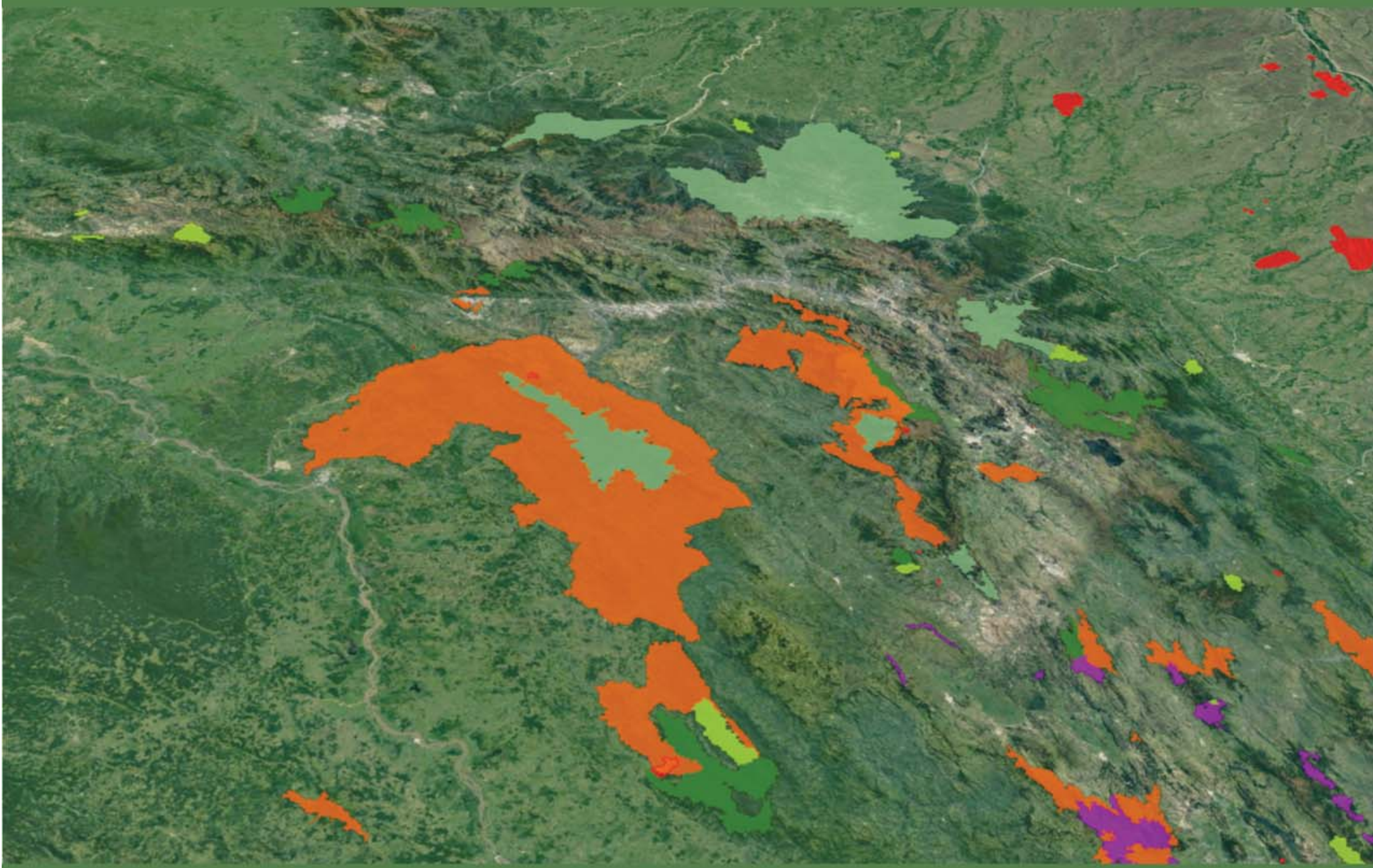
ISSN No. 0974-4134

ENVIS NEWSLETTER

Centre for Environmental Studies (CES)

Dept. of Forest & Environment, Govt. of Odisha

Issue No.54, July-Sept., 2018



Supported by :
Ministry of Environment, Forest & Climate Change
Govt. of India, New Delhi

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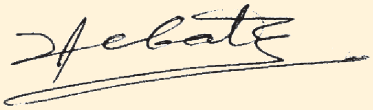
PREFACE

