4. SPATIAL DATABASE CREATION AND ANALYSIS

4.1 OVERVIEW

The GIS database created in this project are of two types, namely, spatial and non-spatial data. The spatial data is comprised of land use/land cover, drainage, base and transport maps. The non-spatial or attribute data is composed of socioeconomic details. In this chapter, the steps involved in deriving all these data products, the sources of data acquisition and the ways of transforming these data products suitable to ARCGIS software are discussed. The base maps have been prepared incorporating all the basic details existing on the topomaps to make easy for quick ground references. The base maps thus prepared are utilized in the development and derivation of thematic maps for transferring the spatial details extracted from the satellite digital data.

Thematic maps are essential inputs for any kind of area development, planning and management of resources. The requirement for thematic maps, in terms of scale, information content, classification system and legend depends on the purpose for which the maps are to be used (Ajai, 2002). Most of the thematic maps required for natural resources management are being prepared, operationally using satellite data. There has been sustained improvement in thematic mapping based on satellite data interpretation during the past three decades. It has
happened due to continued improvement in the quality of satellite data in terms of spectral, spatial, radiometric and temporal resolutions. Both, visual interpretation and digital analysis techniques are being used for preparation of thematic maps from satellite images.

4.1.1 Acquisition and Processing of Topomaps and Satellite Data

Acquisition and processing of raw data for preparation of thematic maps involve the following steps.

1. Acquisition of IRS-P6 LISS-IV-MX data of the year 2007 from NRSC, Balanagar, Hyderabad and toposheets from Survey of India, Hyderabad.

2. Geo-referencing of toposheets based on latitude and longitudinal values.

3. Edge matching of the toposheets and preparation of digital mosaic depicting the entire study area.

4. Geo-coding and geo-referencing of satellite data by extracting the Ground Control Points (GCPs) from SOI toposheets.

5. Digital image enhancement and application of correction models for making the digital data free from errors and distortions both radiometry and geometry of the satellite data.

4.1.2 Visual Image Interpretation

Aerial and space images contain a detailed record of features on the ground. An image interpreter systematically examines the images, and frequently, other supporting materials such as maps and reports of filed observations. Based on this study, an interpretation is made as to the physical nature of the objects and phenomenon appearing on the images. Interpretation occurs at a number of levels of complexity, from the simple recognition of objects on the earth’s surface to the derivation of detailed information regarding the complex interactions among earth surface and subsurface features. A systematic study of aerial and space images usually involves several basic characteristics of features shown on an image viz., colour / tone, texture, pattern, size, shape and so on, which help in the recognition or interpretation of various features on the enhanced satellite imagery during the classification of features (Thomas M. Lillesand, 2000) Table 4.1 explains various elements of visual interpretation.

In the present study, a preliminary image classification key is prepared for the fused pictorial data and is used during interpretation process. Using the image interpretation key, preliminary interpretation of satellite imagery is carried by transferring the features from base map on to the transparency. This transparency with base line data features is then overlaid on the satellite imagery. Then the thematic features are extracted and transferred from the satellite pictorial data.
The doubtful areas (due to similar spectral response and spectral signature) identified during the preliminary image classification are listed out before ground verification. After finalizing the ground traverse plan, the doubtful areas are physically verified and field observation about terrain condition and land use pattern are noted. Based on the ground information collected, corrections and modifications of doubtful areas are carried out.

4.1.3 Generation of Spatial Database

Based on the physical characteristics of the study area, their sources, method of derivation of maps (IMSD Technical Guidelines, NRSA, 1995), suitability and environmental sensitivity, the following maps are generated. The classification of these maps is listed below. Data types with their relevance in the digital database are classified based on the source of acquisition and creation. For the preparation of the baseline digital database, Topographic, Collateral and thematic data are defined.

a) Topographic data

These maps are generated from Survey of India toposheets on 1:25,000 scale. They include,

- Base map
- Administrative boundaries
- Transportation map
- Drainage map
- Watershed map
- Slope
- Physiography map

b) **Collateral Data**

Collateral data for the project consist of the

- Detailed Socio Economic Data
- Cadastral survey points
- Development work details from mandal Head quarter
- GPS Survey points
- Other Miscellaneous data

c) **Thematic Data**

These are the maps generated from IRS-P6 LISS-IV-MX satellite data using Visual image interpretation technique at 1:10,000 Scale They include,

- Land use / Land cover map
- Geomorphology
- Soil
## Table 4.1: Elements of Visual Interpretation and their Description for each LU/LC Class

<table>
<thead>
<tr>
<th>Land use / Land cover Category</th>
<th>Tone/colour</th>
<th>Size</th>
<th>Shape</th>
<th>Texture</th>
<th>Pattern</th>
<th>Location</th>
<th>Association</th>
<th>Season</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built up land</td>
<td>dark bluish green in the core and bluish on the periphery</td>
<td>small to big</td>
<td>irregular &amp; discontinu</td>
<td>coarse &amp; Mottled</td>
<td>clustered to scattered &amp; Non-Contiguous</td>
<td>plains, plateaus on hill slopes, desers, water front, road, Rail &amp; canal etc.</td>
<td>surrounded by agriculture lands, forest cover, wastelands, march network of river road &amp; rail etc.</td>
<td>Oct to March</td>
<td>Built up land can be of big or small size settlement, industrial structures, buildings or any other artifact physical spread or sprawl along with density to transport network are useful surrogates to classify it as urban or rural. Perceptible land transformation can be noticed around built up land.</td>
</tr>
<tr>
<td>Crop land</td>
<td>bright red to red</td>
<td>varying</td>
<td>regular to irregular</td>
<td>medium to Smooth</td>
<td>contiguous to Non-Contiguous</td>
<td>plains, Hill, Sopes, valleys, cultivable wastelands etc.</td>
<td>amidst irrigated (canal, tank well etc) &amp; unirrigated (rainfed/dryfarming arable lands, proximity to rivers /streams etc.</td>
<td>June to Oct to April</td>
<td>It provides connectivity linkages between settlements and accelerates development. Road, rail and canal vary in dimension and importance. It can be mapped in detail Using infrared bands and higher spatial resolution data. It Forms part of non-agricultural use</td>
</tr>
<tr>
<td>Land Type</td>
<td>Color (depending on soil type &amp; moisture)</td>
<td>Size</td>
<td>Shape</td>
<td>Texture</td>
<td>Contiguity</td>
<td>Land Uses</td>
<td>Season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------------------</td>
<td>------</td>
<td>---------</td>
<td>---------</td>
<td>------------</td>
<td>----------------------------------------------------------------------------</td>
<td>----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fallow land</td>
<td>yellow to greenish blue</td>
<td>small to large</td>
<td>regular to irregular</td>
<td>medium to Smooth</td>
<td>contiguous to Non-contiguous</td>
<td>Plains, valleys, uplands etc. as harvested agricultural Fields etc.</td>
<td>Jan to Dec.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantation (agricultural)</td>
<td>dark red to red</td>
<td>small to Medium</td>
<td>regular to irregular with sharp Edges</td>
<td>coarse to Medium</td>
<td>dispersed, Contiguous</td>
<td>Plains, foothills &amp; uplands, dry lands or unirrigated lands. uplands occasionally amidst cropland, proximity to rivers &amp; on gentle hill slopes.</td>
<td>Jan to Dec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciduous / Scrub land</td>
<td>dark red to red</td>
<td>varying in size</td>
<td>irregular to discontinuous</td>
<td>smooth to medium Dep., up on crown Density</td>
<td>contiguous to Non-contiguous</td>
<td>Medium relief mountains/hill slopes &amp; within notified areas. Different forest types/sub-types of species which shed leaves.</td>
<td>Jan to April</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It consists of different arable lands left uncultivated as Season/temporary fallows for less than a year and as Permanent fallows upto 5 years or more because of diverse reasons. Fallow lands devoid of vegetation accelerated erosion.

