BUREAU OF INDIAN STANDARD
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भारतीय मानक मसौदा

पर्यावरणीय प्रभाव आकलन और पर्यावरण प्रबंधन योजना में रिमोट सेंसिंग और भौगोलिक सूचना प्रणाली का उपयोग — अनुसंशाएँ

Draft Indian Standard

USE OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM IN ENVIRONMENTAL IMPACT ASSESSMENT AND ENVIRONMENT MANAGEMENT PLAN — RECOMMENDATIONS

Environmental Assessment and Management of Water Resources Projects Sectional Committee, WRD 24

Last Date for Comments: **04 August 2024**

FOREWORD

(*Formal clauses of the foreword will be added later*)

Remote sensing, using satellite or aerial platforms, has been considered to be one of the most potential tools for evaluation of the physical attributes of land and water resources in the country. The synoptic and repetitive coverage provided by the satellites can effectively complement the conventional data to monitor the progress and impact of the above projects. As the science of remote sensing is evolving with the adoption of newer technologies, the scope of operational applications of remote sensing technology is continuously adapted to suit the observational requirements.

The integration of remote sensing and geographical information systems (GIS) has become an essential tool for surveying and monitoring natural resources. These technologies are particularly effective for conducting environmental impact assessments (EIA) and developing environmental management plans (EMP) for water resources projects. This standard aims to summarize well-established principles and describe widely used procedures, equipment, and techniques. It is designed to assist the Engineer-in-charge of a water resources project in assessing the project's environmental impact. The guidelines emphasize the importance of an experimental approach and learning through trial and error, allowing the project leader to exercise discretion without compromising overall project requirements. This standard has been formulated to provide comprehensive guidelines for this purpose.

In formulation of this standard due consideration has been given to the international standards and practices prevailing in different countries, along with aligning it to the practices in the field of remote sensing within India.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (second *revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1 SCOPE

This standard provides recommendations to cover primarily the application of remote sensing and geographical information system techniques in the environmental impact assessment and environment management plan of water resources projects.

2 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

2.1 Remote Sensing — It is the science and art of obtaining information about an object, area or phenomenon, generally with respect to the Earth, through the analysis of data acquired by a sensor that is not in physical contact with the study object, area or phenomenon.

2.2 Geographical Information System (GIS) — It is an assemblage of computer equipments and a set of computer programs for capturing, storing, querying, analyzing, and displaying geographically referenced data present on the Earth's surface and the events (non-spatial attributes linked to the geography under study) that are taking place on it. A geographic information system is a powerful technique for turning large volumes of spatial data into useful information. The spatial data is generally in the form of maps which could be topography, geology, soil types, forests, land use/ land cover, water availability, etc., and stored as layers in a digital form in the computers. There are essentially two kinds of databases: one, the specific characteristics of a location (e.g. its slope, soil type, rainfall, etc.) called spatial data; and the other, attribute data (e.g. statistics or written text, tables and lists of data). Attributes are often termed ‘non-spatial data’ since they do not in themselves represent locational information. An attribute value is the actual measurement that is stored in the database. GIS fundamentally works with two different types of geographic models.

2.2.2.1 *Vector* — Information is encoded and stored as a collection of x and y coordinates (points, lines, polygons). Linear features are stored as a collection of point coordinates while polygon features are stored as closed-loop coordinates.

2.2.2.2 *Raster* — The dominant feature class is recorded for each cell in the data matrix. The finer the grid used, the more geographic specificity will be in the data file. A coarse grid requires less data storage space, but will provide a less accurate geographic description of the original data. Satellite images and scanned data are in raster format.

2.3 Satellite — Satellites are the space-borne platforms that carry the payloads for collecting the data of the Earth and atmosphere. Satellites are put into the specified orbits, either geostationary or polar, using launch vehicles.

2.4 False Colour Composite (FCC) — It is a satellite imagery of the Earth's surface taken with the sensors on board in digital format. FCC is an image created by representing data from three wavelength bands (such as ultraviolet, red, and infrared) with three visible colors (red, green, and blue) to produce an image that aids in the interpretation and understanding of the data in the three bands.

2.5 Picture Element (Pixel) — In a digitized image, the area on the ground is represented by each digital number called picture element or pixel. A digital image comprises of a two-dimensional array of individual picture elements called pixels arranged in columns and rows. Each pixel represents an area on the Earth's surface. A pixel has an intensity value and a location address in the two-dimensional image.

2.6 DN (Digital Number) — Value assigned to a pixel in a digital image. Digital number is a positive integer resulting from quantizing the original electrical signal from the sensor into positive integer values using a process called analog to digital (A to D) signal conversion. An image is a two-dimensional representation of objects in a real scene. Remote sensing images are representations of parts of the Earth's surface as seen from space. The images may be analog or digital. Aerial photographs are examples of analog images while satellite images acquired using electronic sensors are examples of digital images. The intensity of a pixel is digitized and recorded as a digital number. Due to the finite storage capacity, a digital number is stored with a finite number of bits (binary digits). The number of bits determines the radiometric resolution of the image.

