REMOTE SENSING AND GIS BASED APPROACH FOR ENVIRONMENTAL SENSITIVITY STUDIES A CASE STUDY FROM INDIAN EAST COAST

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ABSTRACT:

In the wake of Earth Summit – 2002 resolutions, and also the recently omni-prevalent environmental awareness across the globe, it has become imperative to pay attention to environmental concerns, and to standardize the procedures, wherever possible. A big step in this direction was the development of Environmental Sensitivity Indices (based on different events and parameters). NOAA and USEPA have taken lead on this front in USA and have got developed Environmental Sensitivity Index (ESI) for coastal areas, and Reach Sensitivity Index (RSI) for inland riparian and lacustrine areas, which have become bench, marks for further research in this direction. The present paper focuses on the application of remote sensing and GIS technologies for deriving the RSI and ESI; and also the validity of the indices in the context of a tropical country like India.

Kakinada Bay situated in the east coast of India is made up of estuary of river Godavari covers an area of about 29.sq.kms. The Godavari delta has undergone phases of erosion and accretion through fluvial and marine changes during its growth in recent times. The delta with rich alluvial soil support multiple cropping pattern providing relatively high crop yields. The bay is fringed on the southern side by mud flats and thick mangrove swamps. The Kakinada spit present on the eastern side of the bay running north south in direction acts as artificial embankment. Its shoreline habitats include mangrove swamps, tidal flats, channels and shallow bar built bay towards north. The mangrove is represented by 15 species belonging to 8 families and 10 genera Duke (1992) besides represented by wide range of invertebrates. Being rich in petroleum and natural gas deposits, this area faces potential threat, in the event of floating slicks running ashore. Results of the present paper examine the proximity and vulnerability of this area with the help of both ESI and RSI to prioritize the areas base on potential threat.

Digital analysis of IRS-1D (LISS-III) satellite data was carried out for deriving the land use / land cover, and allied shoreline and fluvial surfaces information, which were again validated with sample ground checks. The rectified maps were converted into vector coverage for further analysis. Other collateral information like shoreline type, tidal elevation, intensity of tidal energy, biological richness etc. were collected through insitu observations and secondary sources. The insitu and secondary data were integrated in spatial framework in GIS environment for analysis.

The GIS analysis was performed with rule-bases separately, one each for ESI and another for RSI. The RSI results categorized the study area into zones of higher vulnerability, namely 8, 9 and 10 besides a low sensitive zone of 2. The ESI ranking is based on relative exposure to wave and tidal energy, shoreline slope, biological productivity and sensitivity. Areas exposed to high levels of physical energy, such as wave action and tidal currents, and low biological activity is ranked low on the scale, where as sheltered areas with associated high biological activity is ranked as High.

The present paper attempts to showcase - the potential of remote sensing and GIS technologies as viable, and timely sources of information providers; and – the ESI and RSI indices are well applicable in Indian context. However, further validations from other coastal sites in India, is suggested for modeling the same to Indian environment.
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1) INTRODUCTION

Wetlands are the areas that lie between aquatic and terrestrial ecosystems, dominated by the influence of water and play significant role in marinating the ecological balance of both biotic / abiotic life in coastal and inland environment. By virtue of its geographical extent and varied terrain and climate, India supports a rich diversity of inland and coastal wetlands. India's 7500 km coastline has numerous lagoons, estuaries and mangrove swamps.

Coastal zones in India are constantly undergoing wide-ranging changes in shape and environment due to natural as well as human development activities. Natural processes such as waves, erosion, changes in river courses etc., cause long time effect at slower rate; but man made activities, such as settlement, industrial activities, recreational activities, waste disposal etc., affect the coastal environment at comparatively much faster rate. Most of marine finfish and shellfish depend on these coastal habitats for their survival. Continued loss of these wetlands may lead to the collapse of coastal ecosystems. It is, therefore, necessary to monitor coastal zone changes with time. The present paper is intended to identify ecologically sensitive locations identified through modern methods like Digital Image processing and GIS for preparedness in case of oil spill incidents in offshore areas of Bay Of Bengal extending near Kakinada along the east coast of India.

Environmental Sensitivity Index (ESI) maps are an integrated component in oil-spill contingency planning and assessment. In the present study ESI (Environment Sensitivity Index) and RSI (Reach Sensitivity Index) analysis maps are prepared to collect

information regarding environmental baseline status of the study area pertaining to physical, human, biological resources, land use / land cover, and socio-economic attributes which form important attribute for ESI/RSI maps. Thus, environmentally effective coastal zone management depends upon accurate and comprehensive scientific data on which policy decisions can be based (Nayak et al. 1996).