Agricultural plantations consist of a variety of trees, Orchards and groves. These occur throughout the year and are seen very prominently the imagery. Those occurring in the forest areas (but outside the notified forest areas) are also treated as plantations like coffee, tea, arecanut, etc.

These are broad leaved tropical forests which seasonally shed their leaves annually dry forest trees are subject to Wild forest fires particularly during summer/autumn. These occur on the lower elevations and slopes than the ever green/semievergreen forest.
<table>
<thead>
<tr>
<th>Land Type</th>
<th>Color Range</th>
<th>Size</th>
<th>Texture</th>
<th>Soil Type</th>
<th>Location</th>
<th>Time Period</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degraded / Scrub land</td>
<td>light red to dark red</td>
<td>varying</td>
<td>irregular to dis-Continues</td>
<td>coarse to Mottled</td>
<td>contiguous to Non-Contiguous mountain slopes isolated hills and foot slopes and within notified areas.</td>
<td>Jan to April</td>
<td>hill slopes having skeletal soil, different forest types/subtypes and where abiotic interference. It accounts for &lt;20% of the tree cover &amp; are called as open forests. The degradation is due to biotic &amp; abiotic Disturbances caused to dense forest cover. It contributes To land degradation found on uplands and on foot slopes with this soil cover.</td>
</tr>
<tr>
<td>Gullied / Ravinous land</td>
<td>light yellow to bluish green</td>
<td>varying</td>
<td>irregular</td>
<td>very coarse to coarse</td>
<td>Dendritic to Sub Dendritic along river and stream courses &amp; drainage on Sloping grounds.</td>
<td>Jan to March</td>
<td>Gullies and ravines contribute to soil erosion and land degradation. Gullies with deep and steep sides develop Into ravines. These result due to excessive surface runoff On loose sediments.</td>
</tr>
<tr>
<td>Land with or Without scrub</td>
<td>light yellow to brown to greenish blue</td>
<td>varying</td>
<td>irregular &amp; dis-Continuou s</td>
<td>coarse to Mottled</td>
<td>contiguous dispersed in Patches terrain with varying lithology &amp; Landforms.</td>
<td>Oct to March</td>
<td>Thin veneer of soil cover on the top supports, scrub &amp; grass or devoid of vegetation where surface erosion is dominant. Such lands occur more in dry lands, foot hill areas, undulating uplands and also along fallows</td>
</tr>
<tr>
<td>Barren waste/sheet Rock area or Rocky/stony</td>
<td>greenish blue to varying in yellow to brownish size (subject to varying in size)</td>
<td>varying in size</td>
<td>irregular &amp; discontinuous</td>
<td>very coarse to coarse &amp; medium</td>
<td>steep isolated hillocks, hill slopes/crest plateau &amp; eroded plains.</td>
<td>barren &amp; exposed rock/stony wastes, materitic out-crops mined areas &amp; quarried sites, boulders.</td>
<td>Jan to March</td>
</tr>
<tr>
<td>River/Stream</td>
<td>light blue to dark blue</td>
<td>long narrow to side</td>
<td>irregular, Sinuous</td>
<td>smooth to Medium</td>
<td>natural rivers/streams (perennial &amp; non-Perennial).</td>
<td>drainage pattern or hil slopes flood plains uplands, etc also with vegetation along the banks and in river bed.</td>
<td>Jan to Dec</td>
</tr>
<tr>
<td>Lake/reservoir/Tank/Canal</td>
<td>light blue to dark blue (subject to weeds/vegetation)</td>
<td>small / medium to large</td>
<td>regular to Irregular</td>
<td>smooth to mottled (subject to vegetation)</td>
<td>non-contiguous dispersed, linear for canals.</td>
<td>tanks &amp; lakes in lowlands/plain reservoirs surrounded by hills and across rivers, canals in plains.</td>
<td>Jan to Dec</td>
</tr>
</tbody>
</table>

(Source: Padmaja Vuppala, 2007)
4.2 SPATIAL DATA GENERATED FROM TOPOSHEETS

The spatial databases from toposheets of Survey of India (SOI) relevant for this study are Base map, Drainage map, Road network map, Mandal reference map and Watershed Map.

4.2.1 Base Map Generation

Maps are representation of features on the surface of the earth drawn to a scale. A topographic map is a representation of the shape, size, position and relation of the physical features of an area. A base map consists of various features like the road, settlements, water bodies, canals, railway track, vegetation etc., which are delineated from the toposheet. The map thus drawn is scanned and digitized to get a digital output. The base map is prepared using Survey of India (SOI) toposheets (66A06NW, SE & SW) and updated with the help of satellite imagery. The information content of this map is used as a baseline data to finalize all the other physical features of maps. The features included in the base map in general are Taluk/Block/Mandal boundary, rivers/water bodies, major settlements, major roads, railways (Fig. 4.1). The characteristic features of the study area are Railway Track, Metalled Road, Settlements, Rivers, and Water bodies. Since the toposheets are very old and prepared long back, the metalled roads, railways and the other settlements are updated using satellite image and existing maps. The major water body represented in the base map is Ramperu River. The South central railway line passes through the study area.
Fig. 4.1 Base Map of the study area

Prepared by Rajani Ganta, Centre for Environment, IST, JNTUH
4.2.2 Road Network Map

Transport network plays an important role in the overall development. Accessibility by roads and rail is essential for social and educational development besides economic development of a region. Two major classes of transport network namely, the metalled roads and railway line were demarcated from the toposheets and satellite imagery.