2.7 Resolution — Resolution is defined as the ability of a system to render information at the smallest discreetly separable quantities in terms of spatial, spectral, temporal and radiometric resolution.

2.7.1 *Spatial Resolution* — It refers to the size of the smallest object that can be resolved on the ground. In a digital image, the resolution is limited by the pixel size, i.e. the smallest resolvable object cannot be smaller than the pixel size. The intrinsic resolution of an imaging system is determined primarily by the instantaneous field of view (IFOV) of the sensor, which is a measure of the ground area viewed by a single detector element in a given instant in time.

2.7.2 *Spectral Resolution* — It is the ability of the sensor to define fine wavelength intervals and distinguish between grey levels. The dimension and the number of specific wavelength intervals in the electromagnetic spectrum to which a sensor is sensitive.

2.7.3 *Temporal Resolution* — It refers to the frequency of obtaining data over a given area. It is related to the revisit period, which refers to the time taken for a satellite to complete the entire cycle orbit.

2.7.4 *Radiometric Resolution* — It describes the ability of the sensor to discriminate very slight differences in energy. The intrinsic radiometric resolution of a sensing system depends on the signal-to-noise ratio of the detector. In a digital image, the radiometric resolution is limited by the number of discrete quantization levels used to digitize the continuous intensity value. The maximum number of brightness levels available depends on the number of bits used in the representation of the energy recorded.

2.8 Bandwidth — It denotes a certain range of wavelength or width characterizing a band recorded by a sensor (viz., Band1= 0.42-0.48 μm, Band2= 0.52-0.58 μm)

2.9 Sensor — Device that receives electromagnetic radiation and converts it into a digital signal that can be recorded and displayed as either numerical data or an image. It is a sensitive instrument (camera) mounted on the satellite which senses the energy reflected from the object on the Earth's surface.

2.10 Ground Truth — The set of field samples are collected by visiting the actual site and used for interactive image classification. Ground truth is usually carried out on-site, performing surface observations and measurements of various properties of the features of the ground resolution cells that are being studied on the remotely sensed digital image. It also involves taking geographic coordinates of the ground resolution cell with GPS technology and comparing those with the coordinates of the pixel being studied provided by the remote sensing software to understand and analyze the location errors and how they may affect a particular study.

2.11 Repetivity — It is the time interval (in days) between the two successive rotations of the satellite covering the same area.

2.12 Swath — It is the width of the strip of terrain that is imaged by a sensor system. As a satellite revolves around the Earth, the sensor "sees" a certain portion of the Earth's surface. The area imaged on the surface, is referred to as the swath. Imaging swaths for space-borne sensors generally vary between tens and hundreds of kilometers in width.

2.13 Digitization — The process of converting the geographic features on an analog map into digital format using a digitizing tablet, or digitizer, which is connected to a computer. Features on a paper map are traced with a digitizer puck, a device similar to a mouse, and the x and y coordinates of these features are automatically recorded and stored as spatial data. The on-screen digitization is also done on a computer screen using specialized software.

2.14 Geo-referencing — It is to establish the relationship between page coordinates on a planar map and known real-world coordinates. This is done by aligning geographic data (e.g., historical map, satellite image, or aerial photograph) to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data. Merging of two or more adjacent geo-referenced images is called mosaicking.

3 COMPONENTS OF REMOTE SENSING

Remote sensing system in general consists of basically three components.

a) Source of energy;
b) Target; and
c) Sensors.

3.1 The energy can be light, sound or a force field. When the energy strikes any material, it interacts with the object/target resulting in a change in the composition of energy on returning from the object. Since this process causes variation in energy levels, with suitable devices (sensors), it is possible to detect the differences and identify the object.

3.2 The sun is a prime source of energy. The sun's energy, commonly referred to as electro-magnetic radiation (EMR) is a continuous band of energy of different intensities, wavelengths and frequencies, viz. gamma rays, X-rays, ultraviolet rays, visible rays (light), infrared rays, microwaves, and so on.

3.3 The sun's energy falling on various features like land, water, vegetation, etc. on Earth's surface is partly absorbed, transmitted through, and partly reflected back, which is recorded by the sensor onboard satellite. Each of these features has different reflecting characteristics in different energy bands of the electromagnetic spectrum. This property of the objects helps distinguish them by a sensor having different spectral bands. The reflected energy is recorded by the sensors of the satellite, which are sensitive to various wavelength ranges of the electromagnetic radiation spectrum.

3.4 Modern remote sensing is an extension of this natural phenomenon. However, apart from visible light, electromagnetic radiation extending from the ultraviolet to the far infrared and microwave regions are also used for remote sensing of the Earth's resources. If the observation is made based on electromagnetic radiation from the sun or self-emitted radiance, it is called passive remote sensing. It is also possible to produce electromagnetic radiation of a specific wavelength or band of wavelengths to illuminate the terrain. The interaction of this radiation can then be studied by sensing the scattered radiance from the target. This is called active remote sensing.