The study area (Godavari delta) merits special attention from environmental point of view as this area is rich in oil and natural gas and is under 0-11 m topographic contour and appears to be fragile with thick pile of sediments dipping towards sea and underlain by faults and hence any change in existing equilibrium would devastate the entire region (Rao, 1998).

2) STUDY AREA AND DATA USED

Extends from Uppada (approx. 10 km North of Kakinada) in the North along the east coast of India, in the A.P. coastline and approx. 2 km from the coast and up to the area of tidal influence in the inland sector.
Kakinada Bay to the east and southeast of Kakinada town appears to be made up of estuaries of lagoon covering an area of about 29.sq.kms. Like many other bays, incited near river mouth it is a shallow water bay. The southern half is too shallow and depths never exceed 2 meters even in spring tides, while its northern half is 2 to6 meters deep.

The bay is fringed on the southern side by mud flats and thick mangrove swamps. The Kakinada spit present on the eastern side of the bay running north south in direction acts as artificial embankment. Subba Rao (1967) reports that Kakinada Bay is mostly occupied with silty clays. He has established three heavy mineral provinces (a) mica province on the western side of the spit, (b) hornblende province embracing the bay proper, the Kakinada spit and Kakinada-Vakalapudi coast; and (c) garnet – sillimanite province north of Vakalapudi and in the offshore areas north of Godavari point.

2.1 Satellite Data

The basic satellite data selected corresponds to IRS 1D (LISS–III) multispectral data of January and February 2002 period. The exact date of pass is shown in the respective maps prepared. Survey of India (SOI) topographical maps on 1:50,000 scale is also used as collateral information during the study.

3) METHODOLOGY

The methodology attempted here is based on digital analysis of IRS 1D (LISS-III) satellite data on CD using band 1, 2 and 3 bands respectively on 1:50,000 scale, using Erdas software.

The mapping of land use/land cover is carried for 5/2 kms corridor along the coast, in addition using the physical and land use/land cover parameters mapping is carried out separately for the marine and riverine environment as per the ESI (Environment Sensitivity Index) and RSI (Reach Sensitivity Index) guidelines. Table 1.

Table 1

REACH SENSITIVITY INDEX

	CLASS	DESCRIPTION OF REACH
	1	Quiet pool with low-sensitive banks
	2	Currents; low-sensitive banks (non-navigable)
	3	Currents; low-sensitive banks (navigable)
	4	Rapids over bedrock (non-navigable)
	5	Rapids over bedrock (navigable)
	6	Moderately sensitive/low vulnerable wetlands
	7	Highly sensitive/moderately vulnerable wetlands
	8	Straight channel; highly sensitive/highly vulnerable wetlands
	9	Sinuous channel; highly sensitive/highly vulnerable wetlands
	10	Multi-channeled; highly sensitive/highly vulnerable wetlands