The roads are classified as metalled and unmetalled, cart track and pack track. This information is mainly extracted from the Survey of India topographical maps on 1:25,000 scale. The road coverage network from the toposheets is updated with the latest satellite data to extract additional information on the newly developed roads. The metalled roads passing through the study area connecting the settlements and landforms. The road lengths of different types of roads like metalled and unmetalled, pack track and cart track are also calculated using the ArcGIS (9.2 Ver) software. (Fig.4.2)

4.2.3 Drainage Network Map

All the small stream channels shown on the toposheets are extracted to prepare the drainage map. Care is taken that the boundaries of rivers/water bodies appearing on land use/land cover map or base map are perfectly matched with those on the toposheet. All the drainage lines are examined very closely and final drainage map is prepared.
Drainage network map prepared from the SOI toposheets and satellite data is further scanned, digitized and edited using ARCGIS software to produce a digital output (Fig. 4.3). All the water bodies are divided into dry and wet areas. These wet (water spread) areas changes from time to time and some new tanks are found in the satellite images. For this reason, the drainage map is updated from the satellite imagery. Ramperu is the main drain flowing from North-West towards South-East of the mandal. Since the study area is a coastal region back waters predominate. **The drainage system existing is dendritic type.**
Fig. 4.2 Transport map of the study area

Transport Map of Vetapalem Mandal

Legend:
- Mandal Boundary
- Cart Track
- Metalled Road
- Pack Track
- Railway Line
- Unmetalled Road
- Settlements

Scale 1:25,000
Fig. 4.3 Drainage map of the study area
4.2.4 Watershed Map

Watersheds are natural hydrologic entities that cover specific areal extent of land from which rainwater runs to defined gully stream or river at any particular point. Watershed forms a convenient, clearly defined and an unambiguous topographic unit available on the basis of stream network. The size of watershed is dependent on the size of the stream, river, the point of interception of stream or river, the drainage density and its distribution. The size of the watershed could be some lakhs of hectares or if a small stream is chosen the same could be of a few hundred hectares. To avoid this ambiguity and to suggest a stage where land development could be of viable size a hierarchical approach was suggested by the Ministry of Agriculture (MOA), Govt. of India, in 1990. One of the earlier attempts in some systematic delineation of river basins was made in 1949 by Dr. A.N. Khosla of Central Water and Power Commission (CWPC). According to this, the country was distinctly delineated into 6 Water Resources Regions (WRR).

Region 1: Rivers falling into Arabian Sea, excluding Indus system.
Region 2: The Indus basin in India.
Region 3: Rivers falling into the Bay of Bengal, other than the Ganga and the Brahmaputra systems.
Region 4: The Ganga system.
Region 5: The Brahmaputra system.
Region 6: Rajasthan.
Number of Hydrologic Units at Different Stages of Delineation of our Country

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Resources Regions</td>
<td>6</td>
</tr>
<tr>
<td>Basins</td>
<td>35</td>
</tr>
<tr>
<td>Catchments</td>
<td>112+</td>
</tr>
<tr>
<td>Sub-catchments</td>
<td>500+</td>
</tr>
<tr>
<td>Watersheds</td>
<td>3237+</td>
</tr>
</tbody>
</table>

**4.2.4.1 Watershed Codification**

The size at each stage could be on an average as follows:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Resource Region</td>
<td>5.0 la sq.km (+)</td>
</tr>
<tr>
<td>Basin</td>
<td>0.50 la sq.km (+)</td>
</tr>
<tr>
<td>Catchment</td>
<td>0.05 la sq.km (+)</td>
</tr>
<tr>
<td>Sub-Catchment</td>
<td>0.005 la sq.km (+)</td>
</tr>
<tr>
<td>Watershed</td>
<td>A few hectares of land</td>
</tr>
</tbody>
</table>

An alfa-numerical system of codification has been suggested by the MOA under this system:

Water resources regions are assigned numbers 1,2,3,4,5 & 6

i. Basins : A, B, C……..
ii. Catchments : 1, 2, 3……..
iii. Sub-catchments : A, B, C……..
iv. Watersheds : 1, 2, 3……..
v. Sub Watersheds : a, b, c……..
vi. Mini Watersheds : 1, 2, 3……..
vii. Micro Watersheds : a, b, c……..

Thus, watershed map of the study area will have the codes like 1A1A1a1a...4C4D1c1c...
4.2.4.2 Watershed Scale

For delineation and identification of various levels of hierarchy the following map scales are suggested.

Source: SOI Toposheet, Aerial Photograph and Satellite Imagery

<table>
<thead>
<tr>
<th>Level</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>1:1 Million</td>
</tr>
<tr>
<td>Basin</td>
<td>1:1 Million</td>
</tr>
<tr>
<td>Catchment</td>
<td>1:250,000</td>
</tr>
<tr>
<td>Sub-catchment</td>
<td>1:50,000</td>
</tr>
<tr>
<td>Watershed</td>
<td>1:50,000</td>
</tr>
<tr>
<td>Sub-watershed</td>
<td>1:50,000</td>
</tr>
<tr>
<td>Mini Watershed</td>
<td>1:25,000</td>
</tr>
</tbody>
</table>

Survey of India toposheets (1:25,000 scale) in combination with the satellite data are used for watershed delineation, as the toposheet provides location, drainage network and contour while, satellite data is useful in updating information on water bodies, drainage, etc. The below fig. 4.4 showing the watershed coding in the study area.
Fig. 4.4 watershed map of the study area
4.2.5 Physiography Map

The purpose of physiography layer is to understand disposition and distribution of barriers of winds. Physiography map is prepared using the contours derived from Survey of India toposheets. Only one physiography category is demarcated in the map (Fig. 4.5) as under:

- Plains

The high slope areas not only pose physical constraints for developmental activities but also act as barriers for dispersion of air polluting emissions. The plains occupy the total part of the study area, which indicates nearly level, and very gently sloping terrain.
Fig. 4.5 Physiography map of the study area
4.2.6 Mandal Reference Map

The mandal reference map prepared from survey of India toposheets (1:25,000 scale). There are 5 revenue villages in the mandal. The villages are pandillapalli, kothapeta, Nayanapalli, Pullaripalem and Vetapalem. The mandal map of study area has shows in fig. 4.6

