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Geoscience Today: From the Perspective of Environmental Impact Assessment

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Abstract: *Environmental impact assessment (EIA) may be considered as a holistic approach to address most of the environmental maladies which owe their origin to disturbing disparity in utilisation and consumption of available resources by human subsystem, depending on their socio-economic fabric. Anthropogenic activities with infrastructural growth dynamics in general, facilitate landscape heterogeneity by modifying the rhythms of natural processes. Type and degree of environmental impact on 'nature's built-in system' may vary in directness, intensity and duration depending on the nature of the human action and the affected biotic-abiotic communities. Here lies the importance of EIA which primarily focuses on environmental understanding, prediction and assessment of the potential modifications induced by human activities in space and time through short- and long-term studies.*

In this regard, geomorphic and geological indicators facilitate to simplify the environmental quality score using 'factual and functional' parameters of the changing earth's surface. With this perspective, geoenvironmental mapping in conjunction with spatial information technology provide ample opportunity for spatial characterisation of 'geo-bio-cultural' and 'hydro-biological' interrelationships, endorsing effects of various exogenous and endogenous processes active in the area under interest with regional perspective. This leads to modelling, using the generated database to specify environmental vagaries with futuristic approach.

Key words: *Geoscience indicators, environmental impact assessment, geoenvironmental mapping.*

Introduction

The Quaternary or Anthropocene period, a short time span of about two million years in the geological time scale, is interestingly characterised by alternate glacial and interglacial phases with sea level fluctuations. The changing physico-chemical processes and dynamic system of the earth during the period is exemplified by abrupt change in landscape ecology along with evolution of modern flora and fauna as well as appearance of homosapien. The same processes are continuing in the recent Meghalayan Age also, for example, the endogenic processes with exchange of heat and matter between the earth's mantle and crust energised by radioactivity as well as solar induced exogenous processes on the earth surface affecting the hydrosphere and atmosphere. The array of issues has profound impact on the interrelationship between living organisms, man, and rest of the nature.

In this respect, 'biosphere' (the term coined in 1875 by E. Suess, a geologist) may be considered as a complex web of man-environment relationships with orbital variations of the earth, solar variations, and albedo changes (Sen, 1999; Bandopadhyay, 2013). The science of biosphere emphasises the dynamics of life-support systems and biotic-abiotic interrelationships on the earth where human interactions are thought to be a powerful agent with wide range of uncertainties. So, it is pertinent to realise the environmental problems in the context of human subsystem in environmental dynamics with holistic approach. Here lies the necessity of understanding Environmental Impact Assessment (EIA) from the geoscience perspective.

Environmental Impact Assessment (EIA)

EIA is a process-response system analysis to study multifarious alterations in natural/ physical processes induced by anthropic activities and to identify the rational balance between environment and Human Capital and Mobility (HCM). The primary aim of EIA includes reconstruction and evaluation of natural/ physical phenomenon in relation to anthropogenic impact through short- or long-term monitoring of geo-environmental parameters to conclude on specific guidelines for 'geo-bio-cultural' interactions and socio-economic development.

Anthropogenic activities with built-up environment, in general, facilitate landscape heterogeneity by modifying the rhythms of natural disturbance. So, environmental impacts may vary in directness, intensity and duration depending on the nature of the human action and the affected biotic-abiotic communities. The recovery potential mainly depends upon life forces, type and degree of impact on 'natures own-built system' intimately related with hydrodynamic circulation (Chakrabarti, 2002, 2004).

In this regard, the term 'Impact' (I) refers to the relationships among a project, landforms and natural processes (both exogenous and endogenous) and can be expressed as:

$$I = Ga \times F \times Ha$$

where, Ga: geomorphic asset i.e. landscape value including cultural, socio-economic parameters; F: fragility refers to stability/ resistance of geomorphic asset (Ga), i.e. the degree to which the characteristics of Ga could be maintained when affected by a specific anthropogenic activity/ project; and Ha: human activity/ impact related to a project.

The impacts caused by the emplacement of an infrastructure on the natural environment in a given area could be measured using multi-criteria analysis. The indicators used for the analysis can vary considerably according to their specific nature and origin e.g. geo-spatial distribution, biotic-abiotic relationship and synthetic parameters in the context of human interest on aesthetics in relation to ecology. The main difference between Environment Evaluation System (EES) and the Land Evaluation (LE) procedure is that, in EES along with land evaluation parameters special emphasis is given to aesthetics and ecology in orientation with human perception. For example, the East Calcutta Wetlands (declared a Ramsar Site in 2002) is the remnant of the original tidal marsh which had direct connection with the Sundarban, through a number of tidal rivers. A portion of this saltwater marsh was filled up with the dredged silt and sand from the Hugli river in the sixties of the last century, to give shape to the Salt Lake City. Conversion of the salt marsh area to a city, ignoring the ecosystem, adversely affected the natural drainage system of the Salt Lake

City. The reclamation of the marsh to set up a city, which was once viewed as wise decision, had its repercussions which are now being experienced in terms of increased duration of water logging in Kolkata and Salt Lake City during heavy precipitation. The East Calcutta Wetlands plays a positive role for the Kolkata city in terms of ecological balance as storage reservoirs and mitigating storm floods during monsoon (Chakrabarti, 2021; Chakrabarti and Nag, 2015). In addition, the wetlands are used for sewage-fed fisheries as "the silt in the wetland system called 'detritus', offers an ideal niche for a complex chain of micro-organisms to act as decomposer, thereby, providing a habitat to primary consumers (invertebrates) and secondary consumers (fishes and birds)". The sewage water, rich in nutrients is also used for the production of vegetables and paddy — comparable to the urban agriculture through 'Sanitas Wall' in Botswana (Ghosh, 1991). Hence, no further encroachment would be wise in the context of EES to maintain the ecological balance of the Kolkata city and its environs.

