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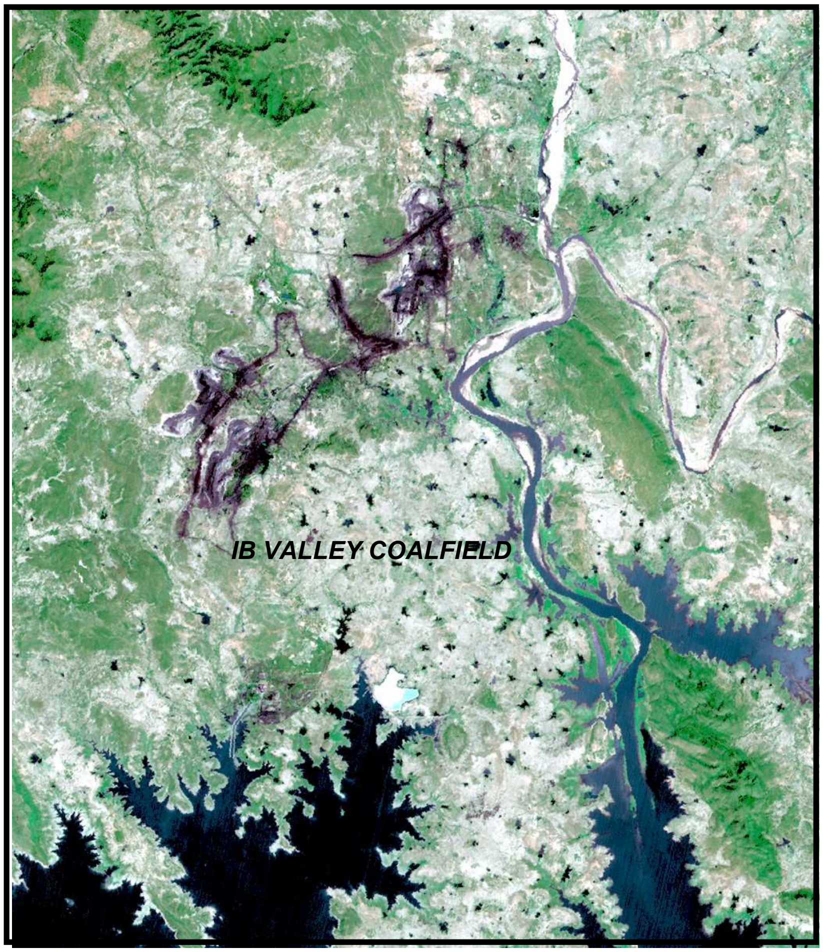
Land Use / Vegetation Cover Mapping of Ib Valley Coalfield based on Satellite Data for the Year 2010



CMPDI

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Report on Land Use/ Vegetation Cover Mapping of Ib Valley Coalfield based on Satellite date of the year 2010

Submitted to

Mahanadi Coalfields Limited
Sambalpur

March - 2011

Remote Sensing Cell
Geomatics Division
CMPDI (HQ), Ranchi

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Chapter 1

Introduction

1.1 Project Reference

Coal India Limited requested CMPDI to take up the study based on remote sensing satellite data for creating the geo-environmental data base of coalfields for monitoring the impact of coal mining on land use and vegetation cover. Accordingly, a road map for implementation of the project was submitted to Coal India Ltd. for land use and vegetation cover mapping of 28 major coalfields for creating the geo-environmental data base and subsequent monitoring of impact of coal mining land environment at a regular interval of three years. In pursuant to the work order no.CIL/WBP/Env/2009/2428 dated 29.12.009; issued by CIL; land use/vegetation cover mapping of Ib Valley coalfield based on satellite data was taken up to create the geo-environmental database.

1.2 Objective

The objective of the present study is to prepare a regional land use and vegetation cover map of Ib Valley coalfield on 1:50,000 scale based on satellite data of the year 2010, using digital image processing technique for creating the geo-environmental data base in respect of land use, vegetation cover, drainage, mining area, infrastructure etc. and up-dation of database at regular interval of three years to assess the impact of coal mining and other industrial activities on land use and vegetation cover in the coalfield area.