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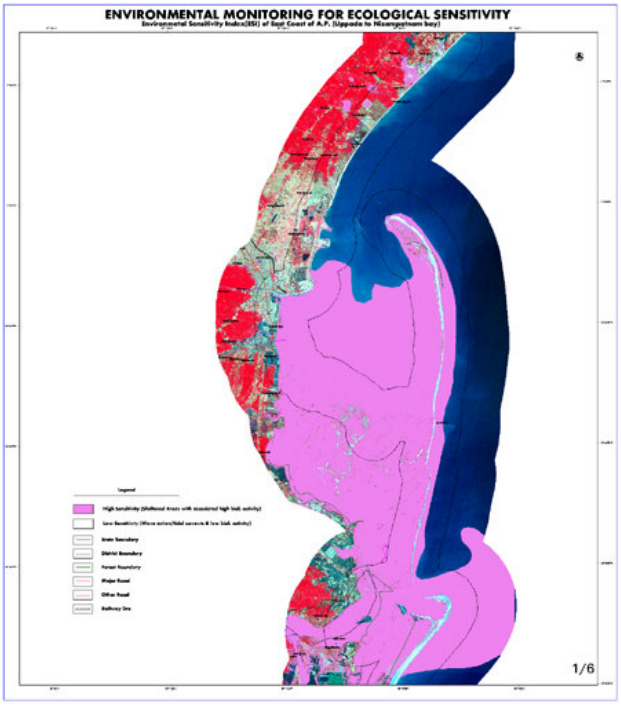
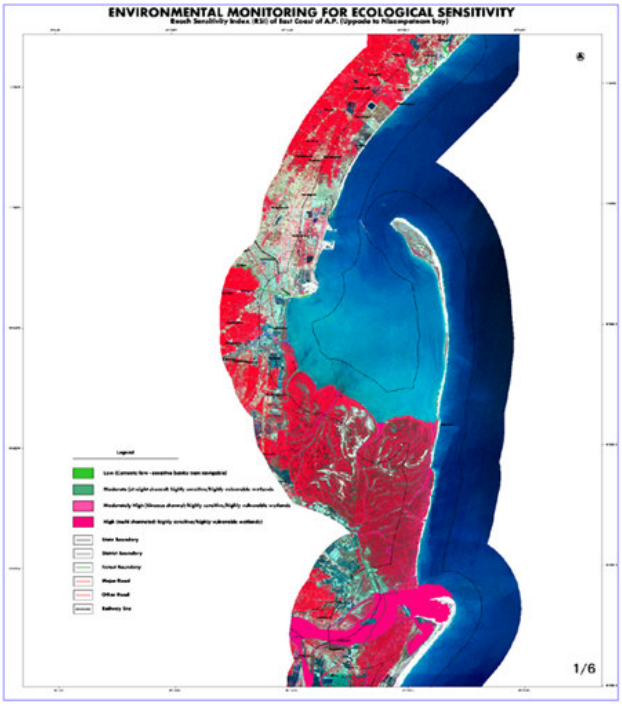
The Marine environment mapping the ESI guidelines used by oil spill planners and emergency responders is followed. The shoreline classification (1:50,000 scale) is based on its relative exposure to wave and tidal energy, shoreline slope, biological productivity and sensitivity.
The Riverine environment classification is based on the RSI principles. Reach was defined as distinct and uniform characteristics within a stretch of stream, which is, based on spill response modes and potential ecological and / or socio economic impacts from a spill. The boundary of a reach is marked by an abrupt change in morphology usually due to stream gradient. The classification (1:50,000 scale) is showing reach classification into category class2, 8, 9,and 10. is indicated in the map. (Refer table 1 for description).

3.1 ENVIRONMENTAL SENSITIVITY INDEX (ESI): - The Environmental Sensitivity Index (ESI), developed by Research Planning, INC (RPI), USA senior scientist in 1976, has become an integral component of oil spill contingency planning and response in USA and other countries world wide. Table 2…
Shoreline habitats are at risk during oil spills because of the likelihood of them being directly oiled when floating slicks come ashore.





Oil fate and effects vary significantly by shoreline habitat type, and many clean up methods are habitat specific. The concept of mapping coast environments and ranking them on a scale of relative sensitivity was originally developed in 1976 for lower cook Inlet (Hayes et al., 1976; Michel et al., 1978). Since that time standardized ESI shoreline habitat rankings have been devised for estuarine, lacustrine and riverine environments.

The following is the shore type classifications ranked in order of increasing sensitivity rating of 1 is the least environmentally sensitive and 10 the most sensitive. Adopted from Cook inlet/ Kenai Peninsula. Table…2

The sensitivity ranking is based on the following factors:

- Relative exposure to wave and tidal energy
- Shoreline slope
- Substrate type (grain size, mobility, penetration and traffic ability)
- Biological productivity and sensitivity

All these factors are used to determine the relative ESI ranking for a shoreline segment. Key to the rankings is an understanding of the relationships amongst physical process, and associated biota, which produce specific geomorphic/ ecologic shoreline habitat types and predictable patterns in oil behavior, sediment transport patterns, and biological impact.

Accordingly the ESI for the area is grouped into two class's High sensitivity and Low sensitivity. (See maps attached).

TABLE – 2
ENVIRONMENTAL SENSITIVITY INDEX (ESI)

ESI CODE	DESCRIPTION		
LOW SENSITIVITY	1	Exposed Rock	Composed of steeply dipping vertical bedrock. Exposed to high to moderate wave energy.
	2	Exposed Wave cut Platforms	Consist of wave cut or low lying bedrock. May be very wide depending on tidal range. Exposed to high to moderate wave energy
	3	Fine-grained Sand Beaches	Usually contain a broad, gently sloping profile of fine-grained sand
	4	Coarse grained Sand Beaches	These wide, steep beaches are composed of coarse-grained sand. They are generally associated with river or stream mouths
HIGH SENSITIVITY	5	Exposed Tidal Flats	Composed of sand and/or gravel. Associated with lagoons and at the head of coastal bays. They are exposed to moderate wave and tidal energy, and river flow
	6	Mixed Sand and Gravel Beaches	Composed of coarse grained sands, gravel of varying sizes, and possibly shell fragments
	7	Gravel, Cobble, Boulder Beaches	Composed of gravel to boulder-sized material. The beach is usually narrow and steep