Steps in EIA

The steps involved in environmental impact assessment are as follows.

- Understanding of the existing environment with special emphasis on natural processes in terms of geological/geomorphological phenomena, e.g. mass movement/ landslides, deformation, subsidence, river bank failure, shoreline shifting etc.
- Identification of effects of potential modifications induced by human activities.
- Prediction and assessment of the impact of human activities in space and time taking into consideration the 'geo-bio-cultural' relationship.
- Selection of proposed 'Action Plan' as well as formulation of alternatives in the context of socio-economic feasibility study.

Geoscience in EIA

The changing landform features on the earth's surface are the resultant effects of three mechanisms operating within the boundary of the landscape—

- Specific geomorphic processes taking place over a long period of time;
- Colonisation/ settlement patterns induced mainly by human influence;
- Short-term area specific local disturbances of individual ecosystems.

More specifically, landscapes reflect three pervasive natural components: (1) geomorphology, which is strongly influenced by climate; (2) biotic-abiotic establishment and spatio-environmental relationship; and (3) soil development and soil-water-vegetation interrelationships.

The main tasks or work elements of Geoscience in EIA include:

- Spatial characterisation of 'rock/soil-water-vegetation' interrelationships and effect of various exogenous and endogenous processes active in the area under interest from the regional perspective.
- Generation of database on the physico-chemical parameters and their space-time relationships and distribution.
- Modelling of natural processes and human-induced changes, using the generated datasets to predict where and when changes are likely to occur. However, such modelling has their own limitations due to inadequate observations and suggests only probabilities. Human activities can modify the magnitude and frequency of landform change. Hence, any predictive modelling has to shift from a nature oriented approach to human-cantered one.

In this context, the role of geomorphology in assessing the impact of anthropogenic activities on the environment should be given special importance. The role of geomorphology in EIA could broadly be grouped under—

- Assessment of geomorphological/ geological resources.
- Terrain analysis in relation to environmental changes, giving stress on both scientific and societal aspects.
- Study and prediction of natural hazards, both exogenous and endogenous in relation to geomorphological/ geological processes
- Analysis of environmental degradation influenced by ‘geo-bio-cultural’ disturbances.

Geomorphological and geological indicators in EIA

Identification of geomorphological/ geological indicators (Table 1) measured over time is essential to describe the surface, sub-surface and underground conditions which are critical for understanding the phenomena, systems, resources, or assets of a region. In EIA the main aim is to analyse the anthropogenic modifications in short- and long-term basis from a relative zero condition i.e. the baseline condition before initiation of a particular project. For example, in a river basin the sedimentation rate is the indicator of climatic, hydrologic, hydrodynamic, eustatic and epeirogenic events. In this context, specific indicators help to understand the geomorphic system as well as to predict changes in response to the anthropogenic activities. For instance, construction of a dam/ barrage on a river changes the sediment transport and erosion processes downstream of the dam/ barrage. For example, in the Farakka Barrage on the Ganga river, West Bengal bank erosion is prevailing along the left bank of the stream, just upstream of the barrage. Active bank failure/ erosion are observed along the right bank, downstream of the barrage; as gates at this side of the barrage are kept open mainly for removal of deposited sand/ silt at the mouth of the Feeder Canal (Chakrabarti, 2012).

It is worth mentioning here that a statistical analysis of related collateral data of earlier projects in similar physiographic province may be performed to tune up the identified geomorphological indicators of a project under consideration. For instance, if we look at the Gandak and Kosi dam/ barrage in Bihar, both are situated in the hilly terrain though the main canals and the distributaries are aligned in the alluvial fan zone. In both the cases, the canals play the role of facilitator in the ‘deep and long lasting’ water logging scenario at many a places. In case of Tista

Table 1. Fundamental indicators in geoscience orientation

Indicators	**Geologic / Geomorphic Components**
Lithology (rock / sediment type)	Resistance/ stability to static load
Slope aspects	Long term slope equilibrium
Landslide hazard	Slope instability
Landform/ terrain capable to be shaken	Seismicity
Epeirogenesis, subsidence, trans-currencies	Geodynamics
Heat flow	Geothermal activities / Volcanism
Drainage network/ pattern development and flow coefficient	Rock / soil properties /erodibility factors — surface hydrology
Effective porosity, hydraulic conductivity, transmissivity and storativity	Ground water hydrology
Sediment dispersion and rate	Basin hydrodynamics in time and space