Geographic Information System (GIS) is a system for capturing, storing, checking, manipulating, analyzing and displaying data that are spatially referenced to earth. It is a decision support system which enables integration of multiple spatial referenced datasets for solving complex environmental planning problems. The components of GIS include computer hardware, sets of application software modules, georeferenced datasets, experts and users. The GIS softwares comprise tools categorized under four functional groups. They are (a) Data input, verification, modeling and storage; (b) Data editing and database management; (c) Data simulation and analysis and (d) Output generation and presentation. The active domains for GIS applications include Environmental Monitoring, Modeling, Impact Assessment, Agriculture, Natural Resource Conservation Planning and Management, Urban and Rural Planning, Disaster Management, Epidemiology and Health Care Planning, Forestry, Weather and Climate, Geology, Civil Engineering, Computer Science, Navigation, Real Estate, Social Studies, Economic and Resource Planning, Tourism etc. So training on GIS will enhance the skills and empower the students and professionals engaged in these diversified disciplines.

Training on GIS will impart basic idea about geographic information system, development of global positioning system coordinate, introduction to google earth and GIS software, use of mobile android applications and remote sensing which will provide information in quality protection and improvement of land and water resources.

In this context it is a new dawn for State ENVIS Hub, at Centre for Environmental Studies (CES), Forest and Environment Department, which is acknowledged for its exquisite endeavor, to start various training programs under Green Skill Development Program (GSDP). These skill development programs comprise GIS studies in their curriculum and it is very timely that the CES is the 54th issue of ENVIS News Letter on GIS.

I appreciate the combined effort of all team members for yet another luminous output.

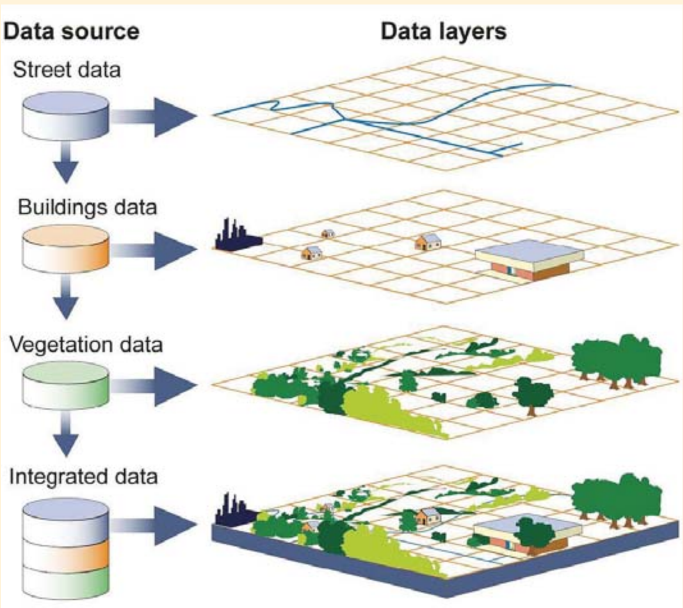


(Ashutosh Debata)

GEOEGRAPHICAL INFORMATION SYSTEM (GIS)

INTRODUCTION

The term "Spatial" refers to any entity (object) or event (phenomena) that pertains to some space in our real world. In other words, any entity that exists in reality and any event that happens or occurs in reality is termed as spatial. Further, any spatial entity or event pertaining to earth is termed as "Geographical" or "Geospatial".



WHY SPATIAL IS SPECIAL

In our day-to-day life in our real world, all of us are concerned with various spatial concepts like location of any entity or event, its distribution over globe, its accessibility, connectivity etc. For example:

- Health care managers solve spatial problems when they decide where to locate new clinics and hospitals.
- Delivery companies solve geographic problems when they decide the routes, and the schedules of their vehicles, often on a daily basis.
- Transportation authorities solve geographic problems when they select routes for new highways.
- Forest departments solve geographic problems when they determine how best to mange forests, where to cut, where to locate roads, and where to plant new trees.
- Governments solve geographic problems when they decide how to allocate funds to different regions or states/districts etc.
- Travelers solve geographic problems when they find their way through various stations, give and receive driving directions, and select hotels in unfamiliar cities.
- Farmers solve geographic problems when they decide where to cultivate which crop.
- Disaster managers are concerned with spatial concepts when they query which place is more risk prone, which place should be given more priority for mitigation of disaster etc.

SPATIAL PLANNING & DECISION MAKING

To achieve our goals by solving the various spatial problems in our real world, we need a proper planning. In fact Spatial Planning involves a chain of processes starting from data collection from the real world, storing the data in an organized way to create a model of the reality, data retrieval and manipulation to simulation, analysis and presentation of information in such a way that a right decision can be derived which will best achieve our solution of the real world problem. These processes, along with the elements like geographically referenced data, users, experts (who perform these processes) and the equipments or tools required to perform these processes, are together called an Information System, as it finally generates the composite information for the support of decision making.

