Chapter II
CHAPTER II
FUNDAMENTAL CONCEPTS OF ENVIRONMENTAL IMPACT ASSESSMENT, REMOTE SENSING AND GIS

2.1 OVERVIEW

Environment is linked and influenced by, atmosphere, climate, terrain and vegetation cover. The agricultural, industrial, habitation and other activities of man have an impact on geological, physical, chemical and biological process taking place in the environment. For an ecologically sustainable development, environmental impact assessment is essential. Environmental Protection and Sustainable Development have been the cornerstones of policies and procedures governing the industrial and other developmental activities in India. For integrated planning and to achieve balanced growth by conserving the quality of environment, the most aptly suited methods are application of modern technologies. The evaluation of the possibilities of application of modern technology has become the central theme in solving the repercussions derived on drastic changes connected with physical developmental changes. The success of planning for developmental activities depends on the quality and quantity of information available on both natural and socio-economic resources. It is therefore, essential to devise ways and means of organizing computerized information systems. These systems must be capable of handling vast
amount of data collected by modern techniques and produce up-to-date information.

2.2 ENVIRONMENTAL IMPACT ASSESSMENT

2.2.1 Relevance of EIA

An environmental impact is (may be) defined as a change in the environmental parameters, over a specified period and in a specified geographical area, resulting from a particular activity compared with the situation which would have existed had the activity not been initiated. The techniques developed for EIA are Overalys, Matrix diagrams, Checklists, and Net Working.

EIA may be considered as a data management process, with three components:

(1) identification and if possible, collection of the appropriate information necessary for a particular decision to be taken,

(2) projection of changes in environmental parameters arising from the implementation of the project, compared with the situation that could exist without the proposal,

(3) recording and analysis of actual change.

EIA, is an activity designed to identify and predict the impact on biogeo-physico-chemical environment and on human's health and to recommend appropriate legislative proposals, policies, programs, projects
and operational procedures to minimize the impact of the activities on the environment. Environmental Impact Assessment (EIA) can provide an important management tool in the development of waste management strategies at the national and regional level in the control of waste generation and in the siting of waste treatment and disposal facilities. The effective use of EIA within waste management is complex because of the need to consider: the interrelationships between management and technical considerations; developing engineering system, tightening regulatory controls particularly in relation to emissions standards, difficulties in establishing specific health or environmental effects, and public sensitivities. The purpose of using the environmental impact assessment (EIA) is to incorporate into development a planning tool, which identifies a plan for environmental protection and enhancement on a project-by-project basis. Analytical functions associated with environmental impact assessment are Defining scope of a EIA, Identification, Prediction, Impact Evaluation and Analysis.

2.2.2 Objective of EIA

The objective of EIA is to foresee the potential environmental problems that would arise out of a proposed development and address them in the project's planning and design stage. The EIA process should then allow for the communication of this information to:
(a) the project proponent;
(b) the regulatory agencies; and,
(c) all stakeholders and interest groups.

The EIA process in India is made up of the following phases: (Ministry of Environment and Forests, Guidelines 2001)

- Screening
- Scoping and consideration of alternatives
- Baseline data collection
- Impact prediction
- Assessment of alternatives, delineation of mitigation measures and environmental impact statement
- Public hearing
- Environment Management Plan
- Decision making
- Monitoring the clearance conditions

Screening, is done to see whether a project requires environmental clearance as per the statutory notifications. Screening Criteria are based upon: Scales of investment, Type of development; and Location of development.

A Project requires statutory environmental clearance only if the provisions of EIA notification and/or one or more statutory notifications.
Scoping

Scoping is a process of detailing the terms of reference of EIA. It has to be done by the consultant in consultation with the project proponent and guidance, if need be, from Impact Assessment Agency. The Ministry of Environment and Forests has published guidelines for different sectors, which outline the significant issues to be addressed in the EIA studies. Quantifiable impacts are to be assessed on the basis of magnitude, prevalence, frequency and duration and non-quantifiable impacts (such as aesthetic or recreational value), significance is commonly determined through the socio-economic criteria.

Baseline Data

Baseline data describes the existing environmental status of the identified study area. The site-specific primary data should be monitored for the identified parameters and supplemented by secondary data if available.

Impact Prediction

Impact prediction is a way of ‘mapping’ the environmental consequences of the significant aspects of the project and its alternatives. Environmental impact can never be predicted with absolute certainty and this is all the more reason to consider all possible factors and take all possible precautions for reducing the degree of uncertainty. The impacts
and changes in namely air, water, noise, land, biological, socioeconomic are to be assessed in the project.