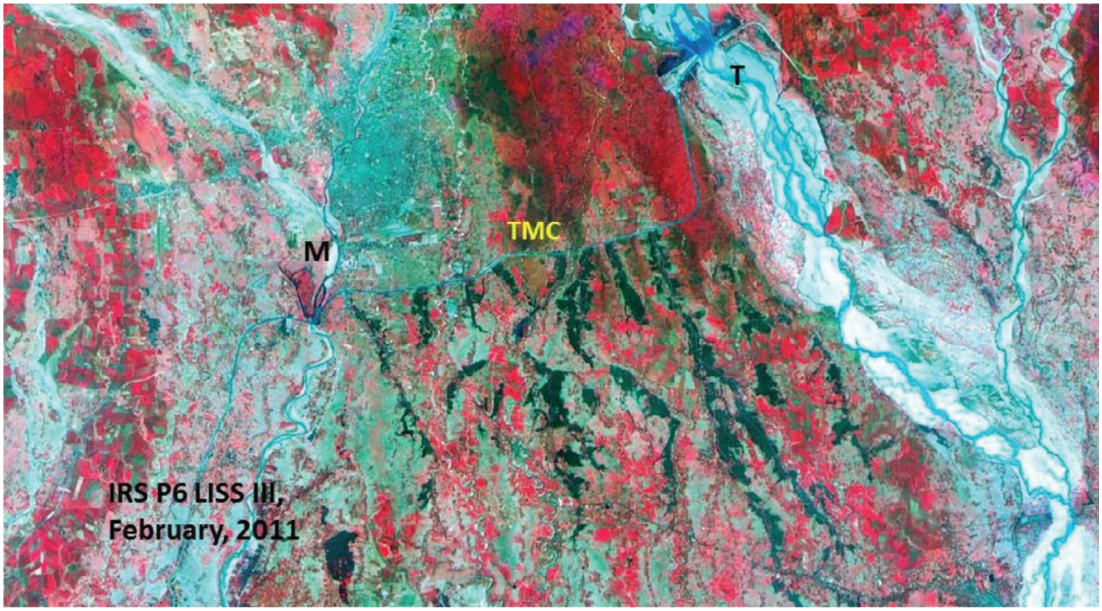

Figure 1. Waterlogging scenario along Tista (T), Mahananda (M) and Tista main canal (TMC), West Bengal (Base of the image: 41.9 km; Central coordinates: 26°38' N, 88°32' E).

river in West Bengal, similar type of water logging conditions are prevailing in upper parts of the right bank canal as reflected in the satellite images as well as on the ground (Fig. 1). It can be assumed that the experience of the Gandak / Kosi canal system was not taken into consideration during the Tista Barrage project though the project area is in the same physiographic province.

It is to mention that complex geological components are reflected on the earth's surface primarily by geomorphological features. So, identification of geomorphological indicators is essential in the first instance and subsequently detailed geological study should be carried out for specifying the geological indicators. In a techno-economic developmental project the prediction of geological risks in the area of interest can easily be done by geomorphological studies. For example, the site selection for the barrage on Tista river, West Bengal is not so suitable from the geomorphological/ geological perspective, especially, in terms of storage purpose. The Quaternary geological and geomorphological studies reveal that the barrage is occupying parts of 'intermediate fan surface'(Matiali / Chalsa formation) and 'distal fan surface'(Baikunthapur/ Saugaon formation) where both lateral and vertical seepage factors are active due to presence of unconsolidated constituent materials like sub-rounded boulders, poorly sorted pebbles and coarse to fine sand. In addition, storage capacity of the barrage will also be reduced day by day due to huge amount of sediments coming from the hinterland (Chakrabarti; 2020).

Geomorphological indicators vary with various geomorphic process-oriented environments such as the fluvial system, coastal system, soil/ land degradation, slope instability etc. (Rix, 1995).

Indicators of change in fluvial system

The change in fluvial systems are related to — changes in bed slope, channel cross section and hydraulic geometry parameters; changes in discharge, sediment load (bed load, suspended load); scour type and depth;

