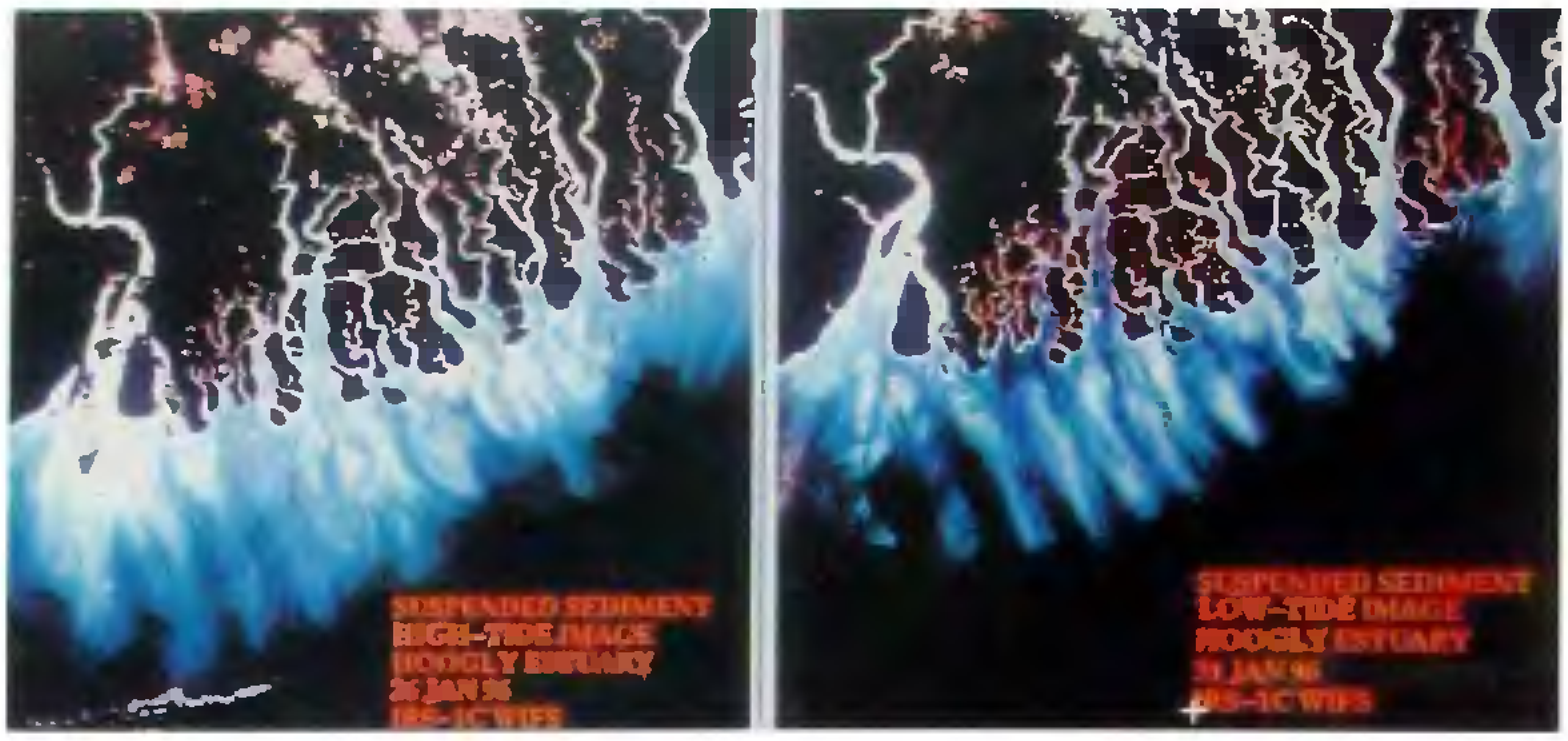

Figure 5. Suspended sediment pattern during high- and low-tide time in the Ganges delta.

movement of suspended sediments. The WiFS data of Kerala coast (6 January 1996) indicated that a sediment plume from the Kochi harbour made a sharp contact with the sediments along the coast, indicating two different water masses. The gradual decrease in concentrations in sediments away from the coast suggests a regular dispersal pattern along the coast. The high turbidity in the backwaters was clearly visible. This has demonstrated that frequent repetitive coverage will provide information on sediment dispersal.

Conclusions

i) The PAN data combined with the LISS-II data are extremely useful in providing detailed spatial information about reclamation, construction activity and ecologically sensitive areas, which are vital for the coastal zone regulatory activities.
ii) The new information available from merged PAN and LISS-III data about coral reef zonation, especially for atolls, patch reef and also coral pinnacles, is valuable for preparation of coral reef conservation plans.
iii) The distinction between tree and shrub mangroves in FCC (middle infrared, infrared and red bands) of LISS-III has provided vital information on bio-diversity studies. This could lead to identifying vital areas for preservation.
iv) The high temporal resolution provided by the WiFS data is found to be a major improvement in studying behaviour of suspended sediments in the coastal waters. This would help in understanding movement of sediments and pollutants.

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