2.2.3. Methodologies and Techniques Adopted in EIA

Important techniques and methodologies of utility for assessing the impacts of development activities on the environment adopted are Adhoc methods, Checklists methods, Matrices methods, Networks methods, Overlays methods. An evaluation of various methodologies is presented in Table 2.1.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Checklists</th>
<th>Overlay</th>
<th>Network</th>
<th>Matrix</th>
<th>Environmental index</th>
<th>Cost/benefit analysis</th>
<th>Simulation modeling workshop</th>
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<tr>
<td>1. Comprehensiveness</td>
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<td>N</td>
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<td>S</td>
<td>S</td>
<td>S</td>
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<td>3. Flexibility</td>
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<td>5. Aggregation</td>
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<td>6. Replicability</td>
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<td>S</td>
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<td>12. Summary format</td>
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<td>13. Alternative comparison</td>
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<td>N</td>
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<td>14. Time requirement</td>
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<td>15. Manpower requirement</td>
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<tr>
<td>16. Economy</td>
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</tbody>
</table>

Legend: L = Completely fulfilled, or low resource need.  
S = Partially fulfilled, or moderate resource need.  
N = Negligibly fulfilled, or high resource need.  

Source: Environmental Impact Assessment: Guidelines for Planners and Decision Marker, UN Publication SI/1 SCAP/351/ESCAP, 1983
Adhoc methods:

Basically adhoc methods indicate broad areas of likely impacts by listing composite environmental parameters (for example flora and fauna) likely to be effected by any development.

Adhoc methods involve assembling a team of specialists to identify impacts in their area of expertise. In this method, each environmental area e.g. Air, water etc. are taken separately and the nature of the impacts such as no effect, short or long term reversible or irreversible etc., are considered. Adhoc methods are for rough assessment of total impact giving the broad areas of possible impacts and the general nature of these possible impacts. For the present study, this methodology is adopted for the impact assessment of Flora and Fauna in the study area.

Checklist Methodologies:

Checklist methodologies range from listings of environmental factors to highly structured approaches involving importance weightings for factors and application of scaling techniques for the impacts of each alternative on each factor.

Checklists are simple checklists, a list of parameters without guidelines provided on how to interpret and measure an environmental parameter. Descriptive Checklists, includes an identification of environmental parameters and guidelines on how parameter data are to be
measure. Scaling Checklists, are similar to descriptive checklist with the addition of information basis to subjective scaling or parameter values.

**Matrix Methods**

Matrix methods are basically generalized checklists where one dimension of a matrix is a list of environmental social and economic factors likely to be affected by a proposal. The other dimension is a list of actions associated with development. These relate to both the construction and operational phases. Impacts are identified by making cells representing a likely impact resulting from the interaction of a facet of the development with an environmental feature. With some matrices qualitative representation of impact importance and magnitude are inserted in individual cells. Figure 2.1 shows the matrix diagram for environmental pollution possibilities and recommended monitoring systems.

2.2.4 **Assessment of Alternatives, Delineation of Mitigation Measures and Environmental Impact Assessment Report**

For every project, possible alternatives should be identified and environmental attributes compared. Alternatives should cover both project location and process technologies. Alternatives should consider 'no project' option also. Alternatives should then be ranked for selection of the best environmental option for optimum economic benefits to the community at large. Once alternatives have been reviewed, a mitigation plan should be drawn up for the selected option and is supplemented with
### ENVIRONMENT POLLUTION POSSIBILITIES AND RECOMMENDED MONITORING SYSTEMS

<table>
<thead>
<tr>
<th>SOURCE OF POLLUTION</th>
<th>Solid waste (a)</th>
<th>Legume afflent (b)</th>
<th>Polluted sediment (c)</th>
<th>Polluted soil (d)</th>
<th>Organic detritus (e)</th>
<th>Particulate (f)</th>
<th>Other (g)</th>
<th>Priority</th>
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<tr>
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</table>

* Footnote: Includes fish, birds, plants, soil, etc.
- *Note refers to mangroves, corals and other forms of aquatic life.
an Environmental Management Plan (EMP) to guide the proponent towards environmental improvements. The EMP is a crucial input to monitoring the clearance conditions and therefore details of monitoring should be included in the EMP.

An EIA report should provide clear information to the decision-maker on the different environmental scenarios without the project, with the project and with project alternatives. Uncertainties should be clearly reflected in the EIA report.

Public Hearing

Law requires that the public must be informed and consulted on a proposed development after the completion of EIA report. Any one likely to be affected by the proposed project is entitled to have access to the Executive Summary of the EIA.

The affected persons may include:
- bonafide local residents;
- local associations;
- environmental groups: active in the area
- any other person located at the project site/sites of displacement

2.2.5 Decision Making

Decision making process involve consultation between the project proponent (assisted by a consultant) and the impact assessment authority (assisted by an expert group if necessary) The decision on environmental
clearance is arrived at through a number of steps including evaluation of EIA and EMP.

Monitoring the Clearance Conditions

Monitoring should be done during both construction and operation phases of a project. Where the impacts exceed the predicted levels, corrective action should be taken. Monitoring will enable the regulatory agency to review the validity of predictions and the conditions of implementation of the Environmental Management Plan (EMP).