1.3 Location of the Area & Accessibility

Ib valley coalfield is located in the state of Orissa. It is broadly subdivided in two parts i.e. northern and southern. The northern half of the coalfield lies in Sundargarh district, whereas southern half lies in Jharsuguda district of Orissa. The area is well connected by rail and road to important business centres in Orissa like Rourkela, Jharsuguda, Sundargarh and Bhubaneswar. The Howrah-Mumbai railway line of the *South Eastern Railway* passes through the coalfield. Brajrajnagar, Belpahar and Himgir are the important Railway Stations through which the coalfield is approachable. Northern half of the coalfield lies in Sundargarh district, whereas southern half lies in Jharsuguda district of Orissa. The area is well connected by rail and road to important business centres in Orissa like Rourkela, Jharsuguda, Sundargarh and Bhubaneswar. The Howrah-Mumbai railway line of the *South Eastern Railway* passes through the coalfield. Brajrajnagar, Belpahar and Himgir are the important Railway Stations through which the coalfield is approachable.

Ib Valley coalfield is confined to area bounded by latitude $22^0$07’00” & $21^0$42’00”N and longitudes $83^0$33’30”E & $84^0$00’00”E, covering an area of about 1214.83 Km^2. The location map of Ib Valley Coalfield is given at Figure 1.1.

1.4 Physiography

Ib Valley coalfield has undulating landscape with elevation ranging from 206 to 350 m above mean sea level. The coalfield is drained mainly by Ib River, Ghoghar Nadi, Sapai Nadi and Bhedan River among others.

