Geo-environmental mapping and spatial information technology

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ARTICLE INFO

Keywords:
Geo-environmental mapping
Geoinformatics
Environmental management

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ABSTRACT

A good understanding between biophysical domain and anthropogenic interactions is very essential in the context of sustainable environmental management. In this respect, Geo-environmental mapping facilitates to identify the suitability of various landforms/ terrain units in relation to the existing utilization or selective alternate use, especially in fragile ecosystem like marine- coastal environment and mountain ecosystem. In the present day scenario, the 'Spatial Information Technology'/Geoinformatics provides a vantage point for collection of required data at varied spatial and temporal scale and to analyse the same with related '*in-situ*' attribute data to generate application specific pragmatic dataset for implementation. This paper deals the subject matter with site specific examples.

1. Introduction

In environmental management vis-à-vis biodiversity conservation landscape ecological surveys play an important role in the context of 'geo-bio-cultural' interactions which is directly related with the 'Hydrodynamic Circulation'/ 'Hydrological Cycle'. This involves systematic in-depth study of the dynamic functions of the terrain in terms of form-process-material interrelationships of the nature's own built system accentuated by the anthropogenic influences. In this respect, geoscientists have to provide 'factual and functional' data on open system of rock/soil- water- vegetation in relation to various endogenous and/or exogenous processes through time and space in a quantitative manner for identifying the genetic causes of future degradation in natural settings. This requires up gradation of the methods/knowledge in spatial data collection and analysis as the spatial characterization is the fundamental prerequisite for combining non-spatial attributes in obtaining the required integrated output.

With the advancement of scientific and technologic world the aero-space data products especially the space borne EOS (Earth Observing Satellites) provide more 'operational', reliable and updated information about the terrain features with synoptic coverage. Now a days, space-based inputs have immensely contributed towards sustainable management of environmental resources required for maintaining ecological balance, supporting the livelihood of dependent communities as well as for national development.

2. Strategic consideration

In the present day scenario, it is being thought that rapid losses of biodiversity possess a global threat to human being. Biological diversity is largely maintained by sustainable use of land and water resources – aiming towards green environment for eco – development or to maintain ecological diversity/ eco-system – most important as it plays facilitator role for genetic and species diversity. Therefore, it is essential to establish rational bi-directional interrelationship between 'rock/soil- water- vegetation' (Nature's own built system) and 'geo- bio – cultural 'aspects (i.e, Human subsystem) through dynamic viewing capabilities of factual and functional data as well as monitoring of acceptable changes between the Environment(E) and Human Capital and Mobility (HCM) which includes —

- Identification of 'Disturbance Gradient zones' in the bio-physical environment through (i) Monitoring and assessment of land use/land cover changes especially in the sensitive environment like mountainous and coastal zones; (ii) Climate – Hydrodynamic Circulation in the context of climate change issues – 'agro-water-ecosystem' potential and vulnerability in response to any change in hydrological cycle – glacial retreat etc. – hydrological modelling of regional basins/ watersheds to 'locale specific' recharge issues on micro-watershed level.

- Prioritization of 'Bio-prospecting zones' for biodiversity conservation – enhancing ecological sustainability to maintain/ conserve uniqueness of biodiversity – study of micro flora(including medicinal plant variety) and fauna, wildlife and animal population in ecological sensitive areas like the Himalayan region, mangrove swamp zone in coastal belt or areas of land degradation.
- Information dissemination for building public awareness in order to ensure public participation includes—knowledge management, training and capacity building.