2.3 COMPONENTS OF EIA

The difference between Comprehensive EIA and Rapid EIA is in the time-scale of the data supplied. EIA report should contain all or some of the following components namely,

a) Air Environment
b) Noise Environment
c) Water Environment
d) Biological Environment
e) Land Environment
f) Socio-economic and Health Environment
g) Risk Assessment
h) Environment Management Plan
2.4 REMOTE SENSING CONCEPTS

The unique capability of space based sensors to provide wide range of information available in the electromagnetic spectrum, in a synoptic and more and more frequent manner, has made this technology an inevitable tool in the sustainable development and utilization of our natural resources (K.Kasturirangan, et al., 1996). Remote sensing is a multi-disciplinary activity which deals with the inventory, monitoring and assessment of natural resources through the analysis of data obtained by observations from a remote platforms. In other words, remote sensing can be defined as the science and art involved with the gathering of data about the earth’s surface or near surface environment, through the use of a variety of sensor systems that are usually borne by air craft, or space craft and the processing of these data into information that can be used for understanding and or managing our environment both natural and cultural (Roger.M.Hoffer, 1994).

The application of Photogrammetry, Surveying, Remote Sensing, Land Information System (LIS), Geographic Information System( GIS), Automated Mapping and Facility Management (AM&FM), and Global Positioning System(GPS) has become the feature in any developmental activities for urban and rural sector environmental planning in the recent past. It becomes necessary to understand the land use patterns, land cover changes, availability of resources such as water and use them in the most
appropriate way to derive maximum benefit. In these efforts, remote sensing techniques come as a handy tool (LRA Narayan, 1999).

Remote Sensing, Geographical Information System, with support from the Global Positioning System, have perhaps the greatest technological breakthrough in the last 21st century. Remote sensing Technology has emerged as an efficient and powerful tool in providing reliable information on various natural resources of a region in a spatial format, so essential for planning, management and for ecologically sustainable development. And developments in remote sensing and geographic information systems is opening up new vistas for the mapping, and monitoring of our natural resources. Using satellite remote sensing information, planners and policy makers can make more effective decisions to ensure a stable supply of water for food and the environment. The civilian application areas include agriculture, forestry, fishing, Oceans, the study of bio-diversity, monitoring of urban growth, mapping of wastelands and managing water resources.

The task of any remote sensing system is simply to detect radiation signals, determine their spectral character, derive appropriate signatures, and interrelate the spatial positions of the classes they represent. This ultimately leads to some type of interpretable display product, be it an image, a map, or a numerical data set, that mirrors the reality of the surface (or some atmospheric properties) in terms of the nature and distribution of the features present in the field of view.
The different stages in remote sensing are (Seelan Santhosh Kumar, 1994)

- Origin of electromagnetic energy (sun, transmitter carried by the sensor)
- Transmission of energy from the source to the surface of the earth and its interaction with the intervening atmosphere
- Interaction of energy with the earth surface (reflection/absorption/transmission) or self-emission
- Transmission of the reflected/emitted energy to the sensor placed on a suitable platform.
- Detection of the energy by the sensor converting into photographic image or electrical output.
- Transmission/recording of the sensor output.
- Preprocessing of the data for generation of data products.
- Collection of ground truth and other collateral information
- Data processing, analysis, and interpretation.

Figure 2.2 illustrates flow of stages in remote sensing. The information received by the sensor is suitably manipulated and transported back to the earth—may be telemetered as in the case of unmanned space craft or brought back through films, magnetic tapes, etc.
as in aircraft, or manned-spacecraft systems. The data are reformatted and processed on the ground to produce either photographs, or computer compatible magnetic tapes (CCTs) which are either interpreted visually or digitally to produce thematic maps and other resources information.

2.4.1. Remote Sensing Satellites and Sensor Characteristics

**Remote Sensing Satellites**

Space borne sensors are currently used to assist in scientific and socioeconomic activities like weather prediction, crop monitoring, mineral exploration, waste land mapping, cyclone warning, water resources management and pollution detection. There are many satellite systems which provide data on an operational basis to the interpreter. The different satellites have different spectral and spatial, radiometric and temporal resolutions and are designed for different applications. The major characteristics of an imaging remote sensing instrument operating in the visible and infrared spectral bands are described in terms of its spatial, spectral and radiometric resolution. These three types of resolutions vary sensor to sensor. Each sensor has its own capability of detecting the energy reflected from earth surface features. Satellites can be classified into three broad categories like earth resources satellites, meteorological satellites and satellites carrying microwave sensors, though not a rigid classification system.
Earth Resources Satellites:

There are three distinct groups of earth resources satellites. Those satellites which record visible and near visible wavelengths fall into one category. The five satellites of Landsat series which are the first generation earth resources satellites are a classic example of this group. The four IRS satellites and the more improved SPOT series of three satellites may be considered as the second generation earth resources satellites of the same group. Group two satellites carry sensors that record thermal infrared wavelengths and include the Heat Capacity Mapping Mission satellites, namely Explorer series. Group three satellites are deployed with sensors that record micro wavelengths. The Seasat series and the ERS are examples of this group (M.Anjireddy, 2001).