4 USE OF GIS FOR DATABASE MANAGEMENT

4.1 The data involving thematic information on environment impact assessment and environment management, their characteristics, and various properties, can be stored and analyzed with the help of GIS using various software.

4.2 GIS offers three invaluable opportunities in the analysis of geospatial data:

a) improved cartographic output capability for visualization;
b) efficient tools and techniques to integrate different data sources; and
c) ability to quantitatively analyze geospatial data.

4.3 The cartographic functions of GIS can be used, for more transparent decision-making, to analyze options more thoroughly and to present results more convincingly especially for security issues (Wood and Milefsy 2002). However, to harness the potential of GIS, the issues of data completeness and data quality need to be addressed. For example, data sets need to have associated appropriate geographical information that allows them to be geo-referenced. Often, even if available, sub-national geospatial data are not as complete as country-level information.

4.4 GIS tools combined with satellite imagery can provide a continuous spatial representation of variables such as land cover or natural resources; road density; population density, distribution or ethnicity; among different layers. Digital elevation models (DEM) derived from radar, laser or optical imagery can be used to derive slopes aspect and elevation that for example can provide physical characteristics along borders or over large areas. Gridded data sets of rainfall as well as other environmental variables such as land cover or extraction of natural resources are built using remote sensing data and can be used as spatial indicators in a geospatial model. Gridded global population data sets in which latitude/longitude quadrilaterals are used as the units of observation have been developed to address environmental issues.

4.5 GIS tools not only provide the structure to build grid-based data sets but also some tools to integrate and overlay the different data sets and to provide spatial indicators such as proximity, shape, size, buffering, accessibility or vulnerability. The GIS allows modelling of different spatial characteristics in a whole system based on the conceptual interactions existing between these characteristics. The model is a tool to predict and simulate "what if" scenarios that help better understand the system. Using GIS systems, the following operational requirements can be addressed:

a) Data overlay and analysis;
b) Site impact prediction;
c) Wider area impact prediction;
d) Corridor analysis;
e) Cumulative effects assessment and EA audits;
f) Trend analysis;
g) Continuous updating; and
h) Habitat analysis.

5 ADVANTAGES & LIMITATIONS OF GIS METHOD

5.1 Advantages

a) Potential for storing and accessing very large data set;
b) Consolidates data from various sources for geographic analysis;

c) Effectively performs multiple map overlays, incorporating logical and mathematical manipulations;
d) Generates descriptive statistics regarding the distribution of spatial phenomena;
e) Allows a number of different scenarios to be investigated quickly and effectively by varying input parameters for successive analysis runs;
f) Can generate maps for output to hard copy as well as displaying map information on the computer screen; and
g) Open-source software are also available for image processing

5.2 Limitations

a) Requires highly trained personnel;
b) Not specifically structured for EIA; and
c) Commercial software are expensive.

6 ENVIRONMENTAL MANAGEMENT AND IMPACT ASSESSMENT

6.1 Environmental Management

Environmental management which involves proper resource management, is an interdisciplinary approach to resource conservation and recycling and it acts as a regulatory force on human greed in resource exploitation and resource wasting. The central theme of environmental management is to reduce or minimize the impact of human activities on the environment in an endeavor to avoid the overuse, misuse and abuse of environmental resources.

6.2 Environmental Impact Assessment (EIA)

Environmental impact assessment can be defined as a formal process used to predict the environmental consequences of any development project. EIA thus ensures that the potential problems are foreseen and addressed at an early stage in the planning and design of the project.

7 ENVIRONMENTAL IMPACT ASSESSMENT PROCESS

7.1 Environmental impact assessment can help to optimize the use of resources and increase the effectiveness of a project by identifying potential environmental impacts, developing mitigation strategies, promoting stakeholder engagement, and ensuring compliance with environmental regulations. Another advantage of a tiered approach is that the extent of the inquiry or examination expands with the advancing development of the project plan. EIA is generally conducted in four broad levels that are given in **7.1.1** to **7.1.4**.

7.1.1 *Screening*

It decides whether the EIA process is applicable at all to the development project. Screening should basically "clear" all those projects where there are no major negative impact issues.

7.1.2 *Scoping*

It helps in understanding the extent of environmental impacts and identifies significant environmental issues for further study. In the activity-component framework, scoping should assist in the identification of impacting activities and impacted environmental components for all major negative impact issues.

7.1.3 *Assessment*

The assessment stage involves a detailed analysis of the potential environmental impacts of the proposed project or development, including both direct and indirect impacts. This analysis may include surveys, studies, and modeling to predict the potential impacts of the project on the environment.