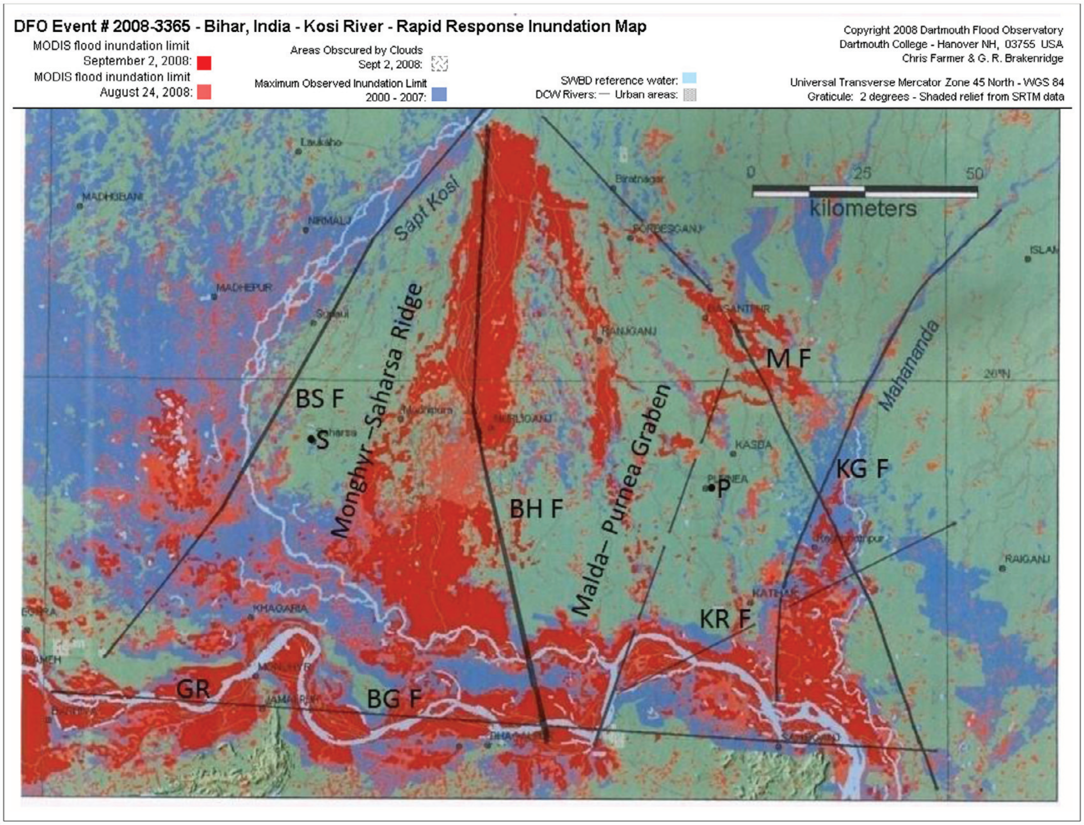

Figure 2. Kosi Fan with structural elements: BS F = Begusarai Fault; BH F = Bhawanipur Fault; M F = Malda Fault; BG F= Bhagalpur Fault; KR F = Katihar Fault; KG F= Kishanganj Fault; S = Saharsa; P = Purnea; GR = Ganga river (Central coordinates: 25°59' N, 87°15' E). Source: floodobservatory.colorado.edu

incision and deposition rate/ area; drainage pattern; percentage of vegetation cover in the catchment, banks and river bed; geological control (both lithological and structural) and bank erosion/ failure.

For example, Kosi river with its catchment area in the Nepal Himalaya is flowing through a gorge for about 10 km up to Chatra, Nepal and debouches into the plains at the apex of the gigantic Kosi fan. Morphogenetically, the Kosi fan is built by the lateral migration of the main and distributary channels significantly (140 km. from east to west in 250 yrs.) due to high monsoonal discharge with average rainfall of 1,456 mm yr^{-1} and sediment load of about 95×106 m^3yr^{-1} (Kumar, 2015; CWC, 1982) as well as neotectonic activities along the pre-existing faults and lineaments along with horst and graben structures of the basement warps.

More precisely, the triangular shape of the fan is flanked by the three well known lineaments in the region viz. NNW-SSE trending Maldah fault in the east, NNE-SSW trending Begusarai fault in the west and the E-W trending Bhagalpur lineament in the south along which the Ganga river is flowing. In addition, the N-S trending Bhawanipur fault is present almost in the central portion of the Kosi fan. Integration and analysis of the geophysical data of the area also indicate the presence of two structurally-controlled blocks in conformity to the regional basement 'highs and lows' (Agarwal and Bhoj, 1992;

Figure 3. Rejuvenation of Bidya nala (BN) around Satkahania (S) Ajoy River (AR) during high flood; causing severe damage to the Panagarh-Moregram Expressway, 2000. A) IRS Satellite Image (Base of the image: 24.10 km; Central coordinates: 23°33'35" N and 87°36'36" E); B) and C) Field photographs showing ground reality.

GSI, 2009) — (a) Maldah–Purnea graben between Maldah and Bhawanipur fault in the east and (b) Monghyr–Saharsa ridge between the Bhawanipur and Begusarai faults in the west (Fig. 2).

Indicators of change in hydrologic system

Changes in hydrological regime are related with infiltration rate/capacity (mm minute^{-1}), soil moisture content, time to runoff/ residence time (hrs), the form of the hydrograph, the depth of flood inundation (m) and duration (hrs day^{-1}), breach in the embankment and flood recurrence period.