Meteorological Satellites

Meteorological satellites designed specifically to assist in weather prediction and monitoring, generally incorporate sensors that have very coarse spatial resolution compared to land-oriented systems. These satellites however afford a high frequency global coverage. U.S.A. has launched a multiple series of meteorological satellites with a wide range of orbit and sensing system designs. The first of these series is called the NOAA, an acronym for National Oceanic and Atmospheric Administration. These satellites are in near-polar, sun-synchronous orbits similar to those of Landsat and SPOT.
Satellites Carrying Microwave Sensors

Microwave imaging is gaining increasing importance with a better understanding of the relation between image tone and earth’s surface characteristics. The clear advantage of microwave sensor is its capacity to penetrate cloud cover. Satellites that carry microwave sensors are Seasat with Synthetic Aperture Radar (SAR), European Remote Sensing Satellite (ERS)-1.

Sensor Characteristics

- **Spatial Resolution:** It is the size of the smallest object that can be discriminated by the sensor. The greater the sensor’s resolution, the greater the data volume and smaller the area covered.

- **Spectral resolution:** It is width of the spectral band and the number of spectral bands in which the image is taken. Narrow band widths in certain regions of the electromagnetic spectrum allow us to discriminate between the various features more easily.

- **Radiometric resolution:** It is the capability to differentiate the spectral reflectance/emitance between various targets. This depends on the number of quantisation levels within the spectral band.

- **Temporal resolution:** It refers to the minimum duration of an event that is discernible. It is affected by the interaction between the duration of the recording interval and the rate of change in the event.
Sensor Characteristics used for the present study:

For the present study, data of LISS III of IRS ID and MSS of Land Sat–IV is acquired for generation of spatial database for the present study area. And the satellite and a sensor characteristics are tabulated in Table 2.2 and 2.3

<table>
<thead>
<tr>
<th>Table 2.2. Orbital Characteristics IRS ID</th>
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<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>Class</td>
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<tr>
<td>Weight (kg)</td>
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<td>Power (W)</td>
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<tr>
<td>Launch</td>
</tr>
<tr>
<td>Height (km)</td>
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<td>Inclination (deg)</td>
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<tr>
<td>Type</td>
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<tr>
<td>Equator crossing time</td>
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<tr>
<td>Repetivity (days)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2.3 Characteristics of Remote Sensors on Board IRS ID</th>
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<tbody>
<tr>
<td>Type</td>
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<tr>
<td>Spectral bands (μm)</td>
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<tr>
<td>Ground Res. (m)</td>
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<td></td>
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<tr>
<td>Swath (km)</td>
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<tr>
<td>Steering</td>
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</tbody>
</table>
**Characteristics of MSS of Land Sat.**

Landsat 4 and 5 reoccupy on a 16 day cycle. Under the above orbital conditions, and with an angular field of view if 11.58 ° the width of a Landsat MSS scene is 185 km (114 statute or 100 nautical miles). Best bands suitable for identifying the earth surface features are tabulated in Table 2.4.

**2.4.2 Remote Sensing Data Processing**

Space borne remote sensing data suffers from a variety of radiometric and geometric errors caused by satellite motion, the sensor system earth’s rotation etc. These distortions would diminish the accuracy of the information extracted and thereby reduce the utility of the data. The visual interpretation of the remote sensing data is based on hard copies, such as the False Color Composites (FCC’s).

**2.4.3 Visual Interpretation**

Image interpretation or analysis is defined as the “act of examining images for the purpose of identifying objects and judging their significance”. Interpreters study remotely sensed data and attempt through logical process in detecting, identifying, classifying, measuring and evaluating the significance of physical and cultural objects, their patterns and spatial relationship. Image interpretation is a complex process of physical and psychological activities occurring in a sequence of time. The
Table 2.4  Best bands of Land Sat MSS for identifying surface features