![Mandal Reference Map]

Fig. 4.6 Showing Mandal Reference map of the study area
4.3. SPATIAL DATA GENERATED FROM SATELLITE DATA AND OTHER DATASETS

Before satellite images can provide meaningful measurements to user, the raw, unbiased reflectance values received by the satellite sensors require considerable mathematical processing. Manipulations are required both to register the grid of pixels to specific locations on the Earth’s surface and to transform the data into useful information. Understanding the various algorithms operating on the raw data is usually beyond the ability of non specialists, and the resulting spatial data must be accepted on faith. Frequently the result of this manipulation is classified data in which pixel values indicate classes of an attribute (e.g., nominal data such as vegetation type or land use classes) rather than interval or ratio data classification algorithms and techniques are among the most highly disputed in the discipline (Estes, 1995). Methods for statistically estimating the errors resulting from the classification of satellite images have been developed and to provide some quality assurance (Burrough, 1998). Figure 4.7 showing the georeferenced high resolution of satellite imagery of the study area.
Fig: 4.7 showing the satellite image of the study area
4.4 GENERATION OF THEMATIC LAYERS

- Land use / Land cover map
- Soil map
- Geomorphology

4.4.1 Land Use/Land Cover Map

Information on the rate and kind of change in the use of land resources is essential for the proper planning, management and regulations of the use of such resources. Knowledge about existing land use and trends of change is essential if the nation is to tackle the problems associated with haphazard and uncontrolled growth. A systematic framework is needed for updating land use / land cover maps that will be timely relatively inexpensive and appropriate for different needs at national and state level.

The rapidly developing technology of remote sensing offers an efficient and timely approach to the mapping and collection of basic land use / land cover data over large area. The remote sensing data is potentially more amenable to digital processing because the remote sensor output can be obtained in digital format as a more expedient means to map land use and land cover. “Land Use data is needed in the analysis of environmental processes and problems that must be understood, if living conditions and standards are to be improved or maintained at current level. Land use map so prepared gives an idea of land use pattern and
trends of change. The last thirty years have witnessed drastic changes in land use in India caused by both increasing population and natural calamities. Thus, the current land use map, which is an important database for land use planning programme, is very much needed.

- Any delineable area of the earth’s terrestrial surface, involving all attributes of the biosphere immediately above or below the surface including those of the near-surface, climate, soil and the terrain forms, the surface hydrology, near surface layers and associated ground water and geo-hydrological reserves, the plant and animal population, the human settlement pattern and physical results of past and present human activity i.e., water storage or drainage structure, roads, buildings etc.

### 4.4.1.1 Land Use vs. Land Cover

- Land use should not be confused with land cover.
- Land cover is an element of land, whereas, land use is not
- Land cover may be determined by direct observations
- Land use requires an interview with the land user.

### 4.4.1.2 Operation Sequence

In the course of a land use a series of operations are carried out and is termed as operation sequence. It is defined as

"A series of operations on land carried out by humans, in order to realize set of land use purposes"
An operation then refers to "A distinct and intended management action carried out by humans on land". Descriptions of an operation include the type and quantity of implements used, the type, quality of material inputs, Labour inputs used, the main power source used, details of the product/benefits achieved and Monitoring and management system.

**4.4.1.3 Land use map can be prepared in two ways**

a) By generalization of land use descriptions. The resulting description is valid for a certain area for a given period.

b) By classification of land use descriptions: The resulting description which is not limited to a set area or time frame.

**4.4.1.4 Objectives**

The main objectives of this new land use / land cover classification system are

- To provide a framework as detail as possible and to cover all the possible categories of land use that could be mapped with certain limitations.

- To see the applicability of latest satellite data delineating various land use / land cover categories through digital image analysis and processing.

- To develop Micro-level land use land cover Classification (i.e. V-Levels)

- To develop land use land cover large scale mapping on 1:10000.
4.4.1.5 Criteria for Land Use / Land Cover Classification

In the context of developing a new classification system, it is essential to consider certain criteria and limitations of satellite data and study area particularly to Indian conditions, as the classification system using satellite data should provide a framework to satisfy the needs of the majority of users. For this certain guidelines and criteria for evaluation must be established.

- Land use / land cover classification should be comprehensive, scientifically sound, practical and applicable over large areas.
- It should meet the needs of a variety of users.
- The classification should be flexible, which can be used at different scales and at different levels of detail.
- Land use / land cover categories should be described with the minimal set of classifiers (less the classifiers used in the definition, less the errors expected and less time and resources necessary for field validation).
- The classification should be amicable for use of multi-seasonal satellite data.
- To decide on an appropriate classification or data level within a classification an arbitrary decision must be made. One must decide on imagery scale or on the scale of representation of data.

Satellite data based on scales of 1:250,000; 1:50,000; 1:25,000;
1:10,000 and 1:5,000 will serve to represent Level-I; Level-II, Level-III, Level-IV and Level-V categories respectively.

- The minimum interpretation accuracy and reliability in the identification of land use / land cover categories from satellite data should be at least 85-95 per cent based on the scale of mapping.
- Due to certain limitations of satellite data, some of the similar categories may be generalized, for example forest and wooded land, can be put together under main head "Forest".

4.4.1.6 Basic Concept of Land Use / Land Cover Classification

Land use information has given nine "major ideas or concepts about land". These are

1. Location or the relation of a specific parcel of land to the poles, the equator, and the major ocean and land masses. There is also relationship between various tracts of land as well as political location.

2. Activity on the land; for what purpose is this piece of land or tract used.

3. Natural qualities of the land, including its surface and sub surface characteristics and its vegetative cover.

4. Improvement on land. This is closely related to activity.

5. Intensity of land use or amount of activity per unit of area.

6. Land price, land market activity, and credit as applied to land.

7. Inter-relation in the use between different tracts of land.
8. Interaction between activities on the land and other economic and social activities.

4.4.1.7 Characteristics of a Good Classification

Good in terms of essentially qualitative generalities based on the usefulness of the data and 95% of all data should be correctly classified. Five characteristics of a good classification as outlined are as follows:

1. The classification should deal exclusively with activities, non-activity data can be input at a later stage.
2. It should be flexible in detail of aggregation and combination.
3. It should be based on what is observed. The interpreter or field man should do only a minimum of grouping. Fieldwork should be based on the smallest unit which can be differentiated.
4. It should be amenable to machine processing.
5. The classification may be restricted so as to be compatible with existing system.