It is worth mentioning here that breaches in the weak zones of the embankment,

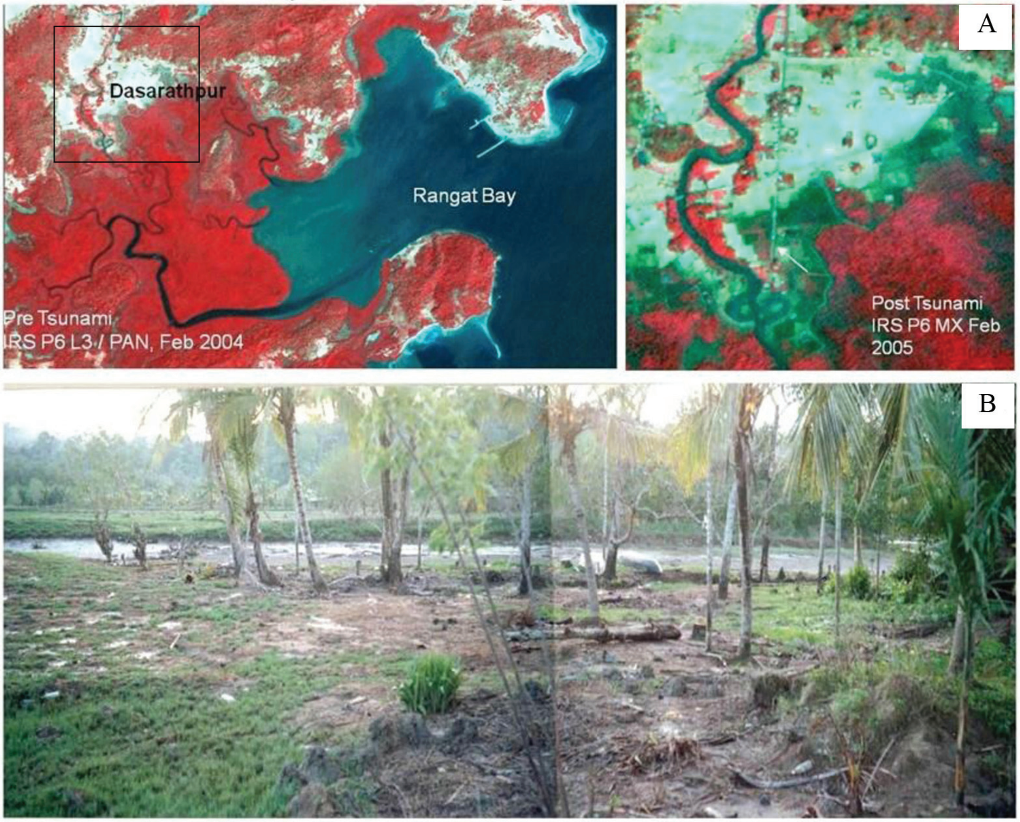

Figure 4. Tsunami damages in Andaman (December, 2004): (A) The pre- and post-tsunami changes detected from satellite image (Base of the image: 7.6 km; Central coordinates: 12°28'52.32" N, 92°56'15.36" E). The Base of the image showing post tsunami scenario is 1.3 km; (B) The damage of reclaimed land, Dasarathpur, Rangat, Andaman.

more specifically at the offtake points of the abandoned spill channels, during high discharge period cause flood inundation for long durations. Such examples can be observed in the Kana Mayurakshi offtake point in the right bank of the Mayurakshi river at village Sunderpur in Birbhum district, West Bengal. Similarly, in the Satkahania-Basudha area in Kanksa-Bhatar blocks of Bardhaman district West Bengal, an abandoned spill channel had been activated during 2000 flood due to breach in the right bank embankment of the Ajoy river which is the offtake point of Bidyanala. The floodwater severely damaged the Panagarh-Moregram expressway as well as vast agricultural land in the surroundings (Fig. 3).

Indicators of slope instability

Slope instability is a response of the forms and segments of slope, dominant processes active (including structural control), and presence of seepage / spring flow. The types of slope failure are based on changes in safety factors and varying magnitudes of human interferences.

Indicators of soil erosion/land degradation

The indicators of soil erosion/ land degradation include — rate of soil erosion (mm yr^{-1}), change in soil depth (cm), the active land degradation processes (e.g. water, wind, waves, glacial, chemical, anthropogenic etc.) and the causes and types of degradation (e.g. waterlogging, sheet erosion; formation of rills / gullies /ravines; conditions of