<table>
<thead>
<tr>
<th>Item</th>
<th>Category</th>
<th>Best Bands</th>
<th>Salient Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Clear Water</td>
<td>7</td>
<td>Black tone in black and white and color.</td>
</tr>
<tr>
<td>b.</td>
<td>Silty Water</td>
<td>4,7</td>
<td>Dark in 7; bluish in color.</td>
</tr>
<tr>
<td>c.</td>
<td>Nonforested Coastal Wetlands</td>
<td>7</td>
<td>Dark gray tone between black water and light gray land; blocky pinks, reds, blues, blacks.</td>
</tr>
<tr>
<td>d.</td>
<td>Deciduous Forests</td>
<td>5,7</td>
<td>Very dark tone in 5, light in 7; dark red.</td>
</tr>
<tr>
<td>e.</td>
<td>Coniferous Forest</td>
<td>5,7</td>
<td>Mottled medium to dark gray in 7, very dark in 5; brownish-red and Subdued tone in color.</td>
</tr>
<tr>
<td>f.</td>
<td>Defoliated Forest</td>
<td>5,7</td>
<td>Lighter tone in 5, darker in 7 and grayish to brownish-red in color, relative to normal vegetation.</td>
</tr>
<tr>
<td>g.</td>
<td>Mixed Forest</td>
<td>4,7</td>
<td>Combination of blotchy gray tones; mottled pinks, reds, and brownish-red.</td>
</tr>
<tr>
<td>h.</td>
<td>Grasslands (in growth)</td>
<td>5,7</td>
<td>Light tone in black and white; pinkish-red.</td>
</tr>
<tr>
<td>i.</td>
<td>Croplands and Pasture</td>
<td>5,7</td>
<td>Medium gray in 5, light in 7, pinkish to moderate red in color depending on growth stage.</td>
</tr>
<tr>
<td>j.</td>
<td>Moist Ground</td>
<td>7</td>
<td>Irregular darker gray tones (broad); darker colors.</td>
</tr>
<tr>
<td>k.</td>
<td>Soils-bare Rock-Fallow Fields</td>
<td>4,5,7</td>
<td>Depends on surface composition and extent of vegetative cover. If barren or exposed, may be brighter in 4 and 5 than in 7, Red soils and red rock in shades of yellow; gray soil and rock dark bluish; rock outcrops associated with large land forms and structure.</td>
</tr>
<tr>
<td>l.</td>
<td>Faults and Fractures</td>
<td>5,7</td>
<td>Linear (straight to curved), often discontinuous; interrupts topography; sometimes vegetated.</td>
</tr>
<tr>
<td>m.</td>
<td>Sand and Beaches</td>
<td>4,5</td>
<td>Bright in all bands; white, bluish, to light buff.</td>
</tr>
<tr>
<td>n.</td>
<td>Stripped Land-Pits and Quarries</td>
<td>4,5</td>
<td>Similar to beaches – usually not near large water bodies; often mottled, depending on reclamation.</td>
</tr>
<tr>
<td>o.</td>
<td>Urban Areas: Commercial Industrial</td>
<td>5,7</td>
<td>Usually light toned in 5, dark in 7, mottled bluish-gray with whitish and reddish specks.</td>
</tr>
<tr>
<td>p.</td>
<td>Urban Areas: Residential</td>
<td>5,7</td>
<td>Mottled gray, with street patterns visible; pinkish to reddish.</td>
</tr>
<tr>
<td>q.</td>
<td>Transportation</td>
<td>5,7</td>
<td>Linear patterns, dirt and concrete roads light, in 5; asphalt dark in 7.</td>
</tr>
</tbody>
</table>
sequence begins with the detection and identification of images and later by their measurements (M. Anji Reddy, 2001).

Detection:

It is a process of ‘picking out’ an object or element from photo or image through Interpretation techniques. It may be detection of point or line locations e.g. agricultural field or small settlement etc.

Recognition and Identification:

It is a process of classification or trying to distinguish an object by its characteristics or patterns which are familiar on the image. Sometimes it is also termed as photo reading e.g. water features, streams, tanks, sands, etc.

Analysis:

It is a process of resolving or separating a set of objects or features having similar set of characters. In analysis, lines of separation are drawn between group of objects and the degree of reliability of these lines can also be indicated, e.g. sands as that of river etc.

Classification:

It is a process of identification and grouping of objects or features resolved by analysis.
Detection:

It is a process where references are drawn about the objects based on direct or indirect evidence of the information or phenomena under study. Detection may be firmly confirmed by ground checks to avoid misclassification.

Idealization:

It is a process of drawing ideal or standard representation from what is actually identified and interpreted from the image or map e.g. set of symbols or colours to be adopted in waste land maps etc.

Basic Elements of Visual Interpretation

A systematic study of aerial photos usually involves several basic characteristics of features shown on a photograph. The exact characteristics useful for any specific task, and the manner in which they are considered, depends on the field of application. There are certain fundamental photo elements or image characteristics seen on the image, which aid in visual interpretation of satellite imagery namely, i) Tone or Colour ii) Size iii) Shape iv) Texture v) Pattern vi) Location vii) Association viii) Shadow ix) Aspect x) Resolution.
2.5. Digital Image Processing.

Digital image processing is that, the digital image is fed into a computer one pixel at a time. The computer is programmed to insert these data into an equation or a series of equations, and then store the results of the computation for each pixel. Virtually, all the procedures maybe grouped into one or more of the following broad types of operations, namely:

1. Preprocessing (Image Restoration and Rectification)
2. Image Enhancement and
3. Image classification.

Preprocessing operation steps typically involves initial processing of raw image data to correct for geometric distortions and to calibrate the data radiometrically, and to eliminate noise present in the data before using it for any application. Geometric corrections involve Platform effects, Scene effects, Sensor effects. Radiometric corrections involve

Line Drop Correction: The line dropout is usually overcome by replacing the zero value by the mean values of the pixels of previous and the following line. Say for example, 10\textsuperscript{th} line is the dropout line, then all the
De-stripping; The stripping of the remote sensing data (MSS) are being corrected with the help of the Detectors Master Calibration Curve. This is discussed by Bernstein and Ferneyhough (1975), Bernstein (1983) and Jenson (1983).