	8	Sheltered Rocky Shores	Consist of vertical rock walls, bedrock outcrops, wide rock platforms, and bolder strewn ledges. Usually found along sheltered bays and/or along the inside of bays and coves
	9	Sheltered Tidal Flats	These are composed of very soft mud or muddy sand. They occur at the head of bays and in wetland areas. Wave activity is low and they may be exposed to moderate tidal currents
	10	Marshes	Comprised primarily of Spartina grasses on an organic rich mud base. Very sheltered from wave and tidal activity. Commonly found as small marshes found along river deltas or at the head of major embayment

3.2 BIOLOGICAL RESOURCES: - There are numerous animal species and plants that are potentially at risk from oil spills. In the ESI data basis, there are seven major biological elements based on major taxonomic and functional grouping. Following are the biological elements:

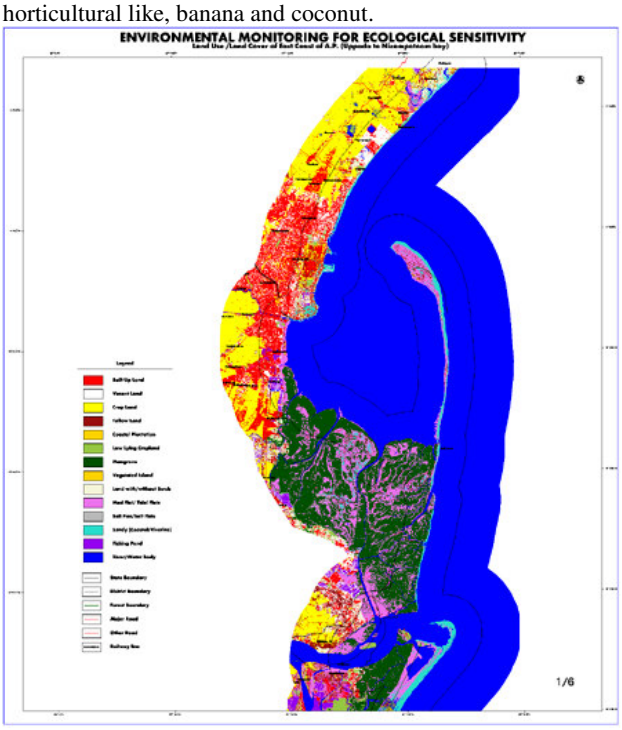
- Birds
- Fish
- Habitat (plants, sub aqueous habitats e.g., coral reefs, wetlands etc.)
- Invertebrates
- Marine mammals
- Reptiles
- Terrestrial mammals

3.3 HUMAN RESOURCES: - Human-used resources can be divided into four major components

- High use recreational use and shore line access areas
- Management areas
- Resource extraction
- Archaeological, Historical and other cultural resources

3.4 LAND USE/LAND COVER ANALYSIS

Delta of Godavari River has traditionally been the areas dominant with agricultural land utilization because of their highly favorable geomorphic terrain, productive soil cover and abundant water supply. These deltas with rich alluvial soil, which gets enriched annually, and irrigation network of canals and tube wells support multiple cropping pattern providing relatively high crop yields. The rich agricultural economy not only sustains higher population (rural more than 700 persons/sq km) and settlement (more than 6 villages/10sq km) densities, but is also supporting industry based on agriculture leading to development including well-connected transport network. Although, over the years, the land use and cropping pattern has remained unchanged in the deltas, yet, a gradual trend of change in land use pattern is being noticeable in river delta and the reasons could be due to climatic vagaries and changing farming techniques and advances in biotechnology. Climatically deltas along the east coast of India experience monsoon rainfall of more than 1000 mm per annum with temperatures ranging between 20 to 30 C (Subramaniam and Venkata Rao, 1981). The deltas constitute a part of irrigated agricultural with predominately food-crops like paddy, sugarcane, pulses and horticultural like, banana and coconut.