7.1.4 *Mitigation and Monitoring*

The mitigation and monitoring stage involves developing strategies to avoid, minimize, or compensate for the potential environmental impacts of the proposed project or development. This stage may also involve the development of a monitoring plan to track the effectiveness of the mitigation measures over time.

7.2 Overall, the four stages of EIA are designed to ensure that potential environmental impacts are identified, evaluated, and addressed in a systematic and transparent manner. This helps to ensure that projects are designed and implemented in a way that is environmentally responsible and sustainable.

7.3 Further, the detailed standard procedure should be followed while implementing the EIA process.

8 APPLICATION OF REMOTE SENSING AND GIS FOR EIA & EMP

8.1 Remote sensing and GIS are the potential tools for environmental impact assessment (EIA) and generation of an environmental management plan (EMP). Remote sensing and GIS play an important role in the field of hydrology and water resources development in terms of mapping and monitoring of many water resources management projects and also in the field of estimating hydrological variables. Remote sensing in combination with the global positioning system (GPS) and GIS can produce terrain maps with high locational accuracy, containing detailed information on the variables under study. The remote sensing observations compulsorily supported by the limited field observation provide significant accuracy in generating spatial information. The major advantages of these techniques include

a) Synoptic viewing of the Earth's surface with a large swath;
b) Imaging at different resolutions;
c) Repeat observations;
d) Multi-spectral imaging;
e) All weather and day and night capability in radar remote sensing;
f) Night-time imaging capability using thermal band;
g) Stereo coverage;
h) Global to local applications; and
j) Timeliness and economy.

8.2 Satellite remote sensing provides multispectral, multi-spatial, and multi-temporal data useful for resource inventory, monitoring and management of natural resources. Satellite data is analyzed by both visual interpretation and digital analysis with the help of software.

8.3 The same remote sensing data (the image) can be used to derive information on various application themes depending on the expertise of the analyst and the application requirements. The utilization of remote sensing data can be broadly classified into three categories:

a) Identify the category, to which the Earth surface expression (manifested as data) belongs, based on signature differences. For example, the area under a particular crop, the extent of the surface water body, flood-affected area, etc. For a specific theme, one may have to optimize the spectral bands or combination of bands, the scale (resolution) of the image, the season of acquisition, etc. Since the remote sensing data is the direct result of the surface expression and hence such inferences are fairly accurate to meet most of the user needs;

b) Use remote sensing data to infer a particular parameter or phenomenon using suitable modelling. For example, the yield of a crop, the volume of timber from forest, ocean currents, etc. Since the extraction of these `secondary' information cannot be solely dependent on the information available from remote sensing, models have to be developed which integrate remote sensing data with other data. The accuracy therefore also depends on model formulation apart from other factors of data derived from remote sensing; and

c) Identify secondary indicators of certain resources through surficial expressions, which cannot be directly observed by remote sensing. For example, lineament faults and paleochannels are good indicators for possible groundwater resources.

9 SATELLITE DATA REQUIRED FOR STUDY AREA

9.1 The satellite images to be utilized in the digital format or printed form on photographic paper shall be obtained only from authorized agencies of repute.

9.2 The selection of satellite data depends on the details of requirements of spatial information in the study area, such as resolution, number of bands and repeat coverage (for dynamic features). The satellite data may be false colour or natural colour composite or panchromatic image.

a) The base map of the study area (toposheet) i.e. a map showing certain fundamental information used as a base on which additional information overlaid to compile a specialized map. It provides the background of geographical context for the content to be displayed. For example, the Survey of India toposheet, a map prepared using satellite data, maps prepared through navigational devices, etc.;

b) Digital elevation model (DEM), contour maps, spot heights;

c) Satellite-derived DEM (SRTM data/ASTER/Cartosat-1) or contour maps prepared from Survey of India toposheets, which are geo-referenced with the study coordinates. Spot heights/ground registered coordinate points are taken by GPS; and

d) Other relevant secondary data such as soil data, surface data (examples), climatic data (lists), GIS maps (examples), census books, revenue maps from the village or khasara level maps/panchayat records, city survey maps, etc.

10 METHODOLOGY

The procedure for environmental impact assessment (EIA) and environment management using remote sensing and GIS technique is depicted in Figure 1.