2.5.1 Atmospheric Scattering Correction

The atmospheric scattering or haze effect is very complicated phenomenon. Generally, scattering is more in the lower wavelength (visible) than higher wavelength (infrared band). Further scattering effect increases the signal value (bias).

Enhancement Techniques

Digital enhancement algorithms are namely contrast stretching enhancement, rationing, linear combinations, principal component analysis, spatial filtering etc. Broadly, the enhancement techniques are categorized as (a) point operations and (b) local operations. Point operations modify the values of each pixel in an image data set independently, whereas local operations modify the values of each pixel in the context of the pixel values surrounding it. Point operations include, contrast enhancement and band combinations, but spatial filtering is an example of local operations.
2.5.2 Image Classification

Image classification is a procedure to automatically categorize all pixels in an image of a terrain into land cover classes. Spectral pattern recognition refers to the family of classification procedures that utilizes this pixel-by-pixel spectral information as the basis for automated land cover classification. Spatial pattern recognition involves the categorization of image pixels on the basis of the spatial relationship with pixels surrounding them. Classification techniques are grouped into two types, supervised classification, unsupervised classification.

2.5.2.1 Supervised classification

Classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. A computer-implemented process through which each measurement vector is assigned to a class according to a specified decision rule, where the possible classes have been defined on the basis of representative training samples of known identity. The process of assigning pixels from a multispectral image to classes, generally on the basis of spectral reflectance characteristics. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to that criteria. The basic idea in supervised classification is to train the computer to recognize landscape elements by their spectral signatures, assuming that we know
what is where in some training sites. This can classify the image according to an existing, possibly standard, classification or for a specific use of interest.

There are five algorithms that may be used for a supervised classification. They are Parallelepiped, Parallelepiped with Maximum Likelihood as tie breaker, Minimum Distance, Maximum Likelihood, Maximum Likelihood with NULL class.

**Parallelepiped**

The parallelepiped classifier uses the threshold of each class signature to determine if a given pixel falls within the class or not. The thresholds specify the dimensions (in standard deviation units) of each side of a parallelepiped surrounding the mean of the class in feature space. If the pixel falls inside the parallelepiped, it is assigned to the class. However, if the pixel falls within more than one class, it is put in the overlap class (code 255). If the pixel does not fall inside any class, it is assigned to the null class (code 0). The parallelepiped classifier is typically used when speed is required.

The parallelepiped classifier with maximum likelihood as a tie breaker is a cross between the parallelepiped classifier and the full maximum likelihood classifier. The basic concept is to use parallelepiped classification unless we have a tie (overlap), in which case the tie is resolved by using full maximum likelihood classification.
**Maximum likelihood**

The full maximum likelihood classifier uses the Gaussian threshold (THRS) stored in each class signature to determine if a given pixel falls within the class or not. The threshold is the radius (in standard deviation units) of a hyperellipse surrounding the mean of the class in feature space. If the pixel falls inside the hyperellipse, it is assigned to the class. If the pixel does not fall inside any class, it is assigned to the null class (code 0). The maximum likelihood classifier is considered to give more 'accurate' results than parallelepiped classification. However, it is much slower due to extra computations.

**Minimum Distance**

The distances between the pixel to be classified and each class centre are compared. The pixel is assigned to the class whose centre is the closest to the pixel.

**2.5.2.2 Unsupervised classification**

In unsupervised classification, the computer separates the imagery using the information theory, into a classification that best differentiates pixels. This does not depend on the (possibly biased) selection of training sites. The system divides the cells of the composite into classes which maximizes the inter class variance and minimizes the intra-class variance by analyzing the histogram of the composite image and looking for peaks and valleys.
ISODATA Classifier

The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set. Each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration. The ISODATA utility repeats the clustering of the image until either a maximum number of iterations has been performed, or a maximum percentage of unchanged pixel assignments has been reached between two iterations. Performing an unsupervised classification is simpler than a supervised classification because the signatures are automatically generated by the ISODATA algorithm.

K-Means Clustering

Performs unsupervised clustering using the K-means (Minimum Distance) method on image data for up to 255 clusters (classes) and 16 channels. The output is a theme map directed database image channel.
2.6 GEOGRAPHIC INFORMATION SYSTEMS

According to the *International GIS Dictionary*, GIS is a "computer system for capturing, managing, integrating, manipulating, analysing and displaying data which is spatially referenced to the Earth." (R McDonnell & K Kemp. 1995). What distinguishes GIS from other forms of information systems, such as databases and spreadsheets, is that GIS deals with spatial information. GIS has the capability to relate layers of data for the same points in space, combining, analysing and, finally, mapping out the results. Spatial information uses location, within a coordinate system, as its reference base. The most common representation of spatial information is a map on which the location of any point could be given using latitude and longitude, or local grid references such as the National Grid.

Effective utilization of the spatial data volume is dependent upon existence of an efficient, geographic handling and processing system that will transform these data into usable information. A major tool for handling spatial data is the Geographic Information System (GIS). GIS provides appropriate methods for efficient storage retrieval, manipulation analysis and display of large volumes of spatially referenced data.