4.4.1.8 Map Scale and its Significance

Satellite imagery is the best medium available to obtain land use / land cover information which is identifiable on different scales over a large area. Areas having smaller dimensions than the size of the minimum mappable unit cannot be mapped. Hence there is a need for a viable and smallest palpable unit to depict the imagery information.
In India especially major part of the land use is mixed, complex with small segments of homogeneous uses. Hence to map such areas, a Minimum Mappable Unit (MMU) is required.

The following criteria are laid down for selecting the smallest mappable unit, they are

1. It should be easily mappable.
2. It should be visible from a distance
3. It should be striking in shape and size
4. It should be comprehensive
5. It should be homogeneous
6. It should be readable
7. It should be easily measurable for area calculations
8. It should be big enough to depict information/data with symbols or colour
9. It should not get concealed or lost within the background information.
10. It should be viable enough for any planning purpose and big enough to use for land suitability or cadastral mapping.
11. Mapping unit being constant if the scale and resolution of the imagery could be increased then the recovery of the information will also increase.
4.4.1.9 Example of Minimum Mappable Unit

- 3 mm is the minimum mappable unit
  
  Example: On 1:1 million scale, 1mm = 1km; i.e. 3 mm = 1x3 = 3km

- Area covered by minimum mappable unit is 3 mm x 3 mm
  
  Example: on 1:1 million scale map, area covered is 3 km x 3km = 9 sq km

Therefore, mappable area on ground is 9 sq km or 900 ha.

4.4.1.10 Describing Land Use / Land Cover at Various Scales

Actual descriptions of land use systems are minimally those of a plot and many studies require information at a smaller scale e.g.:

- By administrative units
- By map unit
- By holding

4.4.1.11 Classification Accuracy

The following items may be considered to achieve required accuracy, they are

- Quality of satellite data for interpretation
- Scale of mapping
- Data analysis / processing method followed
- Sample survey scheme
- Quality of gathered information in the field
- No of sites surveyed
- Accuracy of the interpreted map units
- Domain Knowledge of a person.
4.4.2 Technical Steps of Digital Image Classification to develop LU/LC

Digital Image Processing (DIP) Techniques can be divided broadly into 4 groups. They are:

4.4.2.1 Image Rectification and Restoration

4.4.2.2 Image Enhancement

4.4.2.3 Image Classification

4.4.2.4 Data Merging

4.4.2.1 Image Rectification and Restoration

These operations aim to correct distorted or degraded image data to create a more faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions to calibrate the data radiometrically and to eliminate noise present in the data. Thus, the nature of any particular image restoration process is highly dependant upon the characteristics of the sensor used to acquire the image data. Image rectification and restoration procedures are often termed preprocessing operations because they normally precede further manipulation and analysis of the image data to extract specific information.
4.4.2.2 Image Enhancement:

These procedures are applied to enhance the interpretation capacity of the image. Normally image enhancement involves techniques for increasing the visual distinction between features in a scene. The objective is to create new images from the original image data in order to increase the amount of information that can be visually interpreted from the data. The enhanced image can be displayed interactively on a monitor or they can be recorded in a hard copy format, either in black and white or in color. There are no simple rules for producing the single best image for a particular application. Often several enhancements techniques may be applied on the raw image.

4.4.2.3 Image Classification

The objective of these operations is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene. This normally involves the analysis of multi spectral image data and the application of statistically based decision rules for determining the land cover identity of each pixel in an imager. When these decisions rules are based solely on the spectral radiances observed on the data, the classification process is termed spectral pattern recognition. In contrast the decision rules may be based on the geometrical shape, size and patterns present in the image data. These procedures fall into the domain of spatial pattern recognition. In either case; the intent of the classification process is to categorize all pixels in a digital image into one
of several land cover classes or themes. These categorized data may then be used to produce thematic maps of the land cover in an image, and/or to produce summary statistics on the areas covered by each land cover type.

**4.4.2.4 Data merging**

These procedures are used to combine image data for a given geographic area with other geographically referenced data sets for the same area. The other data sets might simply consist of image data generated on other data by the same sensor, or by other remote sensing systems. Frequently, the intent of data merging is to combine remotely sensed data with other sources of information in the context of a geographic information system (GIS).

**4.5 DEVELOPMENT OF DATA MODEL FOR LU/LC ON 1:10000 SCALES.**

A modern nation must have adequate information on many complex interrelated aspects of its activities in order to make decisions. Land use / Land cover is only one such aspect, but knowledge about land use and land cover has become increasingly important as the nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat. Land use data are needed in the analysis of environmental processes and
problems that must be understood if living conditions and standards are to be improved or maintained at current levels.

The land use / land cover classification Model has been designed with a four level hierarchy based configuration. This model is approved by the national level committee on this data model for LU/ LC on 1:10,000 scales, constituted by Natural Resource Data Management System (NRDMS), Department of Science and Technology, Government of India.

4.6 OBJECTIVES OF LAND USE / LAND COVER MAP (ON 1:10000 SCALE)

The main objectives of land use map are, the land use map will be utilized as a basic database, which provides the information for allocating new land use practices. It will incorporate demographic, economic and environmental impact, which has occurred in an area. Not only will the information indicate where intensive development has already taken place and where there is open land suitable for future expansion, but it will also make it possible to determine special areas, such as prime agricultural lands. Land use/ land cover map will serve as a basis for monitoring land use change. The land use map will serve as a base in the integrated overall planning of agricultural and industrial development of the region.

Land use refers to man’s activities and various uses, which are carried out on land. Land cover refers to natural vegetation, water bodies,
rock/soil, artificial cover and others resulting due to land transformation. Although land use is generally inferred based on the cover, yet both the terms land use and land cover are closely related and interchangeable.

Information on the rate and kind of change in the use of land resources is essential to the proper planning, management and regulation of the use of such resources.

Knowledge about the existing land use and trends of change is essential if the nation is to tackle the problems associated with the haphazard and uncontrolled growth. A systematic framework is needed for updating the land use and land cover maps that will be timely, relatively inexpensive and appropriate for different needs at national and state level. The rapidly developing technology of remote sensing offers an efficient and timely approach to the mapping and collection of basic land use and land cover data over large area. The satellite imageries are potentially more amenable to digital processing because the remote sensor output can be obtained in digital format. Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels.
4.6.1 Methodology for land use/land cover mapping

Flowchart 4.1 showing the methodology adopted for land use/land cover mapping. For analysis and interpretation, two types of data are needed that is basic data and ground data.

4.6.2 Basic data includes:

- Satellite data
- Toposheets
- Local knowledge
- Area map on any scale to transfer details
- Reports and other literature of the study area

4.6.2.1 Ground data: Ground data is very much essential to verify and to increase the accuracy of the interpreted classes and also to minimize the field work.