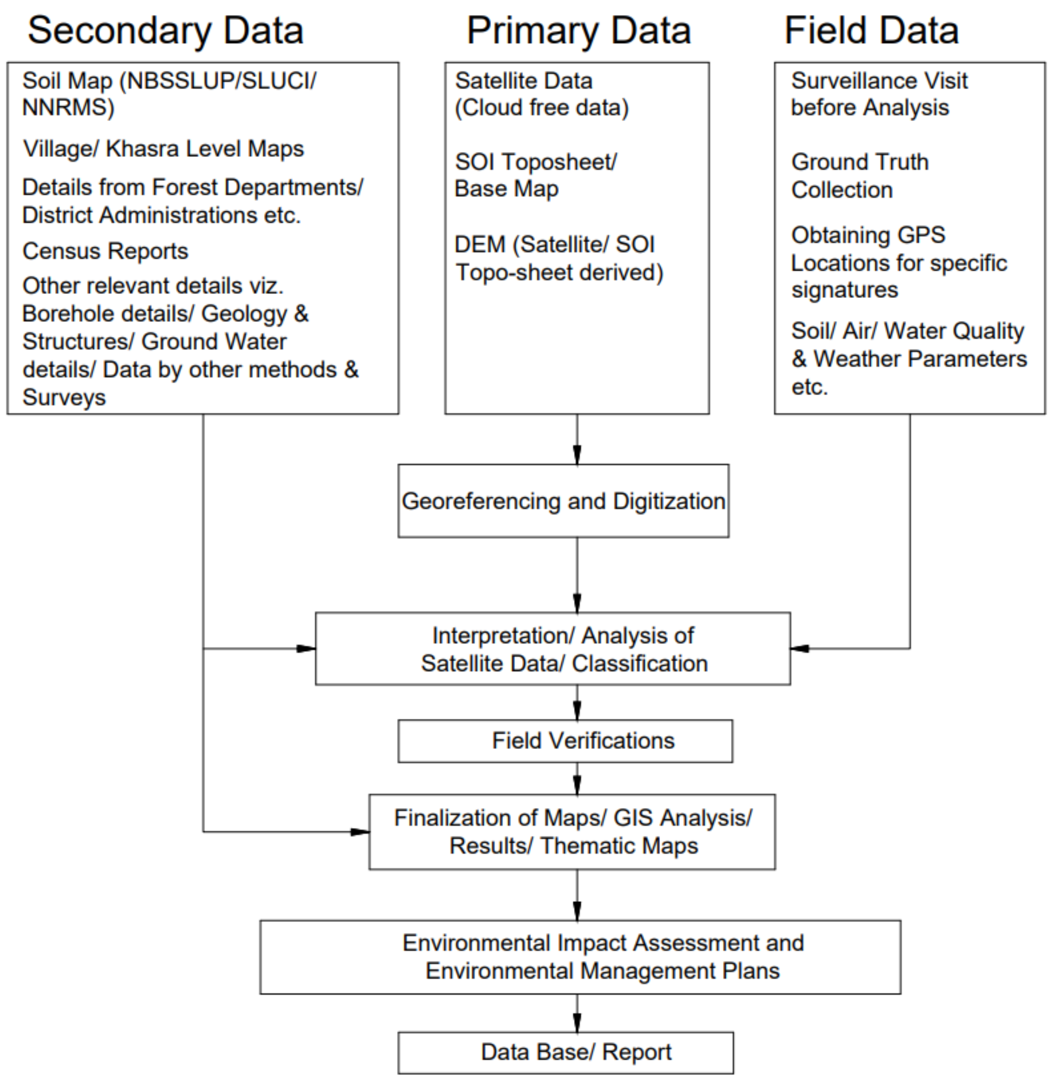

FIG. 1 SCHEMATIC DIAGRAM OF METHODOLOGY

11 SATELLITE DATA INTERPRETATION

The major steps involved in satellite data interpretation are:

11.1 Selection of Satellite Data

Based on the requirement, single or multi-season data is selected. In the absence of cloud-free data or quality-affected data, multi-sensor data can be used.

11.2 Geo-rectification

Geo-referencing of satellite with reference framework having standard projection and datum (e.g. LCC / TM projection and WGS 84 datum).

11.3 Reconnaissance Survey

A reconnaissance field survey is undertaken for acquaintance with the general patterns of vegetation, biomass levels, water bodies, rocks, road network, habitations and density levels, etc., of the study areas.

11.4 Satellite Data Interpretation or Digital Classification

Different land cover classes in satellite data are interpreted visually on-screen following standard visual interpretation techniques or digital classification of satellite images adopting the finalized classification schema. Artificial intelligence (AI) based techniques for digital classification can be explored for improved accuracy.

11.5 Interpretation of Results with Field Data and Ancillary Spatial and Non-Spatial Data

A preliminary interpretation map is prepared delineating the land cover polygons as seen in satellite data.

11.6 Preparation for Fieldwork

The steps involve the identification of statistically sound sample grids verified on the ground. On the basis of the interpretative uncertainty highlighted during preliminary interpretation, a portion of map units is selected for field checking. This first set of points is integrated, if necessary, by an extra set of checks to assure a good statistical representation of the land cover classes.

11.7 Field Verification

Field work is carried out by the interpreter including soil sample collection along with details. During the fieldwork, the relationship between image elements and tentatively identified land cover classes during preliminary interpretation is established. The sample points are readjusted depending on the variability in the field, for which sufficient points are collected, especially for finalization of maps and accuracy assessment.