Accordingly GIS consists of four basic components: data input, and editing, storage of geographic databases, data analysis and spatial modeling, and data visualization and presentation (Fig. 2.3). Geographic
Fig. 2.3 Sub-modules of a GIS input, storage, retrieval, analysis, modeling, and presentation of spatial and non-spatial data.
Information System (GIS) offers such capabilities as they integrate multi-sector, multilevel and multi-period database. The differences between different GIS packages lies in the methods used to perform these functions.

GIS can be defined as "a system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth" (Dueker and Kjerne, 1989). A GIS uses the location of features in a coordinate space as the fundamental referencing principle and as important variables in quantitative analysis. There are essentially two kinds of data bases: one, the specific characteristics of a location called as spatial data, and the other, attribute data. The data analysis in GIS is supported by computer aided mapping and data base management. Powerful utilities of a GIS that facilitate user interaction and presentation offer an added advantage.

2.6.1 Components of GIS

Geographical information system have three important components. They are: computer hardware, a set of application software modules and a proper organizational context.

Computer Hardware:

The hardware components of a GIS include several specialized peripherals, such as digitizer or scanner for converting the resource maps
into digital format for storage in the computer, a plotter for graphical representation of the maps generated and a visual color graphical representation of the maps generated, and a visual graphics display unit (work station) on which the spatial data editing and display can be performed by the user in addition to a central processing unit and a standard computer peripherals.

**Software Modules:**

The software package for a GIS is mainly designed to perform five major functions: (1) Data input and verification (2) Data storage and Database Management (3) Data Processing, (4) Data analysis and Modeling and (5) Data output and presentation.

2.6.1.1 **Data input**

Remotely sensed satellite data offer excellent inputs to provide repetitive, synoptic, and accurate information of the changes in a watershed, and offer the potential to monitor these dynamic changes. Integration of remotely sensed data with a GIS will greatly enhance modeling and analyzing capability of the GIS. Data input is the operation of encoding the data and writing them to the database. The creation of a clean, digital database is an important and complex task upon which the usefulness of the GIS depends. Data input to a geographical information system can be best described under three headings (Burrough P.A., 1994):
a) Entering the spatial data (digitizing): the type of data encountered are existing maps, including field sheets, and hand drawn documents, aerial photographs, remotely-sensed data from satellite or air borne scanners, point sample data and data from census or other surveys in which the spatial nature of the data is more implicit than explicit.

b) Entering the non-spatial associated attributes: also called as feature codes (sometimes) are those properties of a spatial entity that need to be handled in the geographical information system, but which are not of themselves spatial in nature.

c) linking the spatial to the non-spatial data: Linking the spatial data to the already digitized points, lines, and areas can better be done using a special program that requires only that the digital representations of the points, lines, and areas themselves carry unique identifiers. Both the identifier and the coordinates are thus stored in database.

2.6.1.2 Data storage and data base management

Effective data management includes all aspects related to data security, data integrity, data filing, and accessibility, and data maintenance abilities. Data security ensures security against modification of GIS or access of data to unauthorized users. Data integrity defines the ability of the system to protect data from accidental loss or from contamination by
extraneous data. Filing and accessibility provides an authorized user to organize the data into categories, directories, study area, etc. Data maintenance provides the authorized users with the ability to update, delete or add data to the GIS database.

2.6.1.3   Data processing

Data processing operations are those performed on the data to produce information. It includes removal of errors and updating or matching them to the other data. Errors can arise during the encoding and inputting of spatial and non-spatial data which can be either incomplete or double, in the wrong place, at the wrong scale, distorted or linked to the wrong non-spatial data. Besides, data may be over defined and may need to be reduced in volume. Data editing is interactively performed to ensure that all the errors are corrected, data updated and properly verified to achieve the required accuracy, which are vital to analysis.

2.6.1.4.   Data analysis and modeling

Data conversion is only part of the input phase of GIS. What is required next is the ability to interpret and to analyze, quantitatively and qualitatively, the information that has been collected. Spatial analysis involves combining data from multiple spatial data categories and performing analytical/statistical measurement, and other operations on the GIS data sets to transform the data into formation suitable for a given application. Typical operations include overlaying different thematic
maps, computing areas, performing proximity searches, buffer zone creations, performing logical operations, scale changing, etc. other techniques are creation of 3-dimensional perspective view using elevation data and generation of slope maps, net work analysis, costing, etc.

2.6.1.5 Data presentation and output

Data presentation deals with the way the information is displayed to the user. It can be either as a visual display or hard copy in the form of printed maps drawn using a plotter, where the geographical entities are represented as a series of points, lines and symbols.

2.6.2. Integration of Remotely Sensed Data into Geographic Information System

Remotely sensed data can be best utilized if they are incorporated in a GIS that is designed to accept large volumes of spatial data. The major ability of GIS is to overlay layers of spatially geo-referenced data enables in automation of several operations like interpretation, change detection, map revisions etc. integration of remotely sensed data with a GIS will greatly enhance modeling and analyzing capability of the GIS.