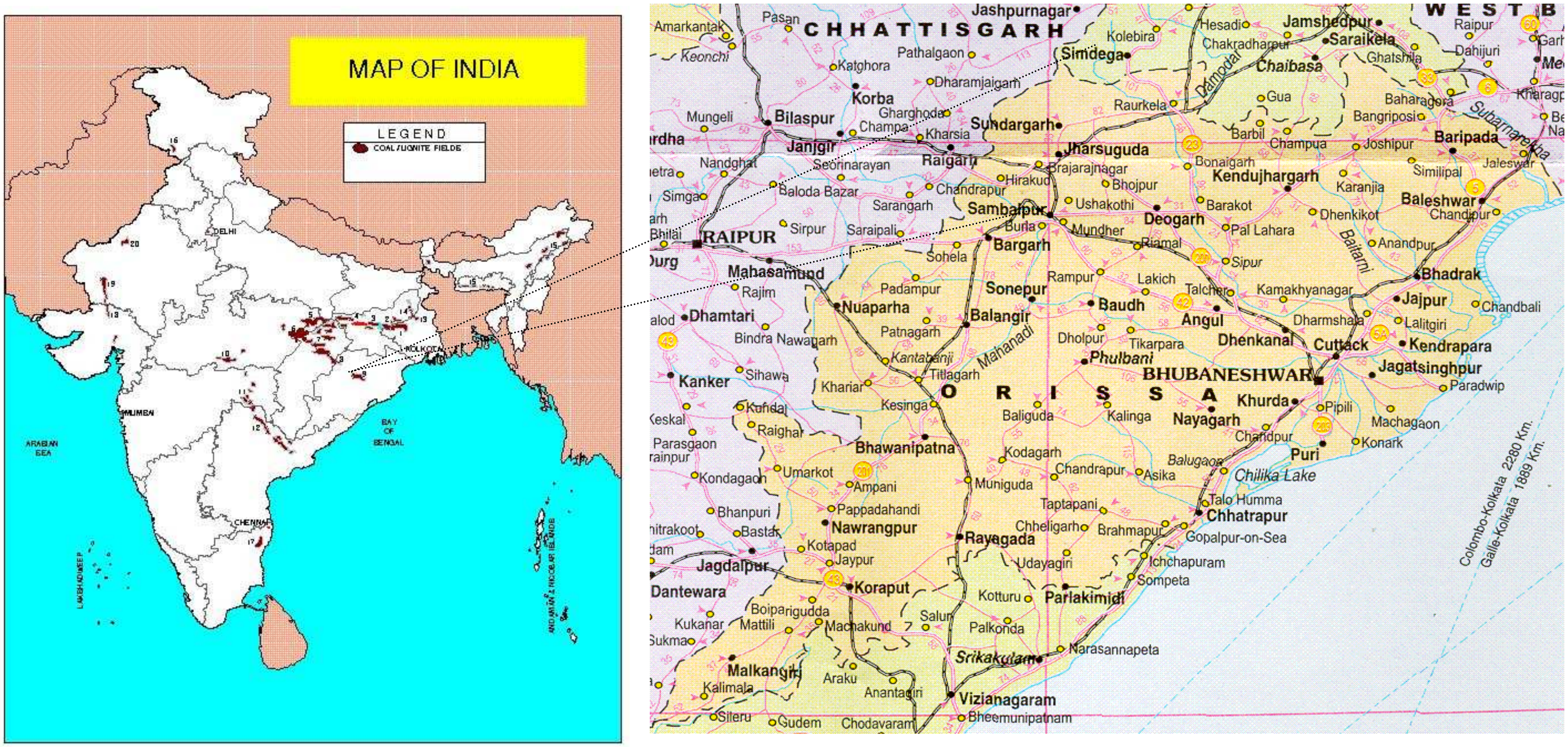


Fig 1.1 : Map of India Showing the Location of Ib Valley Coalfield

Chapter 2

Remote Sensing Concepts and Methodology

2.1 Remote Sensing

Remote sensing is the science and art of obtaining information about an object or area through the analysis of data acquired by a device that is not in physical contact with the object or area under investigation. The term *remote sensing* is commonly restricted to methods that employ electro-magnetic energy (such as light, heat and radio waves) as the means of detecting and measuring object characteristics.

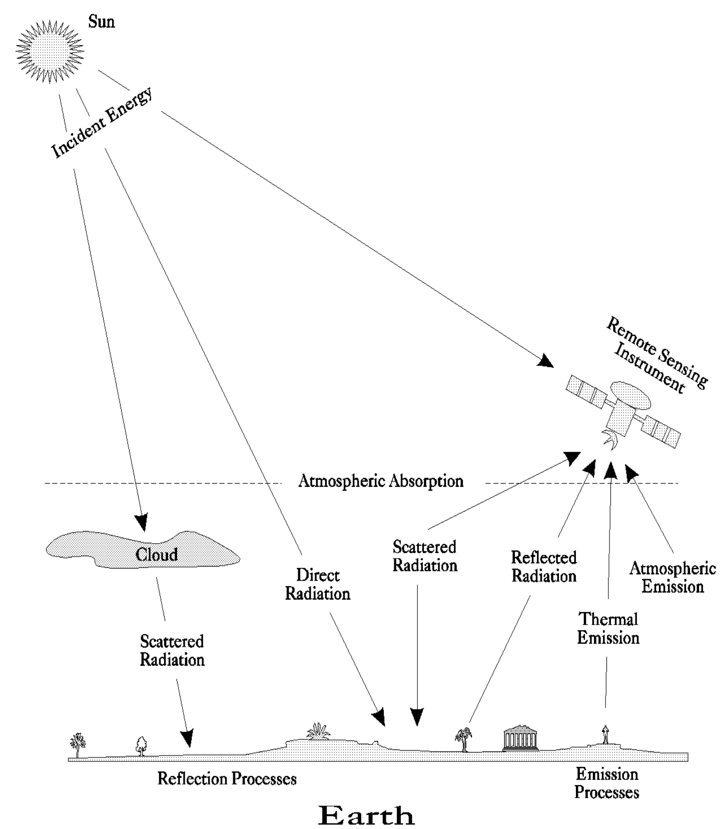


Figure 2.1 Remote sensing radiation system

All physical objects on the earth surface continuously emit electromagnetic radiation because of the oscillations of their atomic particles. Remote sensing is largely concerned with the measurement of electro-magnetic energy from the *SUN*, which is reflected, scattered or emitted by the objects on the surface of the earth. Figure 2.1 schematically illustrate the generalised processes involved in electromagnetic remote sensing of the earth resources.

2.2 Electromagnetic Spectrum

The electromagnetic (EM) spectrum is the continuum of energy that ranges from meters to nanometres in wavelength and travels at the speed of light. Different objects on the earth surface reflect different amounts of energy in various wavelengths of the EM spectrum.