11.8 Final Results

The preliminarily interpreted land cover map is finalized based on ground truth data and soil sample analysis to arrive at the final map. Existing legacy data on forests, wastelands, salt-affected soils, biodiversity, land use/land cover, etc. are used.

12 STANDARD SOFTWARES

Standard image analysis software supported by GIS capabilities as per requirement (of the project and nature of work) and available in the market can be used for Image enhancement, classification, etc. There are various image analysis software supported by

GIS capabilities as per 16 requirements. Various open-source commercial software are available in the market and can be selected according to the requirement of the project and the nature of work.

13 STUDY AND ANALYSIS

13.1 Land Use, Land Cover and Dynamics

Land use and land cover are two related terms that describe different aspects of the Earth's surface. Land use refers to the human activities that take place on land, such as agriculture, urbanization, forestry, and mining. Land cover, on the other hand, refers to the physical and biological characteristics of the land surface, including vegetation, water bodies, and bare ground. Land use and land cover are closely related, as human activities can have a significant impact on the physical and biological characteristics of the land surface. For example, deforestation for agriculture or urbanization can change the land cover from forest to bare ground or urban areas. Similarly, the planting of crops or trees can change the land cover from bare ground to vegetation. Remote sensing is a common method used to collect land use and land cover data. This information can be used to create maps of land use and land cover, which can be analyzed to identify patterns and trends over time.

13.2 Geology (Rock Types and Geological Structure)

Geology is the science and study of the solid Earth and the processes by which it is shaped and changed. It provides the primary evidence for plate tectonics, history of life and evolution, and past climates. Tectonic processes are responsible for many discontinuity planes (fractures, faults, joints) that permeate rock masses. Remote sensing techniques are very useful in identifying and mapping geological structures such as lineaments/folds/faults etc. easily because of the synoptic view, availability of data in different bands, repetitivity, etc.,

13.3 Cropping Pattern

Cropping activities continue round the year in India, provided water is available. The distinct cropping seasons are kharif (July to October), rabi (October to March) and zaid (March to June). Rice cropping patterns in India vary widely from region to region and, to a lesser extent, from one year to another depending on a wide range of soil and climatic conditions. Multi-temporal satellite remote sensing data is effectively utilized in preparing maps showing all three crop seasons viz., rabi, kharif and zaid.

13.4 Terrain Assessment or Watershed Delineation Using DEM

A digital elevation model (DEM) is a two-dimensional array of elevation points with a constant x and y spacing. The simple data structure and widespread availability have made DEM a popular source for digital terrain modeling and watershed characterization. The two primary data sets that are required to perform watershed delineation with DEMs are elevations and flow directions. The DEM elevations are usually available in the form of United States Geological Survey (USGS) digital map.

13.5 Soil Mapping

Soil survey, or soil mapping, is the process of classifying soil types and other soil properties in a given area and geo-encoding such information. Soil mapping provides resource information about an area. It helps in understanding soil suitability for various land use activities. It is essential for preventing environmental deterioration associated with misuse of land. Primary data for the soil survey are acquired by field sampling and remote sensing. GIS helps in delineating soil types in an area and demarcate soil boundaries. A soil map is widely used by farmers in developed countries to retain soil nutrients and earn maximum yield.

13.6 Command Area Creation and Assessment

Command areas are the irrigated areas falling downstream of a dam/reservoir. The dam constructed across a river is used for water storage for power generation, irrigation & agriculture, distribution of water through an efficient canal network, aquatic life, etc. Satellite remote sensing helps in the quick identification of prospective sites for location and creation of command area and is cost-effective as well. This should however be followed by field surveys for studying the geological setup of the area including geological structures, detailed soil investigations, direction of the river course, drainage pattern/network, land use/cover including cropping and agricultural patterns, water bodies, slope of the area, nearby forests, human settlements etc.

13.7 Land Degradation (water logging, salinity/ alkalinity, erosion hazard)

Land degradation in general implies temporary or permanent regression from a higher to a lower status of productivity through deterioration of physical, chemical and biological aspects. Land degradation has numerous environmental, economic, social and ecological consequences. Water logging, salt accumulation, and soil erosion are the major processes of land degradation. In case of salt-affected soil - depending on physio-chemical properties, these soils are classified into saline, sodic and saline–sodic soils. The salt-affected soils on false colour composite (FCC) of satellite data appear in different shades of white tone with fine to coarse texture due to the presence of salts in the background of soils with the presence of crop.

13.8 Water Body

Water bodies or natural ecosystem comprise areas with surface water either impounded in the form of ponds, lakes and reservoirs or flowing as rivers, streams, canals, etc. These are clearly seen on satellite images in blue to dark blue or cyan depending on the depth and turbidity levels of the water.

13.9 Forest Cover

Forests are known to be one of the most important renewable natural resources and play a crucial role in the socio-economic development of the area, apart from maintaining the ecological balance. Remote sensing data is used for forestry and ecology applications. Current studies include biennial forest cover mapping, landscape level biodiversity characterization, inputs for forest working plan preparations, protected area management and forest fire mapping, etc.