INFORMATION TECHNOLOGY IN SPATIAL PLANNING & DECISION MAKING: GIS

The incorporation of Information Technology (IT) has revolutionized the process of spatial planning in these days. So a present day Geographical Information System (GIS) or Spatial Decision Support System (SDSS) is a set of:

- Elements which include Computer Hardware, Software, Spatial data and Live ware (Personnel involved like users and experts)
- Processes performed by above elements which include- i) Data collection, Input, Modeling and Storage; ii) Data Editing, Management and Scientific Manipulation; iii) Analysis functions and iv)Output Generation and Presentation

DEFINITION OF GIS ACCORDING TO VARIOUS AUTHORS

- A GIS is a specific information system applied to geographic data and is mainly referred to as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced data for solving complex planning and management problems" (Burroughs, 1986, NCGIA, 1990)
- Geographical Information System is a powerful computerized information system for spatial data referenced by the geographic coordinates. GIS is a set of tools for collecting, storing, retrieving (at will), transforming, analyzing and displaying spatial data from the real world for a particular purpose. It may also be elaborated as an computerized information system for spatial data and is designed to acquire, store, retrieve, manipulate, analyze and display these data according to user defined specifications" (Clarke, 1986).
- GIS is an information technology which stores, analyses and displays both spatial and non-spatial data.... GIS is actually a technology and is not necessarily limited to the confines of a single, well-defined software system" (Parker, 1988)
- GIS is any manual or computer based set of procedures used to store and manipulate geographically referenced data" (Aronoff, 1989)

COMPONENTS OF GIS

A GIS has the following well defined components:

- Computer Hardware
- Software
- Spatially/ Geographically referenced data
- Personnel involved

Computer Hardware

The hardware is the important component of GIS anatomy which includes the computer and the peripheral devices that the users interact with directly in carrying out GIS operations. The present day platforms for a GIS range from low end PCs to high end Workstations with a wide range of system capabilities in terms of performance, memory and hard disk. Thus the hardware components for GIS include- Processor, Monitor, Input devices (like Key board, Mouse, Digitizer, Scanner), Storage devices (like Floppy disk, CDs, Hard Disk, Magnetic Tapes) and Output devices (like Monitor, Printer, Plotter)

Software

Softwares are computer programmes, which contain a set of instructions to be performed by hardwares to derive the desired outputs. The major GIS softwares include: ARCGIS (developed by ESRI, USA), QGIS (an open source and free software), AUTOCAD MAP (developed by AutoDesk Inc.), MAPINFO (Mapinfo corporation), SPANS (PCI Geomatics, Canada), ISROGIS (India), GISNIC (NIC, India), GRAM++ (CSRE, IIT, Bombay).

Spatially Referenced Data

The spatially referenced data are the data, which describe the entities and events of the real world in terms of their-

- Position or Location (with respect to a known coordinate system)
- Attributes (the spatial and non-spatial characteristics associated with them)
- Spatial relationship with each other (Topology or Geometry)

Every spatial entity or event has specific position or location as it pertains to some space in our real world. So without having knowledge regarding location, we cannot identify an entity or event. As for example, "Bhubaneswar" is a spatial entity, but to identify it, we must first describe its location in terms of geographical coordinates (i.e. Latitude and Longitude). Apart from its location, the Bhubaneswar also needs some other characteristic definition to be defined. These characteristics are called attributes. As for example, after location the name "Bhubaneswar" needs to be described. The attributes may be spatial or non-spatial. As for example, the "Area" is a spatial attribute whereas the "Name" is non-spatial attribute. Every spatial entity or event has a geometric relationship with other spatial entities or events. For better analysis of spatial data, the understanding of this relationship is necessary. This relationship is called "Topology". This may include adjacency, containment and connectivity.

Personnel Involved

A GIS is useless without the people who design, programme and maintain it, supply it with data, and interpret its results.

DATA STRUCTURE IN GIS

As the spatially referenced data has two components:

- Spatial component (which describes location and geometry of the spatial feature or event)
- Attribute component (which describes the characteristics of the spatial feature or event)

The organization or structuring of this data can be studied under two headings:

- Spatial data model: There are two ways of modeling or structuring spatial component of the geographically referenced data. They are- Raster model and Vector model
- Attribute data model: There are three classical ways of representing attribute data. They are- Hierarchical model, Network model and Relational model

Raster Model

It is an explicit representation of spatial component of data in which a set of cells is located by coordinates and each cell is independently addressed with the value of an attribute. In other words it is the representation of spatial component of data in terms of grids or pixels.