2.6.3 Raster and Vector Data Structures

Remote sensing systems use raster (or grid-based) format for collection and acquisition of data. Information (ordinal or nominal) in raster format is stored as a collection of picture elements (or pixels), each
holding only value for the information at specific spatial coordinates. Raster structures are more compatible with modern input / output hardware, has an advantage that the order of elements, as stored in digital form, dictated by their geographical positions. In Vector format, data are collected as points, lines, and polygons where each structure holds information for a specific region. Digital representation of line and polygon information generally consists of an ordered sequence of $(X,Y)$ coordinate pairs. Figure 2.4 shows representation of spatial data in a GIS.

Integration of remotely sensed data with GIS data occurs naturally in raster GIS because data structures are approximately the same for both sources. Important problems in the integration are the raster vector dichotomy, generalization and accuracy of digital information. (Piwowar et al., 1990; Lunetta et al., 1991).

Fig 2.4 Representation of spatial data in a GIS: (a) raster formatted data consists of a sequence of orderly placed pixels; (b) vector formatted data consists of polygon entities to represent features.
2.7 FUNCTIONAL ELEMENTS OF GIS

a) Database approach

It stresses the ability of the underlying data structures to contain complex geographical data.

b) The process-oriented approach

It focuses on the sequence of system elements used by an analyst when running an application.

c) An application oriented approach

It defines a GIS based on the kinds of information manipulated by the system and the utility of the derived information produced by the system.

d) Toolbox approach: It emphasizes the software components and algorithms that should be contained in a GIS.

There are five essential elements that a GIS must contain data acquisition, preprocessing, data management, manipulation and analysis and product generation. For any application of GIS, it is important to view these elements as a continuing process.

Data Acquisition: It is the process of identifying and gathering the data required for your application. This typically involves a number of procedures. One procedure might be to gather new data by preparing large-scale maps of natural vegetation from field observations. Other procedures for data acquisition may include locating and acquiring
existing data, such as maps, aerial and ground photography, surveys of many kinds and documents from archives and repositories.

Preprocessing: Preprocessing involves manipulating the data in several ways so that it may be entered into the GIS. Two of the principle tasks of preprocessing include data format conversion and identifying the location of objects in the original data in systematic way. Converting the format of the original data often involves extracting information from maps, photographs and printed records and then recording this information in a computer database. A second tasks of the preprocessing phase is to establishes a consistent system for recording and specifying the locations of objects in the datasets. During these process it is very important to establish specific quality control criteria for monitoring the operations during the preprocessing phase, so that the databases can be maximum value to the user. The essential preprocessing procedures include:

a) Format conversion
b) Data reduction and generalization
c) Error detection and editing
d) Merging of points into lines and lines into points
e) Edge matching
f) Rectification/registration
g) Interpolation
h) Photointerpretation
Data Management

The functions of database management govern the creation of an access to the database itself. These functions provide consistent methods for data entry, update, deletion and retrieval. Modern database management systems isolate the users from the details of data storage, such as the particular data organization on a mass storage medium. A Modern Database Management System (DBMS) uses one of the following data models for constructing its structure.

1. Flat file: Data in a single table
2. Hierarchical: Keys for data retrieval are clearly defined
3. Relational: Normalized tables with common redundant fields for relational link.

Flat Files and Spreadsheets:

A flat file or spreadsheet is a simple method for storing data. All records in this database have the same number of "fields". Individual records have different data in each field with one field serving as a key to locate a particular record. This type of database is simple in its structure, expanding the number of fields usually entails reprogramming. Additionally, adding new records is time consuming, particularly when there are numerous fields.
Hierarchical Files

Hierarchical files store data in more than one type of record. This method is usually described as a "parent-child, one-to-many" relationship. One field is key to all records, but data in one record does not have to be repeated in another. This system allows records with similar attributes to be associated together. The records are linked to each other by a key field in a hierarchy of files. An advantage is that when the relationship is clearly defined, and queries follow a standard routine, a very efficient data structure results.

Relational Files

Relational files connect different files or tables (relations) without using internal pointers or keys. Instead a common link of data is used to join or associate records. The link is not hierarchical. A "matrices of tables" is used to store the information. As long as the tables have a common link they may be combined by the user to form new inquiries and data output. This is the most flexible system and is particularly suited to SQL (structured query language).

Data Manipulation and Analysis

The development of new derived data layers, which may form the input to further analysis, is an important function of any GIS. The list of data manipulation and analysis operations are:
1. Reclassification and Aggregation

2. Geometric Operations: rotation, translation and scaling, rectification and registration

3. Controlled determination

4. Data structure conversion

5. Spatial operations: Connectivity and neighborhood operations

6. Measurement: Distance and Direction

7. Statistical analysis: Descriptive statistics regression, correlation and cross-tabulation

8. Modelling.

9. Product Generation: It is the phase where final outputs from the GIS are created. These output products might include statistical reports, maps and graphics of various kinds. Some of these products are softcopy images and hardcopy.
2.8 REFERENCES