4.6.2.2 Data analysis: For analysis and interpretation of satellite data, the study can be divided into three parts:

- Preliminary work
- Field work
- Post field work

4.6.2.3 Preliminary work includes:

- To see the limitation of satellite data
- To lay down the criteria for land use classification to be adopted
- To fix the size of mapping units, which depends upon the scale
- Interpretation of different land use/land cover classes
- Demarcation of doubtful areas
- Preparation of field land use/land cover map

4.6.2.4 Field work:

- Type of ground data to be collected
- Selection of sample area for final classification
- Checking doubtful areas
- Change in land use/land cover due to wrong identification, fresh development, nomenclature.
- General verification

4.6.2.5 Post field work:

- Reinterpretation and analysis or correction of doubtful areas
- Transfer of details on base map
- Marginal information
- Preparation of final land use/land cover map
Flowchart 4.1: Flowchart showing the Methodology adopted for Land Use/Land Cover mapping

1. Basic data
2. Data source
3. Secondary data
4. IRS -P6-LISS-IV-MX
5. Preparation of base map
6. Development of interpretation key based on image characteristics.
7. Interpretation and mapping of land use/land cover categories
8. Ground verification of doubtful areas and modification of thematic details
9. Final land use/land cover map with symbols and colour
10. Area estimation of each Land use/Land cover classes

Flowchart 4.1: Flowchart showing the Methodology adopted for Land Use/Land Cover mapping
### Table: 4.2 Data Model for Land use/Land cover on 1:10,000 Scale

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Built-up</td>
<td>11 Urban/ Built-up Land</td>
<td>111 Residential</td>
<td>1111 High Density 1112 Medium Density 1113 Low Density</td>
<td>11111 Single Unit High densities 11112 Multiple dwelling Low rises 11113 Multiple dwelling high rises</td>
</tr>
<tr>
<td></td>
<td>112 Industrial</td>
<td>1121 Light industrial 1122 Heavy industrial 1123 Power generation</td>
<td>1224 Power plants 1125 Power generation 1126 Power transmission 1127 Power generation 1128 Power generation 1129 Power generation 11210 Power generation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>113 Commercial</td>
<td>1131 Central Business centres 1132 Commercial strips 1133 Commercial establishments for goods and services 1134 Isolated commercial office buildings 1135 Shopping centers 1136 Resorts, Hotels &amp; related Facilities</td>
<td>1141 Educational institutions 1142 Health institutions 1143 Correctional institutions 1144 Government centers 1145 Military installations 1146 Other institutions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>114 Services</td>
<td>1141 Educational institutions 1142 Health institutions 1143 Correctional institutions 1144 Government centers 1145 Military installations 1146 Other institutions</td>
<td>1224 Power plants 1125 Power generation 1126 Power transmission 1127 Power generation 1128 Power generation 1129 Power generation 11210 Power generation</td>
<td></td>
</tr>
</tbody>
</table>
| 115 Recreational | 1151 Parks  
|                  | 1152 Play grounds 
|                  | 1153 Stadiums 
|                  | 1154 Race course 
|                  | 1155 Golf course 
|                  | 1156 Swimming pools 
|                  | 1157 Cultural centres and Theatres 
|                  | 1158 Other recreational places |
| 116. Transportation Communication and Utilities | 1161 Major road ways |
|                  | 1162 Railway facilities |
|                  | 1163 Bus stands 
|                  | 1164 Airports 
|                  | 1165 Power facilities 
|                  | 1166 Telephone 
|                  | 1167 Port facilities 
|                  | 1168 Water & sewage treatment 
|                  | 1169 Others |
| 117 Open spaces or vacant land | 1171 Undeveloped land within urban area |
|                  | 1172 Inactive land 
<p>|                  | 1173 Open areas |
| 118 Others |</p>
<table>
<thead>
<tr>
<th>12 Village / Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2. Agriculture</strong></td>
</tr>
<tr>
<td>211 Kharif</td>
</tr>
<tr>
<td>212 Rabi</td>
</tr>
<tr>
<td>213 Kharif + Rabi</td>
</tr>
<tr>
<td>214 Summer Crop</td>
</tr>
<tr>
<td><strong>22 Fallow</strong></td>
</tr>
<tr>
<td>222 Permanent Fallow</td>
</tr>
<tr>
<td><strong>23 Plantations</strong></td>
</tr>
<tr>
<td>2311 Tea</td>
</tr>
<tr>
<td>2312 Coffee</td>
</tr>
<tr>
<td>2313 Rubber</td>
</tr>
<tr>
<td>232 Horticultural Plantations</td>
</tr>
<tr>
<td>2321 Coconut</td>
</tr>
<tr>
<td>2322 Areca nut</td>
</tr>
<tr>
<td>2323 Citrus fruits</td>
</tr>
<tr>
<td>2324 Orchards</td>
</tr>
<tr>
<td>2325 Nurseries</td>
</tr>
<tr>
<td>2326 Flours culture</td>
</tr>
<tr>
<td>233 Agro-Horticultural Plantations</td>
</tr>
<tr>
<td>2331 Seed forms</td>
</tr>
<tr>
<td>2332 Others</td>
</tr>
<tr>
<td><strong>24 Aquaculture / Pisciculture</strong></td>
</tr>
<tr>
<td><strong>3. Forest</strong></td>
</tr>
<tr>
<td>32 Deciduous (Moist / Dry)</td>
</tr>
<tr>
<td>311 Dense / Closed</td>
</tr>
<tr>
<td>312 Open / Degraded</td>
</tr>
<tr>
<td>321 Dense / Closed</td>
</tr>
<tr>
<td>322 Open</td>
</tr>
</tbody>
</table>
| 33 Forest Plantations | 331 Teak Forest  
332 Bambino Forest  
333 Eucalyptus  
334 Casuarinas |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>34 Scrub Forest</td>
<td>36 Mangroves</td>
</tr>
</tbody>
</table>
| 35 Forest Blank     | 361 Dense        
362 Open/ Degraded |
| 36 Scrubland        | 37 Shifting cultivation |
| 37 Shifting cultivation | 361 Dense        
362 Open/ Degraded |
| 4 Wastelands        | 41 Salt Affected Land |
| 42 Gullied/ Ravenous Land | 43 Scrub land  
431 Dense Scrubs  
432 Open Scrubs |
| 43 Scrub land       | 44 Sandy area    |
| 44 Sandy area       | 441 Coastal Sand  
442 Reverine Sand   |
| 44 Sandy area       | 45 Mining/ Industrial waste/ Ash |
| 45 Mining/ Industrial waste/ Ash | 451 Mine Dumps  
452 Industrial Dumps  
453 Ash Ponds |
| 5 Water bodies      | 51 Rivers/ Stream |
| 51 Rivers/ Stream   | 511 Perennial  
512 Dry (Ephemeral)  
513 River Island  
514 River bed Cultivation |
| 52 Canals | 521 Lined Canal  
522 Unlined |
|-----------|----------------|
| 53 Reservoirs/ Tanks | 531 Perennial  
532 Dry |
| 54 Lakes/ Ponds  
55 Cooling pond/ Cooling reservoir | 541 Perennial  
542 Dry |
| 56 Bay | 561 Back waters  
562 Estuary/ Kayal  
563 Creek  
564 Lagoon |
| 6 Wetlands | 61 Inland Natural |
| | 62 Inland Manmade |
| | 63 Coastal Natural |
| | 64 Coastal Manmade |
| 7 Natural / Semi-Natural Grass land and Grazing land | 71 Alpine/Sub-Alpine |
| | 72 Temperate/ Sub-Tropical |
| | 73 Tropical/Desertic |
| | 74 Man Made Grasslands/ Fodder Crop |
| 8 Snow covered |
4.6.3 Land use/land cover description of study area