The area under various land use / land cover classes for the 2 km corridor area is tabulated and is presented in *Table 3.* It may be observed that the Agricultural land (with or without crop together with plantation) occupies area of 216.90 sq. km., which is 14.84 % of the total corridor area, wasteland (land with/without scrub) 7.14 sq. km (0.49%), Built upland of 51.46 sq. km (3.52%), water bodies of 811.61sq. km (55.55%) of the corridor, wet lands 245.42 sq. km (17.30%)include (Mangrove, Saltpan/Salt flat, Mud flat/Tidal Flat and Fishing Pond), Sandy coastal/Riverine 115.88 sq. km (7.93%). The area estimates for RSI and ESI of various classes/ is tabulated separately. (Table-3).

TABLE – 3
LAND USE LAND COVER AREA STATISTICS

Sl. No.	Category	Area (in sq. km.)	% to total
1	Built Up Land	51.46	3.52
2	Vacant Land	12.62	0.86
3	Crop Land	38.13	2.61
4	Fallow Land	32.64	2.23
5	Low Lying Cropland	139.26	9.53
6	Coastal Plantation	6.87	0.47
7	Mangrove	95.68	6.55
8	Land with/without Scrub	7.14	0.49
9	Salt Pan/Salt Flats	27.55	1.89
10	Mud Flat/ Tidal Flats	107.91	7.39
11	Sandy (Coastal/Riverine)	115.88	7.93
12	Fishing Pond	14.28	0.98
13	River/Water Body	811.61	55.55
	TOTAL	**1461.03**	**100**

3.5 WETLANDS

Wetlands are defined as all submerged or water-saturated lands, natural or man-made, inland or coastal, permanent or temporary, static or dynamic, vegetated or non-vegetated, which necessarily have a land-water interface. This category occupies an area of 25.73 sq. km (4.20%) of corridor. The major wetland categories identified in the study area are Mangrove, Saltpans and Mudflats.

3.5.1 Mangroves

It appears bright red in color. It occurs along the coastal areas/inland areas of Krishna and Godavari River. This category occupies an area of 95.68 sq. km (6.55%) of corridor.

Usually luxuriant vegetation prevails over large areas of the delta plains as saline mangrove swamps. Freshwater swamps or marshes, in humid tropical and subtropical regions along the intertidal environment are treated as builder of new landmass. Mangrove growth depends upon salinity of water, tidal, range, muddy strata, nature of shoals, ocean current protection and air temperature.

3.5.2 Mudflats/Tidal Flat

The mudflats are classified on the basis of their relation to the tidal conditions into the following, sub-tidal, inter-tidal and high tidal flat. However in the study area these have been grouped as one. The sub tidal zone is exposed only during low tide. The inter-tidal slopes lie between high water and low water mark, while the high tide flat lie above mean high water mark. The tidal flat environment is observed to be an elongated feature running parallel to the coast over tens of kilometer and are intersected by tidal channels and river estuarine system. The main part of the Kakinada Bay extensive tidal flats are developed along the gently sloping sea coasts with significant tidal flats in the Gautami estuary. Vasista estuary and in pandi lagoon. Tidal flat located between inter tidal zones, towards land is the supra tidal zone.

This category is noticed along the coast of the study area and occupies an area of 107.91sq. Km (7.93%) of the corridor.

3.5.3 WATER BODIES

Rivers/streams/canals, sea and lake/reservoir/tank are the important water bodies seen in the study area. The river seen in the study area is Godavari. The Godavari flows into the Bay of Bengal through three major distributaries, namely Gautami Godavari, Vainateyam Godavari, and Vanish Godavari. Nilarevu is a very small distributaries branching out from Gautami Godavari. The Godavari delta has undergone phases of erosion and accretion through fluvial and marine agencies during its growth in recent times. Largely the detritus materials brought by the river from its drainage basin and subsequent effect of coastal processes over a long period in the modern Godavari delta were responsible for shaping the geomorphic units. The Godavari river channel from Dowaleswaram to the confluence of Gauthami is 90 Km, and of vainateyam and Vasista, 96 Km and with a maximum width of 2 km. The tidal effect is up to 42 km upstream in the river channel. River channel sediments are composed of mostly sands..

4) CONCLUSIONS

Satellite based remote sensing techniques have proved successful in providing a comprehensive, reliable and up-to date information on land use/land cover in the most cost effective manner. Knowledge of the agro-climate and agro-ecological conditions of the area will helped to identify ecologically sensitive locations with special reference to Environmental Sensitivity Index (ESI) and Reach Sensitivity Index (RSI) identified through modern methods like Digital Image processing and GIS for preparedness in case of oil spill incidents in offshore areas of east coast of Andhra Pradesh.

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