Vector Model

It is an implicit representation of spatial component of data in which three main geographical entities such as point, line, and polygon are used to describe the spatial entities or events. In other words in vector representation, the spatial features or events are represented in terms of either point or line or polygon.

Hierarchical Model

Hierarchical model assumes that each part of the hierarchy can be reached using a "Key" that fully describes the data structure. These models are good for data retrieval, but disadvantageous since it leads to data redundancy which increases storage and access costs.

Network Model

In a network data model an entity can have multiple parents as well as multiple child relationship. It is very useful in cases where much more rapid linkage is required, particularly in data structures for graphic features where adjacent items in a map or figure need to be linked together even though the actual data about their coordinates may be written in very different parts of the database.

Relational Model

The relational database model in its simplest form stores no pointers and has no hierarchy of data fields within a record. Instead, the data are stored as collection of values in the form of simple records, known as "Tuples", containing an ordered set of attribute values that are grouped together in two dimensional tables, known as relations. Each table or relation is usually a separate file. The pointer structures in network models and the keys in hierarchical models are replaced by data redundancy in the form of identification codes that are used as unique keys to identify the records in each file. This structure of attribute data organization is very flexible which can meet the demands of all possible queries using rules of Boolean logic and other mathematical operations. It is also easy for update, retrieval, maintenance, analysis etc.

FUNCTIONALITIES/TOOLS OF GIS

The GIS softwares along with other elements, offer a variety of tools or functionalities for performing a wide range of desired data input, storage, editing, manipulation, analysis and presentation related activities, which can be grouped under four major modules:

1. Data input, modeling, storage module
2. Data retrieval, editing, scientific manipulation and management module
3. Analysis module
4. Presentation and output generation module

Data input, modeling and storage

After the data is collected through different primary and secondary sources from the real world, they are input to the GIS system. The spatial component of the data is entered through various devices like digitizer, scanner, mouse etc. The attribute data is entered through the keyboard. The various data input and modeling related activities include:

- Data layering
- Digitization
- Attribute data entry
- Importing digital data from other formats
- Linking of attribute data to spatial data etc

Data retrieval, editing, scientific manipulation and management

During the data input processes many errors exist in the database due to human biasness, error in source data, defects in data input devices etc. So before going for any analysis, the database needs to be edited and rectified properly. The data editing functionalities may include:

- Editing spatial data
  - Adding, deleting, copying, moving features Points, lines, polygons)
  - Rotating, Splitting and joining features
- Editing attribute data

As the data is collected from various sources due to non-availability of all the required and relevant at a single source, the data need to be standardized so that integrated analysis will be possible. For this various manipulation and management functionalities are applied which include:

- Transformation of all data to a common coordinate system and map projection
- Map joining and Edge matching of maps of adjacent areas
- Densification and smoothening of arcs etc

Analysis functions

The GIS offers a range of desired analysis functions to be performed on the GIS-database containing spatial as well as attribute component. The analysis functionalities may broadly include:

- Arithmetic Operations
  - Addition, Subtraction, Multiplication, Division, Exponential, functions, Trigonometric functions etc
- Geometric Operations
  - Computation of areas, distances, coordinates etc
- Logical Operations
  - Boolean functions like And, Or, Nor, Not etc.
  - Set operations like equal to, greater than, les than, intersection, union etc
- Statistical operations
  - Sum, maxima, minima, average, dispersion etc.
- Search and query operations

- Selection and Reclassification
- Spatial integration (Overlaying)
- Spatial proximity (Buffering)
- Neighborhood operations (Interpolation and Surface (3-D) generation etc.)
- Connectivity and Network operations (Optimal path allocation, Finding best route etc)

Presentation and Output generation

For better understanding and perception, after the various analysis have been made, the resultant information is presented and output is derived in terms of maps, charts, diagrams, tables etc. "Cartography" is the science of making maps and charts. So, the maps and charts are prepared according to cartographic symbolization principles.