Present land use/land cover map showing the spatial distribution of various categories and their aerial extent is vital for the present study. The spatial distributions of various land uses are interpreted based IRS-P6, LISS IV-MX data. The different land use/land cover classes existing in the area over space and time are briefly discussed here in their dimension. The land use/land cover map of study area has shows in fig.4.8. The following pie chart 4.1 and table 4.3 are showing the LU/LC percentage wise distribution and area in sq.km. of the study area.

![Pie Chart: 4.1 chart showing percentage distribution of Land use/ Land cover in the study area](image-url)
Fig. 4.8 Land Use / Land Cover map of the study area
Table 4.3 Land Use/Land Cover Distribution in the Study Area

<table>
<thead>
<tr>
<th>Class</th>
<th>Area (Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back water</td>
<td>0.08</td>
</tr>
<tr>
<td>Canal</td>
<td>0.29</td>
</tr>
<tr>
<td>Cashew plantations</td>
<td>5.79</td>
</tr>
<tr>
<td>Casuarina plantations</td>
<td>2.57</td>
</tr>
<tr>
<td>Current fallow land</td>
<td>0.09</td>
</tr>
<tr>
<td>Double crops</td>
<td>19.29</td>
</tr>
<tr>
<td>Drain</td>
<td>0.16</td>
</tr>
<tr>
<td>Dried fish ponds</td>
<td>1.6</td>
</tr>
<tr>
<td>Fallow land</td>
<td>0.44</td>
</tr>
<tr>
<td>Fish ponds</td>
<td>4.43</td>
</tr>
<tr>
<td>Grass lands</td>
<td>4.82</td>
</tr>
<tr>
<td>Harvested land</td>
<td>0.28</td>
</tr>
<tr>
<td>Land with scrub</td>
<td>2.81</td>
</tr>
<tr>
<td>Land without scrub</td>
<td>8.29</td>
</tr>
<tr>
<td>Plantations</td>
<td>7.25</td>
</tr>
<tr>
<td>Reserved forest</td>
<td>5.59</td>
</tr>
<tr>
<td>Residential area</td>
<td>8.6</td>
</tr>
<tr>
<td>River drain</td>
<td>3.12</td>
</tr>
<tr>
<td>Road</td>
<td>0.73</td>
</tr>
<tr>
<td>Salt pans</td>
<td>0.86</td>
</tr>
<tr>
<td>Single crops</td>
<td>17.27</td>
</tr>
<tr>
<td>South central railway main line</td>
<td>0.25</td>
</tr>
<tr>
<td>Wet Lands</td>
<td>0.63</td>
</tr>
</tbody>
</table>
i. **Settlements**

It is defined as an area of human habitation developed due to non-agricultural use and that which has a cover of buildings, transport, and communication, utilities in association with water, vegetation and vacant lands. Settlements appears as dark bluish green in the core and bluish on the periphery on satellite imagery. It may be either big or small in size, irregular in shape with coarse or mottled texture. The total settlements area in the present study is about 860 Ha,

ii. **Crop land**

Cropland consists of different crops grown in different seasons under different farming and land tenural systems. Mixed and multiple cropping patterns generate mixed spectral response on the images. The croplands appear bright red to red in tone on the imagery, have varying sizes and may be regular or irregular in shape with medium to smooth texture. They are usually located on plains, hill slopes, valleys and cultivable wastelands. This type of land use occupies 3655 Ha. the study area.

iii. **Fallow land:**

Fallow land is described as agricultural land which is taken up for cultivation but is temporarily allowed to rest, un cropped for one or more seasons, but not less than one year. These lands are particularly those which are seen devoid of crops at the time, when imagine taken up for both seasons. The area under this category is estimated as 44 ha.
iv. **Plantations:**

It is described as an area under agricultural tree crops, planted adopting certain agricultural management techniques. It includes Cashewnuts, Casuarina, and other horticultural nurseries. This mostly confined to the beach ridges, sandy areas and along river courses. Plantation can be seen very prominently on the imagery with a dark red to red tone, regular in shape, sharp edges and coarse to medium texture. Their size varies from small to medium. The area under this category forms 1561 ha.

v. **Land With Scrub**

It is the land, which has an undulating topography with thin soil cover and scattered trees/scrubs. These lands are being used for grazing and are ideal sites for plantations. They occupy relatively higher topographic grounds with scrub. These are also marginal agricultural lands which have been left waste due to various reasons such as lack of water, poor soils and erosion etc. With proper soil and water management, these lands could be brought under social forestry/silvipasture. 281 Ha. i.e. 3% of the study area is occupied by this pattern of land use.

vi. **Land without Scrub**

It is the land, which has an undulating topography with thin soil cover and devoid of any scrubs. These areas are prone to sheet wash and rill erosion. They appear light yellow to brown to greenish blue in colour with coarse to mottled texture on satellite image. They are located on terrain
with varying lithology and landforms. 829 ha. i.e., 9% of the total area is occupied by this type of land cover.

**vii. Reserved forest**

They appear bright red to red in tone on the imagery, have varying sizes and may be regular or irregular in shape with medium to smooth texture. This type of land use occupies an area of 559 Ha. of the total study area in the South West part.