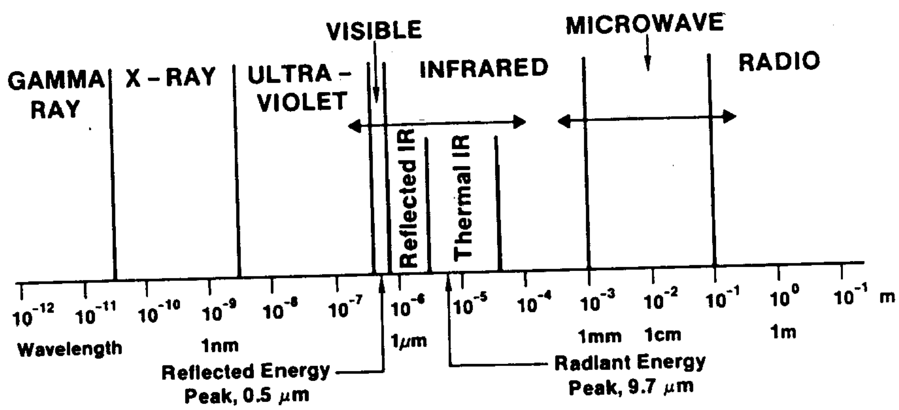


Figure 2.2 Electromagnetic spectrum. Expanded versions of the visible, infrared and microwave regions are shown in Figure 2.3.

Figure 2.2 shows the electromagnetic spectrum, which is divided on the basis of wavelength into different regions that are described in Table 2.1. The EM spectrum ranges from the very short wavelengths of the gamma-ray region to the long wavelengths of the radio region. The visible region (0.4-0.7µm wavelengths) occupies only a small portion of the entire EM spectrum.

Energy reflected from the objects on the surface of the earth is recorded as a function of wavelength. During daytime, the maximum amount of energy is reflected at 0.5µm wavelengths, which corresponds to the green band of the visible region, and is called the *reflected energy peak* (Figure 2.2). The earth also radiates energy both day and night, with the maximum energy 9.7µm wavelength. This *radiant energy peak* occurs in the thermal band of the IR region (Figure 2.2).