13.10 Biodiversity Characterization

Vegetation maps derived from satellite data when superimposed over the landscape ecology layer establish the biological richness, biodiversity disturbance gradient, etc., at the landscape level, and thus, characterize biodiversity. Further, it is also possible to prioritize the areas for bio-prospecting and biodiversity conservation.

13.11 Submergence

The submerged or inundated areas are the floodplains often under the control of dams/levees which are exploited for agriculture production and associated human settlements. The spatial extent, pattern and area under submergence can be easily derived from using satellite remote sensing data in the form of inundation maps. More recently radar data is being used in place of or in addition to optical data to map inundated areas.

13.12 Reservoir Sedimentation

Soil erosion in the catchment, movement and deposition of sediments are part of the natural hydrological process leading to reservoir sedimentation. This is accelerated by the changes in land use, deforestation and lack of soil conservation measures in the catchment areas. The storage capacity of a reservoir and, in turn, its economic life is reduced due to the deposition of sediments. Efficient reservoir management calls for periodic assessment of its capacity including capacity loss due to sedimentation. Multi-date satellite remote sensing data provides information on elevation contour areas directly in the form of water-spread areas which is used to estimate the quantity of sediment load.

13.13 Groundwater Prospects Identification

The term groundwater is used to denote water, which has saturated the pores or interstices of the sub-soil. Groundwater is derived from precipitation on the Earth’s surface gradually percolating to the sub-soil through porous strata or openings through rock formations. Thematic data on lithology, geomorphology, geological structures and hydrology are integrated to derive groundwater prospective zone maps, which facilitate narrowing down the target areas for drilling wells and identifying suitable locations for constructing recharge structures.

13.14 Habitat Analysis

Habitat analysis/evaluation is the assessment of the suitability of land or water as habitat for a particular wildlife species. A wildlife habitat suitability map is defined as a map displaying the suitability of land or water as a habitat for a particular wildlife species. Remote sensing and GIS technologies together provide vital information support for relevant, reliable, and timely information needed for conservation planning and habitat analysis.

13.15 Infrastructure

Infrastructure which includes communication network, transport network, irrigation infrastructure, location of human settlements, availability of construction materials nearby, etc. can be mapped using remote sensing data.

13.16 Disaster Management

GIS can help with risk management and analysis by displaying which areas are likely to be prone to natural or man-made disasters with the input of historical data analysis. When such disasters are identified and/or predicted, preventive measures can be developed.

13.17 Zoning of Landside Hazard

Landslide is a major hazard in the development of watersheds and dam/hydropower construction sites etc. Identification and zoning of such areas is the process of ranking different parts of a specific area according to the degrees of actual or potential hazard from landslides. The evaluation of landslide hazards is a complex task. The structural, surface cover and slope characteristics of an area can be used for hazard zonation.

13.18 Estimation of Flood Damage

GIS helps document the need for disaster relief funds when appropriate and can be utilized by insurance agencies to assist in assessing the monetary value of property loss. A local government needs to map flooding risk areas to evaluate the flood potential level in the surrounding area. The damage can be well estimated and can be shown using digital maps.

13.19 Management of Natural Resources

geographic information systems (GIS) have become an essential tool in natural resources management. GIS technology allows natural resources managers to collect, store, analyze, and present geospatial data related to natural resources and their management. GIS is used for monitoring and assessing natural resources such as vegetation cover, wildlife habitats, and water quality. With the help of GIS, the agricultural, water and forest resources can be maintained and managed. For example, foresters can easily monitor forest conditions; agriculturalists estimate crop acreage and yield, monitor crop rotation, assess crop damage and more The spatial information is used to track changes in natural resource conditions and inform management decisions.

13.20 Wetland Mapping

Conservation of wetlands is important for sustaining the biological diversity. GIS technology enables detailed mapping and analysis of wetlands, which can provide valuable information for wetland conservation and restoration efforts. Wetlands contribute to a healthy environment and retain water during dry periods, thus keeping the water table high and relatively stable. During flooding, they reduce flood levels and trap suspended solids and attached nutrients. GIS can be used to analyze the spatial relationships between wetlands and other habitats, such as uplands or riparian zones. GIS also helps to develop and monitor wetland restoration projects to identify the most suitable locations for wetland restoration and to design restoration projects that maximize ecological benefits.

13.21 Irrigation Management

GIS and remote sensing technologies have been widely used in irrigation management to optimize the use of water resources in agriculture. These technologies enable efficient management of irrigation systems by providing valuable information about crop water requirements, soil moisture levels, and water availability. GIS can be used to map water resources such as rivers, lakes, and groundwater sources. This information can be used to optimize the use of available water resources in irrigation. It also helps to map irrigation systems and their components, such as canals, pipelines, and irrigation networks. This information can be used to identify areas where water is being lost due to leaks or channel discontinuity and to optimize the distribution of water to crops. Further remote sensing technology is used in irrigation commands to estimate crop yields based on factors such as vegetation index and biomass. This information facilitates in optimizing irrigation scheduling and improving overall crop management and crop yields.