Case studies reveal—

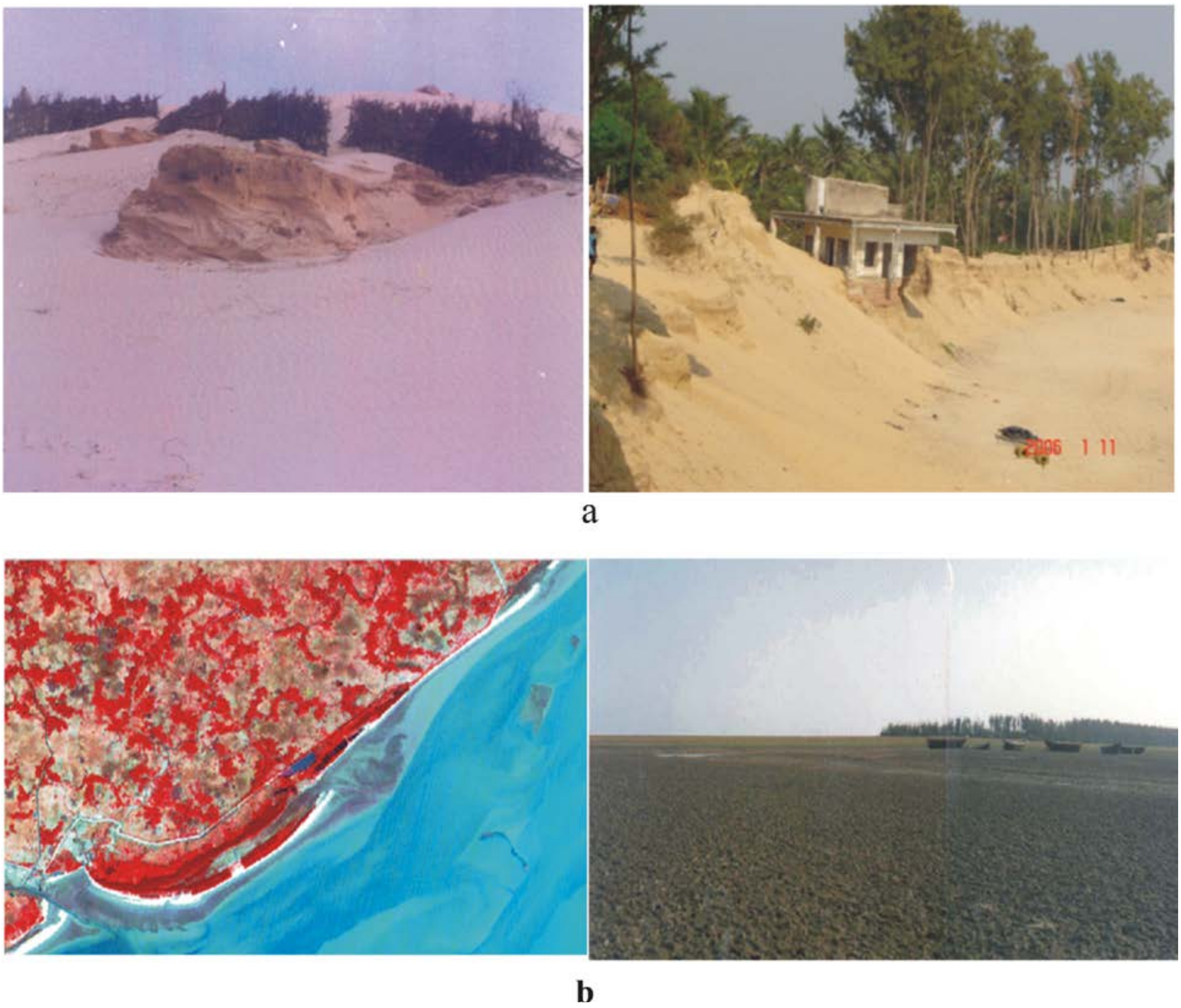
- Co-existence of rural poor societal condition and environmental degradation including natural hazards.
- 'Technology Push' without considering the terrain condition and societal settings, breaking natural resource assets vis-a-vis environmental deterioration.
- Education, shelter, food and water security i.e. poverty alleviation leads to build natural assets for environmental security/ biodiversity conservation as well as to reduce the adverse effects of global warming.