**4.7 SOIL MAP**

Soil is a major component of land system which provides a medium for plant growth. The potentials and limitations of a soil for sustained use under agriculture, horticulture, silvipasture and forestry as well as its response to irrigation and other management practices are controlled by its inherent qualities and characteristics. The quality of the soil is a function of its morphological, morophometric, physical and chemical characteristics. These characteristics are expressed a taxonomic class as depicted on soil map with locational reference. Soil mapping of the region is intended to serve as a crucial input for preparing an integrated plan for sustainable development of the area. Soil surveys provide desired information on nature, location, extent and physio-chemical characteristics along with their spatial distribution. Earlier, soil surveys have been carried out using topographic maps and cadastral maps as data base. The development of aerial photo interpretation technique in
late sixties in India substantially augmented the efficacy of soil mapping programme. The launch of first satellite of Landsat series during 1972 and subsequently earth observation satellites opened a new vista in this endeavor. By virtue of fairly large area coverage in discrete bonds of the electromagnetic spectrum at a regular interval besides amenability of such data to digital analysis on image processing/analysis systems, the space borne data have been founded to provide timely, reliable and cost-effective information on natural resources including soils. Conventional soil mapping through intensive field traversing is tedious, slow and subjective. Application of remote sensing for soil mapping helps to overcome these shortcomings encountered in traditional system. The properties and ultimate use of soils are affected to a great extent by climatic parameters. In addition, these parameters also govern the crop growth. Hence they have been included as soil properties, namely soil temperature at various categorical levels in soil taxonomy (U.S. Dept. of Agriculture, 1951).

The specific objectives of the soil mapping are:

1. Identification, characterization and classification of the soils of the area.
2. Generation of derivative maps
3. Land evaluation for food/cash and horticultural crops.
4.7.1 Methodology

For preparing soil resources map, a collective approach comprising monoscopic visual interpretation and adequate field verification along with the collateral data namely topographic maps and published soil survey reports and maps was adopted. Topographic information taken from SOI toposheets on 1:25,000 scale was superimposed onto Satellite data. An image interpretation key in terms of lithology, Physiography, contour information, land use, and IRS image characteristics namely colour, texture, shape, pattern, association etc. was developed in order to correlate them with the distribution of soils. Sample strips were randomly selected for further field verification. Field visits were made to study soil profile characteristics and to correlate the interpretation units with the soils of the study area. Intensive profile examinations were carried out in the sample strips. Soil samples were collected from representative profiles for analysis in the laboratory. Random observations were however also made outside the sample strips in order to account for variation in soil therein. The soil profile data along with their taxonomic classification were incorporated into image interpretation units. Based on observations in the field, soil boundaries drawn during preliminary visual interpretation were modified and a legend showing soil series and associations was prepared. Subsequently the soil scape boundaries were transferred onto base maps prepared from Survey of India toposheet at 1:25,000 scale. The soil map is shows in fig.4.9
Fig. 4.9 Soil map of the study area

Prepared by Rajani Ganta, Centre for Environment, IST, JNTUH
### 4.7.2 Distribution of soil type in the study area

<table>
<thead>
<tr>
<th>Soil Code</th>
<th>Description</th>
<th>Soil Taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>227</td>
<td>Very deep, somewhat excessively drained, sandy soils, with very low awc, on</td>
<td>Mixed, Typic</td>
</tr>
<tr>
<td></td>
<td>very gently sloping sandy plains, slightly eroded; associated with deep,</td>
<td>Ustipsamments -- Fine</td>
</tr>
<tr>
<td></td>
<td>imperfectly drained, alluvial loamy soils, with high awc</td>
<td>Loamy, Mixed, Typic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ustopepts</td>
</tr>
<tr>
<td>231</td>
<td>Deep, well drained, gravelly clay soils with surface crusting and low awc,</td>
<td>Clayey skeletal, kaolinitic,</td>
</tr>
<tr>
<td></td>
<td>on gently sloping plains, slightly eroded; associated with: very deep,</td>
<td>typic Haplustalfs</td>
</tr>
<tr>
<td></td>
<td>well drained, clayey soils with high AWC</td>
<td>Fine, kaolinitic, Typic Ustropepts</td>
</tr>
<tr>
<td>232</td>
<td>Very deep, well drained, clayey soils with surface crusting and medium AWC,</td>
<td>Fine, kaolinitic, Typic</td>
</tr>
<tr>
<td></td>
<td>on gently sloping plains, slightly eroded; associated with:</td>
<td>Hapluststsslfs</td>
</tr>
<tr>
<td></td>
<td>Very deep, well drained, gravelly clay soils with low AWC</td>
<td>Clayeyskeletal, kaolinitic,</td>
</tr>
</tbody>
</table>


Deep, well drained, clayey soils with surface crusting and medium AWC, on very gently sloping plateau, moderately eroded; associated with Deep, well drained, clayey soils

Deep, well drained, red coastal clayey soils with high AWC, on very gently sloping plains, slightly eroded; associated with very deep, well drained, red coastal clayey soils.

Moderately deep, moderately well drained, black cracking clay, calcareous soils with high AWC, on very gently sloping plains, slightly eroded; associated with deep, well drained, black clayey soils.
4.8 GEOMORPHOLOGY

4.8.1 General

Information on landforms is an important input for land management, soil mapping and identification of potential zones of groundwater occurrence. The aspects of morphography, morphogenesis, morphochronology and morphometry are vital inputs in preparation of geomorphologic maps. The geomorphological processes, which result from manifold effects of geological and climatological changes, leave their distinctive imprint upon landforms and each geomorphological process develops its own particular assemblage of landforms. Different landforms are identified through interpretation of satellite imagery together with ground truth data to enable the evaluation of groundwater potential of the watershed. (fig. 4.10)

4.8.2 Description of Geomorphic Units

<table>
<thead>
<tr>
<th>Map Unit</th>
<th>Geomorphic Unit Description</th>
<th>Hydro Geology &amp; Structure</th>
<th>Description</th>
<th>Ground Water Prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPD</td>
<td>Coastal plain moderate to deep,</td>
<td>Unconsolidated to semi consolidated Sand, Silt &amp; Clay.</td>
<td>Gently sloping plain along the coast formed by marine action with Coastal Plain Moderate to Deep, Salt Flat, Mud flat and Beach.</td>
<td>Fresh water occurs as a thin layer over brackish water in the beach ridges and elevated tracts occupied by wind blown sand.</td>
</tr>
<tr>
<td>CPM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPLIT</td>
<td></td>
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Fig. 4.10 Geomorphology map of the study area

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