APPLICATIONS OF GIS

Now a day, GIS is applied in wide range of fields including environmental studies, geology, hydrogeology, engineering, agriculture, meteorology, developmental planning, socio-economic studies, health studies etc. Some major application areas can be outlined as follows:

- Environmental Management (Land fill site selection, Land cover/Landuse change analysis, Site suitability analysis, Pollution monitoring, Natural Hazard assessment, Disaster Management, Resource Management, Environmental Impact Assessment etc.)
- Socio-economic/Government (Health infrastructure planning, Local government, Transportation planning, Service planning, Urban management etc.)
- Defense agencies (Target site identification, Tactical support planning, Mobile command modeling, Intelligence data integration, Target Sight and Viewshed analysis etc.)
- Commerce and business (Market share analysis, Insurance, Fleet management
- Direct marketing, Target marketing, Retail site location etc.)
- Utilities (Network management, Service provision, Telecommunications, Emergency Repairs)

REMOTE SENSING

Remote sensing is an advanced technological development for collection of information regarding earth surface features and mapping them. Remote Sensing is a process in which information is obtained about an object, area or phenomena through the analysis of data acquired by a device that is not in contact with the object or phenomena under investigation. In fact every object on earth's surface having temperature above 0° K (-273° C) radiates energy. In addition to this, every object also gets solar energy in day time, most of which is reflected in Visible, Near Infra Red (NIR) and Middle Infra Red (MIR) wavelength regions. This energy, radiated or reflected, though all of them cannot be seen by human eyes, yet can be detected and recorded by technological advanced sensor devices, installed onboard aerial or satellite platforms. Since each object has its own peculiar characteristic of radiation or reflection (depending upon its structure and composition), its recording can be identified. Such distant identification of objects is the key principle of remote sensing. Remote sensing is a very effective tool for acquisition of spatial data regarding natural resources due to its manifold advantages like synoptic and repetitive coverage of an area, high precision and real time data acquisition. So its integration with GIS has added a new dimension to the spatial planning.

GLOBAL POSITIONING SYSTEM (GPS)

INTRODUCTION

The Global Positioning System "(GPS) is a satellites-based radio-navigation system established by the U.S. Department of Defence for military positioning applications and as a by-product has been made available to the civilian community. Navigation, surveying and integration with Geographic Information (GIS) are just a few of the fields which have seen the successful application of GPS technology.

GPS is a complex system which can be used to achieve positional accuracies ranging from 100 m to a few millions depending on the equipment used and procedures followed. In general, higher accuracies correspond with higher costs and more complex observation and processing procedures. Therefore it is important for users to understand what techniques are required to achieve desired accuracies with the minimal cost and complexity. The objective of these notes is to provide the background and procedural information needed to effectively apply GPS technology.

SYTEM DESCRIPTION

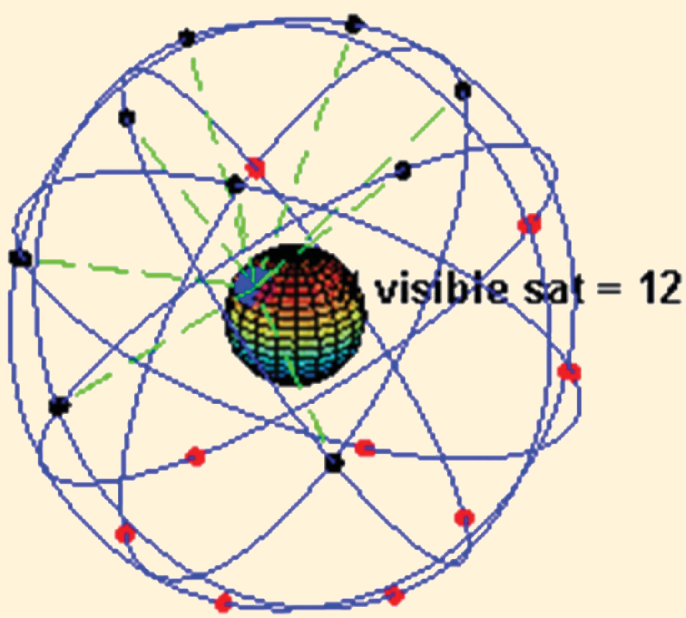
The Global positioning system (GPS) consists of 1) a constellation of radio-navigation satell9ites, 2) a ground control segment which manages satellite operation and 3) users with specialized receivers who use the satellite data to satisfy a broad range of positioning requirements. The system was established by the United States Department of Defence (DoD) to fulfil defence-positioning needs and as a by-product, to serve the civilian community.

The satellite constellation, which was fully operationalised at the end of 1993, consists of 24 satellites and three active spares positioned 20,200 km (about three times the earth's radius) above the earth. The satellite were distributed in a manner that ensures at least four satellites are visible almost anywhere in the world at any time. Each satellite receives and stores information from the control segment, maintains very accurate and stores information from the control segment, maintenance very accurate time through on board precise atomic clocks and transmits signals to the earth..