3. Science driven approach

Biodiversity conservation

Study of Landscape ecology – generation of full featured spatial and temporal data of the existing scenario with morphogenetic approach in terms of:

- Spatial database identifying biophysical land units/terrain units/ geo-environmental units.
- Land evaluation – a value neutral exercise, if not, societal values added.
- Agro-ecological characterization agricultural environment-identification of domains of technical adjustment and social adaptation e.g. marginal farmers do not consider the environmental hazard created by them in the context of using pesticides etc. for their livelihood.
- Environmental impact assessment considering socio-economic factors and agricultural production activities (a spatial database) especially in the fringe zone of the forests.



Photograph 1. Erosinal and accretional regime in Digha (a) – Junput (b) coastal belt, West Bengal, India

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Geo-environmental mapping (GEM) & terrain mapping unit (TMU) concept

Conceptually, the Geo-environmental mapping is the spatial representation of the human activities (mainly dependent on the socio-economic condition) on the nature's own built system (rock/soil- water- vegetation interrelationships) exemplifying the suitability of different terrain units in relation to the existing utilization or selective alternate uses i.e, sustainable land use planning (Chakrabarti, 2004).

Easy-to-understand presentation of data in 'environmental mapping' requires identification of Geo-environmental indicators (GEI) and Geo-environmental unit (GEU) in relation to Natural system unit (NSU) or Terrain mapping unit (Fabbri and Patrono, 1995).

Geo-environmental indicator (GEI): 'Process sensitive and easy-to-measure' physico-chemical characteristics of the dynamic earth which help in identifying the various geomorphic environment in human orientation through space and time (Cavallin et.al, 1995). Two types—

- Qualitative indicator: identify the specific characteristics of landform unit(s) in terms of spatial change detection e.g. landslide/soil erosion/flood prone areas, bank line shifting of a river or shore line changes etc.
- Quantitative indicators: supplementary to Qualitative indicator. Numerical attributes related to change detection generated through *in situ*/conventional measurements are of basic importance e.g. round the year beach profiling data to specify the zone of erosion or accretion; the mass balance study of glaciers over a period of time to measure the health of the glacier; sediment monitoring station to generate data on soil erosion; measurement of fragmentation status, disturbance index, biological richness of forest; depth to water level monitoring for seasonal variation study; chemical analysis of water in identifying the quality of water etc.

Geo-environmental Unit (GEU): Spatial database with certain entity/ boundary as defined by GEI. A Geo-environmental unit may contain one or more TMU (Meijrink, 1988) or NSU and vice-versa (Chakrabarti, 2015). For example–

- In the Midnapore Coastal Plain, West Bengal, active erosional regime is prevailing in the 'Beach-face Dune Complex' (BDC) zone of Digha- Shankarpur- Mandarboni area (of about 20 km stretch); whereas, accretional regime is present in the same 'Beach-face Dune Complex' zone in the eastern part (for a stretch of about 25km.) between Dadanpatrabar –Junput area (Chakrabarti, 1991, 1995; Chakrabarti and Nag, 2015) (Photograph 1 a and b). In both the cases, the terrain unit same but two GEU may be identified based on the prevailing erosional and accretional environment as GEI:

TMU (Terrain mapping unit)	GEU (Geo-environmental unit)
Beach-face Dune Complex(BDC)	Erosional BDC zone Accretional BDC zone

Accordingly, the land use/land cover (LULC)/ environmental management programme will be different for the two sectors considering the process sensitivity.

- In Jambudwip, a tidal shoal in the Hooghly estuary, mangrove forest covering two TMU's. Viz. Mangrove Swamp and Supra-tidal Core zone. Both the units are fast deteriorating due to human interactions. In this case, 'Mangrove Forest zone' may be identified as a GEU considering the geomorphic environment (as GEI) challenged by anthropogenic activities (Chakrabarti, 2010) to safeguard the eco-system (Photograph 2).