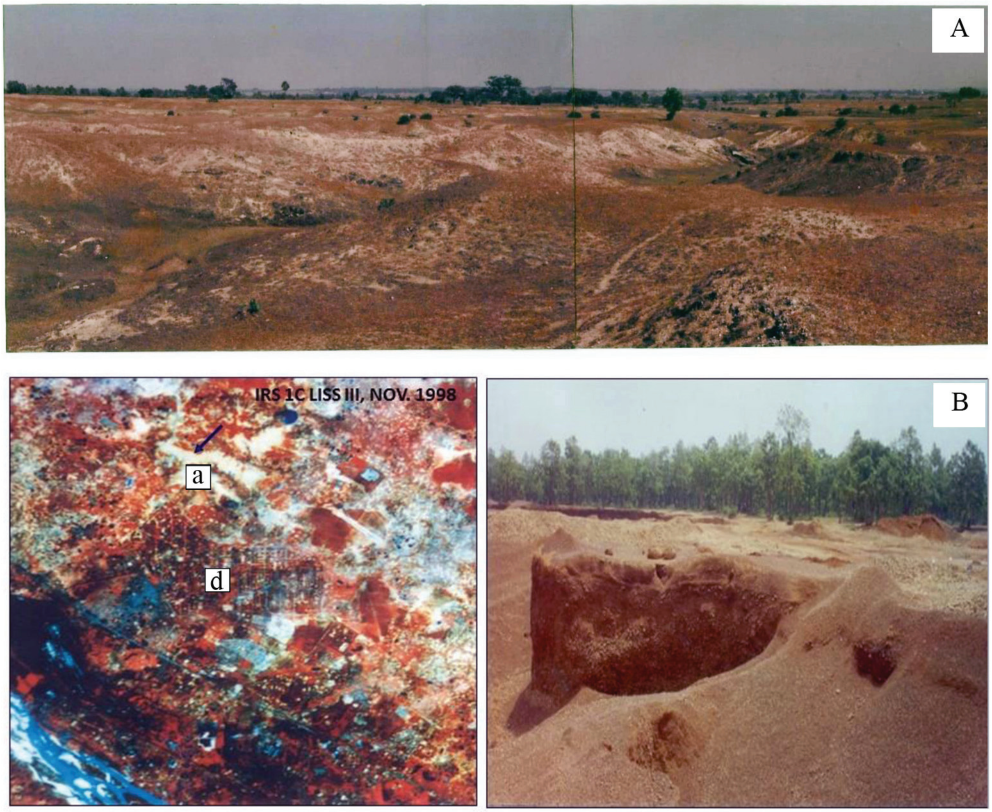

Figure 5. (A) Land degradation by weathering process and formation of gullies in Chhotanagpur plateau fringe area, Gourdanga, Arsha Block, Puruliya. (B) Land degradation due to anthropic activities, identified from satellite image (Base of the image: 14.9 km; Central coordinates: 23°33'30.24" N, 87°19'30.72" E) (a) near Durgapur, West Bengal, (d), and field photograph of the same area.

saline/sodic / acidic soils and frost heaving / shattering etc.). Anthropic activities like disposal of industrial effluent, dumping of mining residues and smoke effusion from brick kilns have their own set of geomorphic and environmental impacts (Fig. 4 and 5).

Indicators of change in coastal system

Changes in the coastal system are directly related to coastal energy (tide, wave, current, wind action) and fluvial discharge. The indicators of coastal change are rate of beach erosion / accretion, rate of dune migration/sand movement (this can be monitored through beach profiling), reclamation of wetlands / lowlands, cliff erosion and changes in vegetation density and assemblages. The most prominent signatures of coastal change are shifting of shore line due to coastal erosion, effect of storm surges / tsunami, changes in the nearshore / offshore bathymetry and anthropogenic activities.

In eastern India, the coastal belt along the states of West Bengal and Odisha is marked by the presence of four distinct coastal environs viz. i) macro-tidal (tidal range >4 m) Hugli estuary, ii) meso-tidal (tidal range 2–4 m) Balasore-Contai coastal plain, iii) micro-tidal (tidal range <2 m) Mahanadi-Brahmani-Baitarani delta and lacustrine-barrier island environment around Chilika lake.

The Hugli estuary forms the western part of the Ganga-Brahmaputra delta, the largest tide dominated delta of the world. The bell or funnel

Figure 6. Balasore-Contai coastal plain characterised by ancient dune complex (AD) and beach-face dune (BD) (Base of the image: 115.3 km; Central coordinates: 21°46'30" N, 87°44' 42"E). The field photograph shows the eroding beach-face dune in Digha.

shaped Hugli river mouth is characterised by a group of islands set in a labyrinth of tidal creeks marking their outlines. This macro-tidal domain with bidirectional tidal currents is marked by the presence of 'sickle shaped' near-shore configuration with partially or totally emergent linear tidal shoals (aligned perpendicular to the shore line), separated by intervening swales e.g. Jambu island and Chuksar island. It is to be mentioned that the famous Sunderban mangrove forest with clay substrate exemplifies the very sensitive ecosystem of the area (Chakrabarti and Nag, 2015).

In the west of Hugli river, the meso-tidal Balasore-Contai coastal plain is characterised by the presence of successive rows of dunes (viz. ancient, older and beach-front dunes) with intervening clayey tidal flats and sandy beach ridges. The southern coastal belt is bordered by the beach-face dunes while in the north the ancient dune complex can be observed, comprising of brownish-yellow to yellowish-brown oxidised sand. The beach ridge is a wedge shaped sandy terrain with the widest portion bordering the fluvio-deltaic plain of the Subarnarekha river in the west and narrows down in the east (Fig. 6).

The Mahanadi-Brahmani-Baitarani compound delta occupies a vast coastal plain of Odisha. This micro-tidal delta has an arcuate front built in an environment dominated by relatively strong longshore currents which has given rise to spits, hooks and barrier islands along the present day shoreline. The deltaic plain is characterised by beach-dune ridges and swales.

The Chilika lake is the largest coastal lagoon representing a lacustrine and barrier island environment. The inlet mouth of the lagoon towards the sea front (locally known as Magarmukh) is frequently changing its position due to constant shift of the sand barrier. In 1973, there were two openings and in 1993, only one narrow opening was there. The longshore sediment transport is predominantly towards the north even during the NE monsoon period along the sea front of Chilika lake (Chakrabarti, 2018; Niyogi, 1989).

So, considering the difference between the coastal environment indicators are to be chosen accordingly with proper weight input. This has been reflected on the amended CRZ (Coastal Regulation Zone) notification of Government of India, 2019, to a certain extent.

Geo-environmental mapping (GEM)

Geo-environmental mapping plays the role of a facilitator in EIA in terms of:

- Unravelling the impact of anthropic development on biophysical environment through space and time identifying the factual and functional parameters i.e. geomorphological and geological indicators.
- Framing guidelines for maintaining a rational balance between environment and HCM through technological adjustment and social adaptations.

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

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 units (NSU) or terrain mapping units (TMU).