The ground control segment operates the satellite system on an on-going basis. It consist of five tracking stations distributed around the earth of which one, located in Colorado springs, is a master control station. The control segment tracks all satellites, ensures they are operating properly and computers their position in space.

GPS Satellite constellation

If a satellite is not operating properly the ground control segment may set the satellite "unhealthy" and apply measures to correct the problem. In such cases, the satellite should not be used for positioning until its status is returned to "healthy". The computed positions of the satellites are used to drive parameters, which in turn are used to predict where the satellites will be later in time. These parameters are uploaded from the control segment to the satellites and are referred to as broadcast ephemeredes.



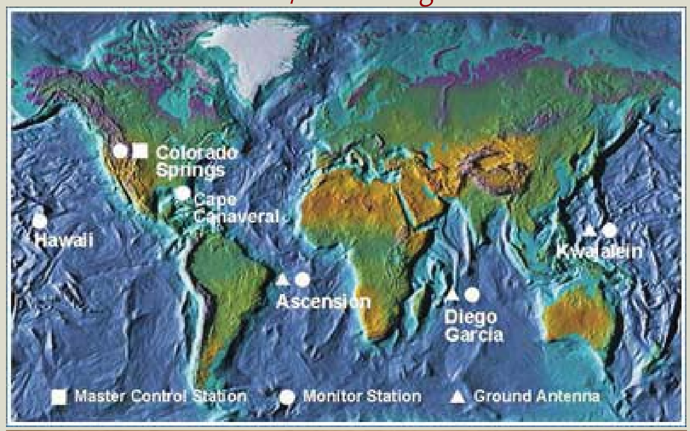
24 satelite GPS constellation in motion with the Earth rotating 6 Orbits and 4 satellites in each orbit

The user segment includes all those who use GPS tacking equipment to receive GPS signals to satisfy specific positioning requirements. A wide range of equipment designed to receive GPS signals is available commercially, to fulfil even wider range of user applications. Almost all GPS tracking equipment have the same basic components: an antenna and RF (Radio Frequency) section a microprocessor, a control and display unit (CDU), a recording device, and a power supply. These components may be individual units, integrated as one unit, or partially interacted usually all components, with the exception of the antenna, are grouped together and refereed to as a receiver. Some GPS receivers being marketed now in fact only consist of computer cards which may be mounted in portable computers or integrated with other navigation systems.

Ground Control Station

The prediction data is up-linked or transmitted, to the satellites for transmission back to the users. The control segment also ensures that the GPS satellite orbits and clocks remain within acceptable limits.

Master/Monitoring GCS



GPS Receivers

REMOTE SENSING & GIS IN ENIVIRONMENTAL IMPACT ASSESSMENT (EIA)

The EIA process deals with multiple and often conflicting legal requirements, proponents' and stakeholders' objectives, and physical constraints. This increases the need for information acquisition and analysis, many of which deal with spatial data. The demand for EIA is growing rapidly worldwide and techniques to visually illustrate the implications of spatial decisions are much in demand. Geographical information systems (GIS) can be very effective information and communication tools in this regard. GIS can be applied in all EIA stages: from the acquisition, storage and display of thematic information relative to the vulnerability of the affected resources, to impact prediction and quantification, evaluation, and finally, presentation. The execution of EIA depends to a great extent on good supply of environmental data. Unfortunately, most EIA studies lack of sufficient information to describe specific problems, define the problem's magnitude, and be used for other related spatial analyses. Consequently, many effects and trends cannot be investigated unless there is a systematic collection of environmental data. With the advancement of GIS, varieties of analyses tools have been developed and applied to produce information that could be used for the description of environmental components as well as predicting impacts.

According to Erickson (1994) there are four methodologies associated with impact assessment. Each of these methods have their advantages and disadvantages. So searching for an ideal technique is meaningless. Rather a more realistic approach is to identify the relative merits of these alternatives and a combination of techniques can be chosen to meet the needs of a particular problem. The methodologies are: Overlay, Checklist, Matrix and Network. In the Overlay method of impact assessment, physical or computerized overlays of individual maps of social and physical attributes of the project area are integrated. The data used include topological data, air dispersal patterns, land and resource use data, wildlife, surface and ground water intakes. These data may be obtained from aerial photography and satellite remote sensing. This method is advantageous as it focuses on graphical display of data, but it is limited in that it lacks analytical capabilities. As the basic utility of GIS is spatial data integration through overlaying, it is the ultimate tool for overlay EIA. The Checklist method can be a very simple or complex list of environmental components, attributes and processes, which are categorized under disciplinary headings such as geology, vegetation and air. GIS provides a computer platform for organizing, storing and analyzing these checklists. The Matrix method, which is a modification of checklist, facilitates relating specific project activities to specific types of impacts. Matrices are found wanting because they emphasize only direct impacts. They force consideration of impact of each aspect of a proposal for a range of environmental concerns and they consider both the magnitude and importance of impacts. Again, GIS provides a powerful tool for organizing, analyzing and storing matrices.