TMU	GEU
Supra-tidal core zone Mangrove Swamp	Mangrove Forest zone

- In support of rapid urbanization brick kilns are coming very fast around major towns/ cities. In and around Kolkata, brick kilns use soil from either from (a) accumulated silt from the tidal rivers/streams viz. Hooghly, Rupnarayan, Ichamati rivers or (b) agricultural lands- accelerates land degradation process. Considering process sensitivity as GEI two environs may be identified for brick kilns accordingly-

GEU	NSU (Natural System Unit)
Tidal-zone brick kiln Agri-zone brick kiln	Alluvial Plain

- The 'Flood Plain' is a geomorphic unit where flooding and bank failure both may present. But flooding and bank failure are two distinctly different phenomena. In a flood prone area, considering 'flood inundation duration' as GEI, the GEU may be identified as- area of deep and long lasting inundation, deeply submerged area, submerged but drains off well, shallowly submerged area and rarely submerged area.
  Similarly, considering the intensity of bank failure as GEI, the GEU may be identified as – highly vulnerable, vulnerable, moderately vulnerable and slightly vulnerable.

It is worth mentioning here that the Geo-environmental mapping, on principle, facilitate systematic monitoring of changing dynamics of the terrain features in respect of LULC and biodiversity characterization in watershed level. In this respect, the spatial information technology plays a vital role by providing updated spatial information about terrain features as well as cover types in relation to anthropic influences.

4. Modern tools

The 'Space Information Technology' may be defined as the 'geo-information' provided by the satellites which includes both Earth Observing Satellites (EOS) and communication /meteorological satellites along with Global Navigational Satellite System (GNSS). Whereas, the 'Spatial Information Technology' can be defined as the technique by which integration and analysis of spatial data with the aspatial/non-spatial data (i.e. attribute data) are carried out on GIS (Geographical Information System) platform in user orientation (Chakrabarti,2014). It is worth mentioning here that GIS allows people to analyze problems with individual thinking in different way with geographical representation of reality/ real world scenario. GIS is a tool to facilitate the convergence of two or more spatial data layers and non-spatial/ attribute data to conclude on application specific 'pragmatic/ strategic dataset' which could be utilized for—

- Technological adjustment by the Technical Departments with applications of S&T inputs.
- Societal perspective by involving community i.e. peoples' participation through awareness programmes etc.

Interpretation of RS data

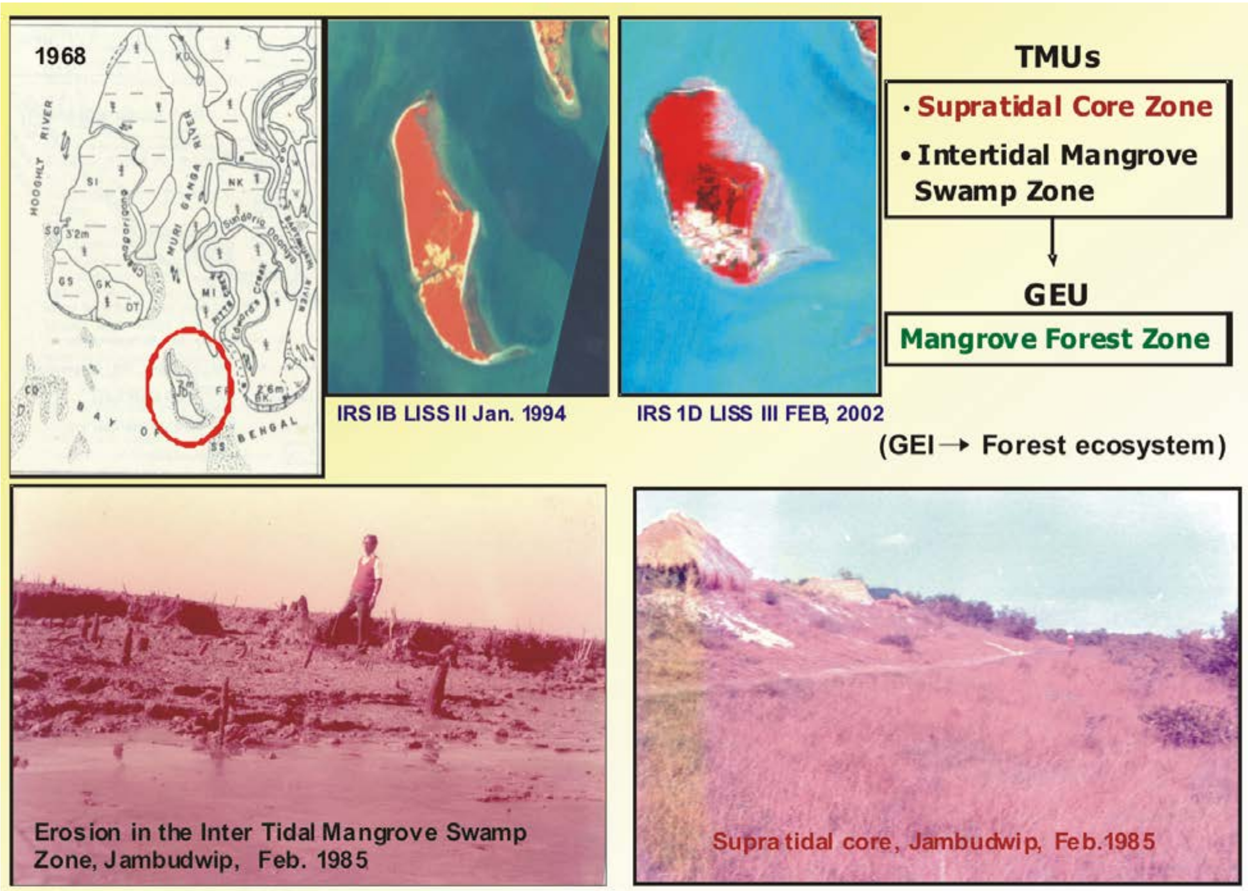
Remote sensing data is the core of GIS. So, RS data interpretation should be carried very accurately in accordance with the real world; then only pragmatic conclusion could be obtained. In this respect, one should choose what type of interpretation techniques to be taken into consideration for the work envisaged.