Geo-environmental indicator (GEI)

The GEI are the process sensitive and 'easy-to-measure' physico-chemical components of the dynamic earth which help in identifying the various characteristics of the geomorphic environment in human orientation through space and time (Cavallin *et al.,* 1995). The GEI are of two types (Fabbri and Patrono, 1995):

- Qualitative indicators, which identify the specific characteristics of landform unit(s) in terms of spatial change detection in areas affected by landslide/ soil erosion, flood prone areas, bank line shifting of a river or shore line shifting etc.
- Quantitative indicators, which are supplementary to qualitative indicators. 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 zones of erosion or accretion; the mass balance study of glaciers over a period of time to measure the health of the glacier; sediment monitoring stations to generate data on soil erosion. Habitat fragmentation status, disturbance index, biological richness of forests; depth to water level monitoring for seasonal variation; chemical analysis of water to identify the quality of water are other important quantitative measurements of GEI.

Geo-environmental unit (GEU)

The GEU is the spatial database with certain entity/ boundary as defined by GEI. A Geo-environmental unit may contain one or more TMU (Meijrink, 1988) or NSU

Figure 7. Accretional environment at Junput as viewed in satellite image (Base of the image: 14.3 km; Central coordinates: 21°44'25.44" N, 87°48'53.28" E) and on ground.

Table 2. Examples of TMU and GEU in two different scenarios of NSU.

Scenario	Terrain mapping unit (TMU)	Geo-environmental unit (GEU)
1. Medinipur coastal plain	Beach-face dune complex (BDC)	Erosional BDC zone
		Accretional BDC zone
2. Jambu island	Supra-tidal core zone	Mangrove forest zone
	Mangrove swamp	

(Chakrabarti, 2015). A few examples of GEU are as follows

- In the Medinipur coastal plain of West Bengal (Table 2, Sceario 1), active erosional regime is prevailing in the beach-face dune complex (BDC) zone of Digha-Shankarpur-Mandarmani area (a stretch of about 25 km); whereas, accretional regime is observed in the same BDC zone in the eastern part (for a stretch of about 20 km.) between Dadanpatrabar–Junput area (Chakrabarti, 1991, 1995; Chakrabarti and Nag, 2015). In both the cases, the terrain unit is same but the two GEU may be differentiated based on the prevailing erosional and accretional environment as indicated by the GEI (Fig. 7). Accordingly, the land use/ land cover (LULC) and environmental management programmes will be different for the two

Figure 8. Mangrove ecosystem as geo-environmental indicator to safeguard Jambu island, shown by a circle in the map. ITMSZ = Inter tidal mangrove swamp zone; STC = Supra tidal core. (Base of the 1994 image is 6.2 km; Central coordinates: 21°35'10" N, 88°10'29.28" E; base of the 2002 image is 4.7 km; Central coordinates: 21°34' 40"N, 88°11'21.12" E).

Table 3. Examples of GEU in a particular scenario of NSU.

Geo-environmental unit (GEU)	Natural System Unit (NSU)
Tidal-zone brick kiln	Alluvial plain
Agricultural-zone brick kiln	

sectors considering the process sensitivity.

- Jambu island, a tidal shoal in the Hugli estuary, has mangrove forests covering two TMU's viz. mangrove swamp and supra-tidal core zone (Table 2, Scenario 2). Both the units are fast deteriorating due to human interventions. In this case, 'mangrove forest zone' may be identified as a GEU considering the unique geomorphic environment. The entire GEU in Jambu island is challenged by anthropogenic activities and requires proper qualitative and quantitative assessment of the GEI to safeguard the eco-system (Fig. 8).