Lastly, the Network methodology defines a network of possible impacts that may be triggered by project activities and that require the analyst to trace out project actions and direct and indirect consequences. From the network methodology, direct, secondary, tertiary and other higher order impacts of action may be well traced out. This method cuts across disciplinary lines and it forces the identification of site-specific factors and conditions necessary for the establishment of a proposed cause-effect relationship. This technique however requires that the analyst be knowledgeable in the various types of environmental components and dynamics (Erickson, 1994). On a GIS platform, the analyst is further aided as large volumes of data can be better analyzed in a short while.

A case study of an industrial project located at Thiaberna in Sundergarh District of Odisha has been presented here for illustrating the GIS use in EIA studies. In order to carry out a detailed environmental impact assessment of this project, various layers of environmental parameters for the 10 Km buffer zone around project site were generated in a GIS environment by taking information from various secondary sources as well as primary sources like remote sensing and field survey. However the various spatial layers varied in scale. But with the help of Georeferencing function in GIS, these were brought to a common coordinate system, which enabled them for integrated analysis through overlaying. The various layers thus generated included transport network, drainage and surface water bodies, landcover/landuse, geology, hydrogeomorphology, soil, elevation, population distribution, availability of facilities etc. The landuse/landcover and hydrogeomorpholoy layers were generated from satellite images through the digital cum visual interpretation technique. The water quality maps were also generated for pH and chloride by interpolating data obtained through water quality analysis for sample locations. These environmental parameter layers representing baseline conditions of the study area were then integrated in GIS to analyze the various probable impacts of the proposed project. A digital elevation model was also developed to visualize the real world situation and impacts of the proposed project.