In visual/ analog interpretation technique the terrain units are identified based on the image interpretation elements and terrain parameters where intelligence, capacity, experience and local knowledge of the interpreter play very important role.

Digital interpretation is based mainly on set theories and takes care only 'tone' without considering other image interpretation elements. So, the similar spectral responses from different objects and dissimilar spectral responses from similar objects cause spectral confusion leading to misinterpretation.

The 'on-screen' interpretation technique may be considered as the combination of visual and digital techniques. In on-screen interpretation procedure the input satellite data in digital format (as FCC) is being displayed to a screen of the computer system and the features identification could be done using image interpretation techniques as done in case of visual interpretation with hard copy. The advantage with on-screen interpretation and mapping is that the smaller parcels as in our country can be viewed with 'zooming-in' approach. Some of the features can also be discriminated easily using individual band data as well as from multi-seasonal / time sequential data. It is to mention here that the on-screen interpretation technique is similar to the visual interpretation procedure; however, the errors which normally creep-in during the creation of vector data from tracing film drawings by digitization could be avoided. In addition, directly digital data can also be created simultaneously while interpreting the image thereby saving time.

In fine, it is being suggested that one can start with visual interpretation of multi-seasonal/ time sequential geo-referenced scenes and go for on-screen interpretation with subsequent ground validation for providing high quality output.



Photograph 2. Sequential changes in the mangrove forest zone from 1985 to 2002, Jambudwip

5. Conclusion

Geo-environmental mapping (GEM) facilitate systematic monitoring of changing dynamics of the terrain in respect to LULC for enabling people with 'informed participation' in decision making for environmentally sound land use/land cover practices as well as biodiversity characterization at landscape level (BCLL) towards sustainable future.

Recent advancement of the 'Space Information Technology' has offered new opportunities for spatial monitoring of key attributes of biodiversity viz. land degradation, vegetation diversity and richness, glacial and coastal ecosystem etc. vis-a-vis anthropogenic activities.

Conjunctive use of GIS leads to identify the alternative Land use practices for future conservation of basic natural resources in the context of protecting ecosystem relatively rich in biological diversity.

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