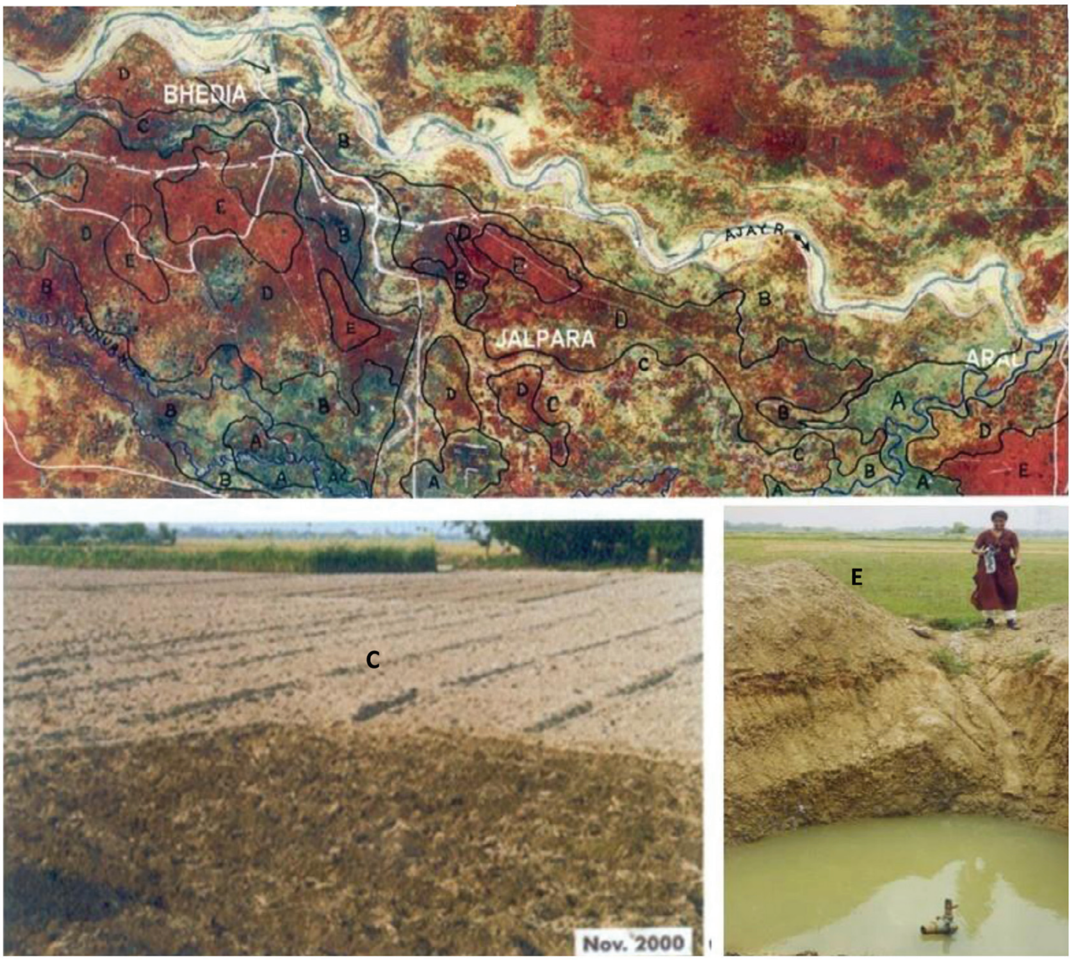

Figure 9. Geo-environmental mapping during flood situation, 2000, for locale-specific flood management (Bhedia-Jalpara-Aral), along the Ajay River. A = Deep and long-lasting inundation; B = Deeply Submerged; C = Submerged but drains off well; D = Shallowly submerged; E = Rarely submerged (Base of the image: 27.9 km; Central coordinates: 23°39'12" N, 87°45'54" E).

- In support of rapid urbanisation brick kilns are coming up 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. Hugli, Rupnarayan, Ichamati rivers) or (b) agricultural lands, accelerating land degradation in the process. Considering process sensitivity as GEI two environs may be identified for brick kilns accordingly (Table 3):
- The flood plain is a geomorphic unit where flooding and bank failure both may be 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 well drained area, shallowly submerged area and rarely submerged area (Fig. 9).
- Similarly, considering the intensity of bank failure as GEI, the GEU may be identified as — highly vulnerable, vulnerable, moderately vulnerable and slightly vulnerable (Fig. 10).

It is worth mentioning here that the GEM, on principle, facilitate systematic monitoring of changing dynamics of the terrain features in respect of LULC and biodiversity characterisation in landscape level, more specifically, in watershed level, considering hydro-biological aspects. 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.

Figure 10. Riverbank failure due to presence of sandwiched sand layer (marked by circle) — highly vulnerable zone along the Ganga, at Akheriganj, West Bengal (upper panel); the Brahmaputra at Neemati Ghat, Jorhat, Assam (lower panel).

Modern tools

The *Space Information* Technology may be defined as '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 non-spatial data (attribute data) are carried out on Geographical Information System (GIS) platform in user orientation (Chakrabarti, 2014). It is worth mentioning here that GIS allows people to analyse problems as per their individual requirements from different perspectives with geographical representation of 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 utilised for:

- Technological adjustment by the technical departments with applications inscience and technology.
- Societal needs by involving community i.e. peoples' participation through awareness programmes etc.

Interpretation of remote sensing data

Remote sensing (RS) data is the core of GIS. So, RS data interpretation should be carried out 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 is 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

Digital interpretation is based mainly on set theories and takes into account only the 'tone' of different objects 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.

On-screen interpretation

The on-screen interpretation technique may be considered as the combination of visual and digital techniques. In on-screen interpretation procedure the satellite data in digital format (as FCC) is being displayed in the computer screen and the identification of features can 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 of land can be viewed by 'zooming-in'. 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 digitisation could be avoided. In addition, directly digital data can be created simultaneously while interpreting the image thereby saving time.

It can be 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.

Conclusion

EIA being a multivariate/ multi-scale approach in human orientation it has a wide range of application. For a successful assessment multiple criteria with their multi-faceted interrelation should be taken into consideration. Land use pattern is to be analysed with socio-economic value addition in the context of technological development. The systematic identification of geo-environmental units in relation to terrain units or natural system units along with geomorphological and geological indicators using RS data supported by ground validation provides the scientific basis for EIA. However, the generation of related attribute data by in-situ/ conventional methods need discipline oriented knowledge based expertise. The key to an unbiased EIA is selection and proper weight input to the geo-environmental indicators vis-á-vis anthropogenic activities using space information technology to construct an index model. But 'technology push' without considering the terrain conditions and societal settings leads to breaking natural resource assets as well as facilitate environmental deterioration. EIA should aim at enabling people for informed participation in decision making to create 'application pull' for environmentally sound LULC and biodiversity conservation at landscape level (BCLL), leading towards sustainable future. Above all an appropriate integration of both spatial and non-spatial data in GIS environment demand trained multidisciplinary personnel in handling and processing the data.

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