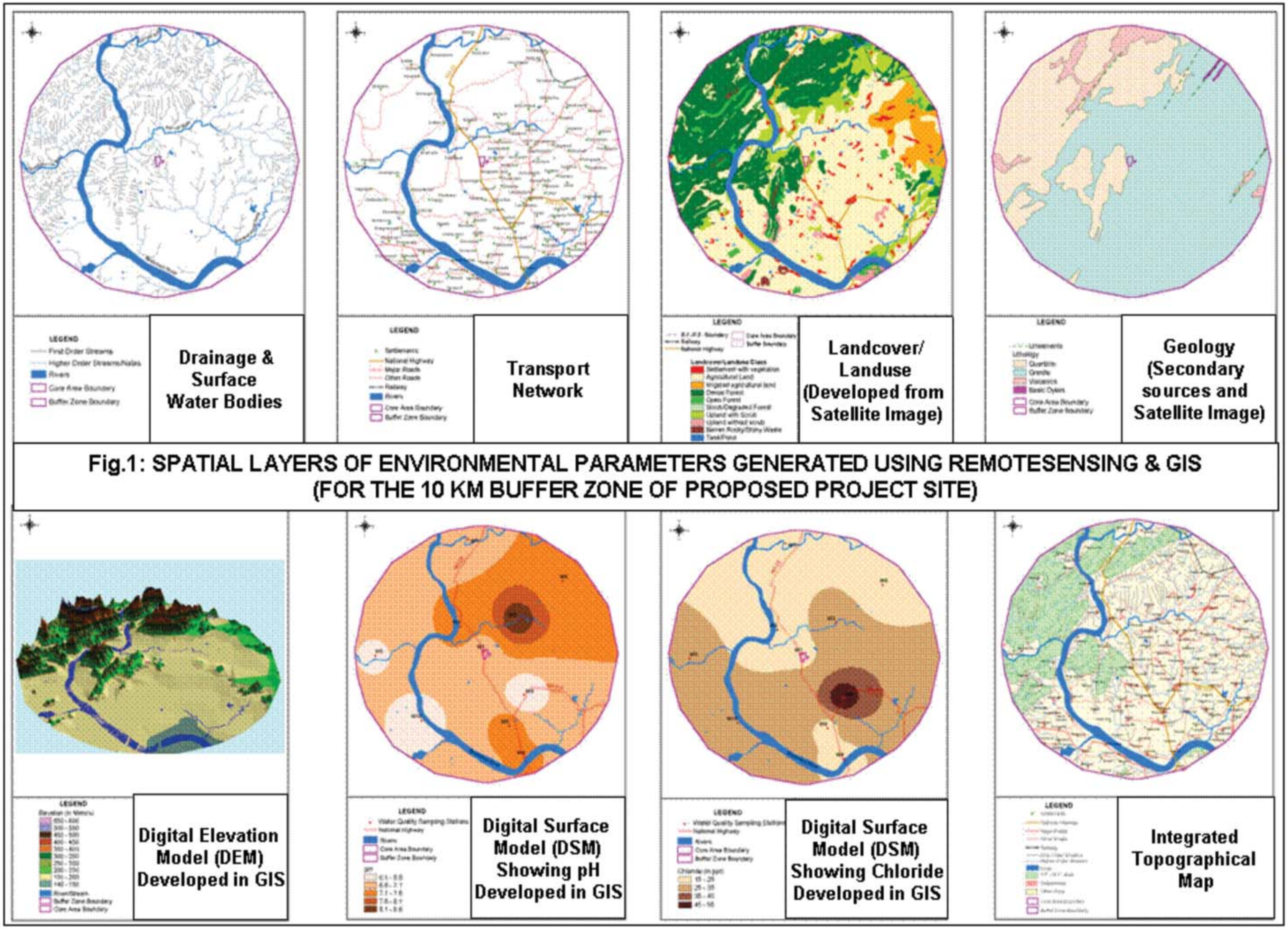


Fig.1: SPATIAL LAYERS OF ENVIRONMENTAL PARAMETERS GENERATED USING REMOTESENSING & GIS (FOR THE 10 KM BUFFER ZONE OF PROPOSED PROJECT SITE)

CONCLUSION

In the early years of GIS, it was characterized by more than a graphic tool with very limited spatial analysis capabilities. It was essentially addressing the needs of the geographical community. Therefore, the traditional environmentalists were skeptical about its usage in solving environmental impact assessment problems. However, the recent GIS have incorporated wide range of analytical capabilities along with multivariate, geostatistical modules and powerful 3-D analysis, which have popularized GIS. The Environmental Impact Assessment studies have become more scientific, realistic and time saving with the help of modern spatial technology. GIS and Remote Sensing helps in detection of temporal changes like changes in saline areas, change in morphology of landforms, change in drainage system, change in water body dimensions, land use, forest cover and grazing lands etc which has impact on the environment directly or indirectly. The information generated by the use of Geographical Information Systems (GIS) in impact identification and prediction stages of Environmental Impact Assessment (EIA) is used in the assessment of impact significance by the computation of a set of impact indices.

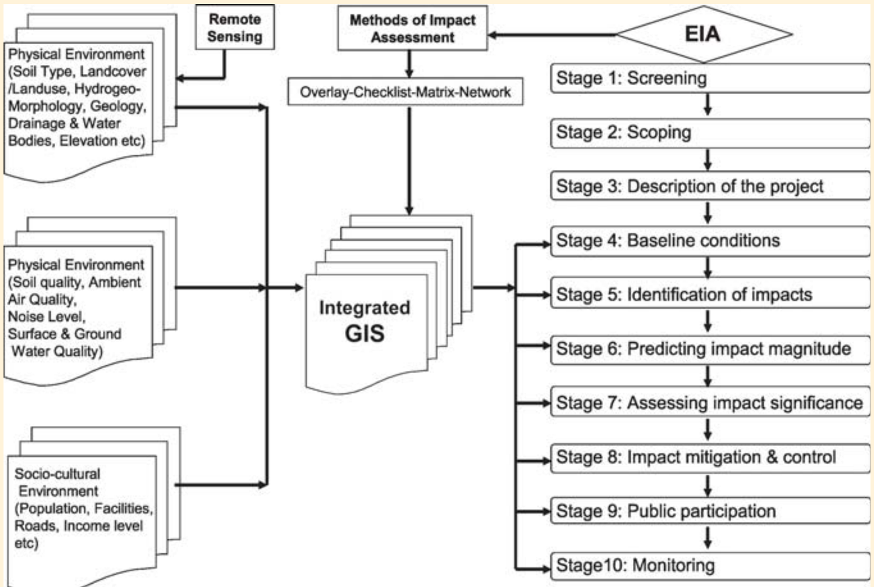


Fig. 2: GIS in EIA

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