14 EVALUATION

14.1 Following are the points required to be considered for environmental impact assessment and environmental management plan of water resources projects in India using remote sensing and GIS techniques as a tool in addition to manual ones.

a) Existing land use pattern in the project area including upstream;

b) Breakup of the submerged area into cultivated land, forest land, and shrubs. Rocky outcrops, open water, and other uses can be analyzed using remote sensing;

c) Type of forest in the catchment and submerged areas;

d) Extent and nature of the forest to be cut for the construction of roads, colonies and appurtenant works;

e) Number of villages/population to be displaced (resettlement work);

f) Resettlement area can be marked with remote sensing & GIS maps;

g) Expected rate of siltation can be estimated with remote sensing and GIS for similar nearby projects or from the database of previous work done for other projects;

h) Flood line downstream. The maximum flood line downstream of a water resources project can be worked out and marked using GIS modules and remote sensing;

j) Present groundwater use pattern in the command area/irrigation;

k) Pollution sources in the region;

m) Industrial and other projects existing and forthcoming. This can be a part of GIS database created for the project;

n) Fish, crocodile breeding grounds, wildlife, birds' habitat. This can be a part of GIS database created for the project;

p) Rare species of flora and fauna in the area. This can be a part of GIS database created for the project work;

q) Waterlogging possibility in the command. Remote sensing and GIS can be used for identification and measuring the waterlogged areas; and

r) Important natural resource loss (minerals, commercial timber etc.). Remote sensing and GIS can be used for identification and measuring the change detection in natural resources.

14.2 In addition to the above points, the other topics related to environmental impact should include the following:

a) Delineation of watershed;

b) Existing land use/drainage/cropping pattern;

c) Reservoir sedimentation analysis;

d) Estimation of ground water;

e) Erosion intensity of the watershed;

f) Water quality estimation;

g) Estimation of impacts by overlays methods;

h) Change in land use pattern;

j) Hydrology regime and its changes in command, village tanks & ponds, rainfall pattern, tidal ranges;

k) Change in cropping intensity in agricultural land;

m) Compensatory afforestation and survivability of the plantation;

n) Impact on reserve and protected forests;

p) Effect on traditional floodplain cultivation;

q) Improved flood control;

r) Changes in water quality;

s) Identification of muck disposal area;

t) Identification of quarry sites and its rehabilitation;

u) Providing a safe corridor for the wildlife;

v) Pollution control points from settlements, effluents, etc.;

w) Catchment area treatment (CAT) works and its implementation;

y) Assessment of topsoil erosion; and

z) Identification of areas facing critical and vulnerable erosion problems.

14.3 Though conventional soil surveys provide information on land degradation they are slow, time-consuming and expensive. Among the new technologies that emerged for studying natural resources, space-borne remote sensing technology has proved to be powerful because of a synoptic view of the terrain features, repetitive coverage of the same area at regular time intervals, collection of data in visible through near infra-red, thermal to microwave regions and amenability of data to computers for quick analysis.

15 REPORT

The report should include all the findings and recommendations in a concise and logical manner. The final EIA report also called the environmental impact statement (EIS) should include the following sections:

NOTE — The review should be done by an officer in the authority responsible for the environment involving the organization technically competent to assess remote sensing and GIS projects within a specified time frame.

15.1 Executive Summary

It summarises EIA of the project in brief.

15.2 Introduction

This section outlines the context for the potential project and may include the terms of reference.

15.3 Project Description

It describes the potential project in distinct phases. For example, construction, operation and decommissioning and specifies what each phase entails.

15.4 Methodology

The section should include the operational procedure adopted to apply remote sensing and GIS towards collecting baseline information and subsequent methods followed for monitoring the project.

15.5 Baseline environment

It can be divided into two sections; the bio-physical and socio-economic environments. In each section details should be provided on relevant components of the overall environment. For example, the biophysical environment includes information on climate, topography, geology, soils, hydrology and flora and fauna. The socio-economic environment includes information on population, income generation, land use (agriculture, livestock horticulture), sites of historical/archaeological/cultural significance etc.

15.6 Impacts

It describes both positive and negative impacts, direct and indirect ones and whether they occur over the short or long term. The checklists are normally included in this chapter. Impacts are generally divided into construction, operation and decommissioning phases of the project.

15.7 Mitigation and Support Measures

It recommends appropriate mitigation and support measures for potential negative impacts, giving an indication of costs where possible.

15.8 Monitoring

It outlines monitoring indicators, who should do the monitoring, how often it should be done and any institutional requirements.

15.9 Conclusion

It summarises the findings of the EIA and states clearly whether or not the project to go ahead.