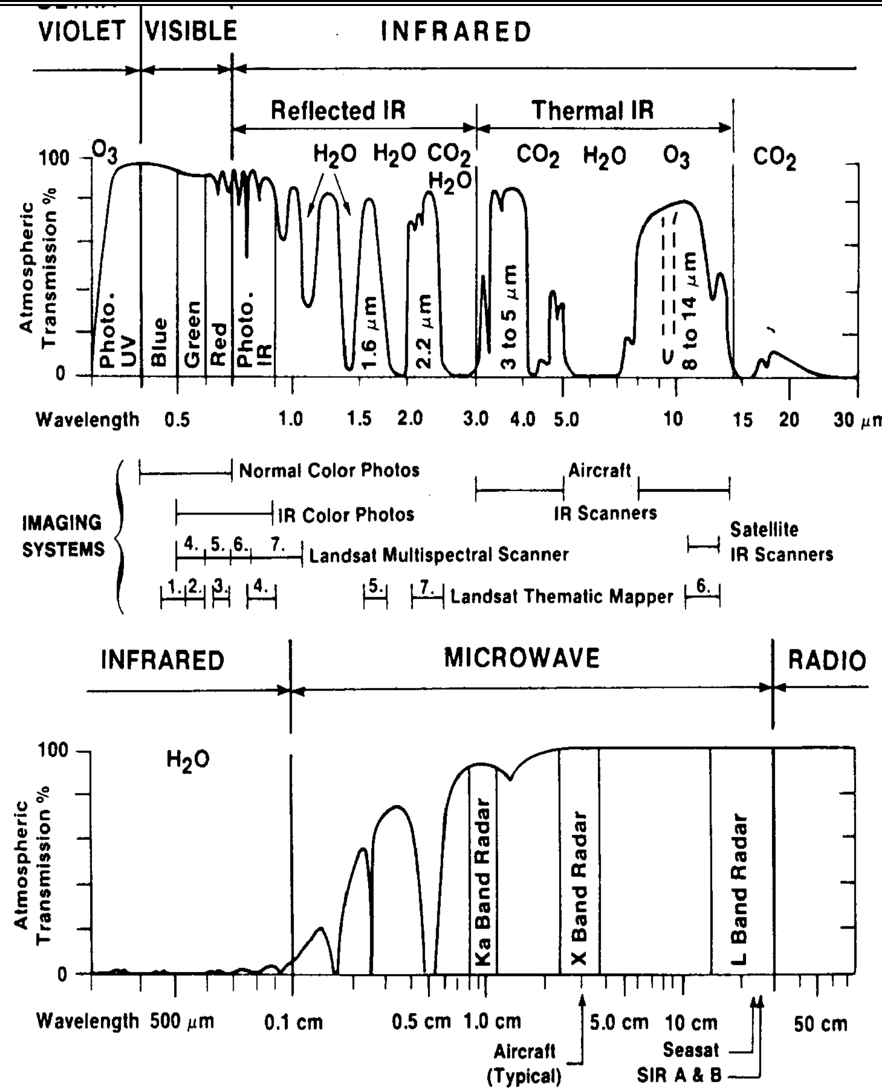


Figure 2.3 Expanded diagrams of the visible and infrared regions (upper) and the microwave regions (lower) showing atmospheric windows. Wavelength bands of commonly used remote sensing systems are indicated. Gases responsible for atmospheric absorption are shown.

Table 2.1 Electromagnetic spectral regions

Region	Wavelength			Remarks
Gamma ray		<	0.03 **nm**	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing.
X-ray	0.03	to	3.00 **nm**	Completely absorbed by atmosphere. Not employed in remote sensing.
Ultraviolet	0.03	to	0.40 **µm**	Incoming wavelengths less than 0.3mm are completely absorbed by Ozone in the upper atmosphere.
Photographic UV band	0.30	to	0.40 **µm**	Transmitted through atmosphere. Detectable with film and photo detectors, but atmospheric scattering is severe.
Visible	0.40	to	0.70 **µm**	Imaged with film and photo detectors. Includes reflected energy peak of earth at 0.5mm.
Infrared	0.70	to	100.00 **µm**	Interaction with matter varies with wavelength. Absorption bands separate atmospheric transmission windows.
Reflected IR band	0.70	to	3.00 **µm**	Reflected solar radiation that contains no information about thermal properties of materials. The band from 0.7-0.9mm is detectable with film and is called the *photographic IR band*.
Thermal IR band	3.00 8.00	to to	5.00 **µm** 14.00 **µm**	Principal atmospheric windows in the thermal region. Images at these wavelengths are acquired by optical-mechanical scanners and special Videocon systems but not by film.
Microwave	0.10	to	30.00 **cm**	Longer wavelengths can penetrate clouds, fog and rain. Images may be acquired in the active or passive mode.
Radar	0.10	to	30.00 **cm**	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
Radio		>	30.00 **cm**	Longest wavelength portion of electromagnetic spectrum. Some classified radars with very long wavelength operate in this region.

The earth's atmosphere absorbs energy in the gamma-ray, X-ray and most of the ultraviolet (UV) region; therefore, these regions are not used for remote sensing. Details of these regions are shown in Figure 2.3. The horizontal axes show wavelength on a logarithmic scale; the vertical axes show percent atmospheric transmission of EM energy. Wavelength regions with high transmission are called *atmospheric windows* and are used to acquire remote sensing data. The major remote sensing sensors records energy only in the visible, infrared and micro-wave regions. Detection and measurement of the recorded energy enables identification of surface objects (by their characteristic wavelength patterns or spectral signatures), both from air-borne and space-borne platforms.

2.3 Scanning System

The sensing device in a remotely placed platform (aircraft/satellite) records EM radiation using a *scanning system*. In scanning system, a *sensor*, with a narrow field of view is employed; this sweeps across the terrain to produce an image. The sensor receives electromagnetic energy radiated or reflected from the terrain and converts them into signal that is recorded as numerical data. In a remote sensing satellite, multiple arrays of linear sensors are used, with each array recording simultaneously a separate band of EM energy. The array of sensors employs a spectrometer to disperse the incoming energy into a spectrum. Sensors (or *detectors*) are positioned to record specific wavelength bands of energy. The information received by the sensor is suitably manipulated and transported back to the ground receiving station. The data are reconstructed on ground into digital images. The digital image data on *magnetic/optical media* consist of picture elements arranged in regular rows and columns. The position of any picture element, *pixel*, is determined on a x-y co-ordinate system. Each pixel has a numeric value, called digital number (DN), which records the intensity of electromagnetic energy measured for the ground resolution cell represented by that pixel. The range of digital numbers in an image data is controlled by the radiometric resolution of the satellite's sensor system. The digital image data are further processed to produce master images of the study area. By analysing the digital data/imagery, digitally/visually, it is possible to detect, identify and classify various objects and phenomenon on the earth surface.

Remote sensing technique provides an efficient, speedy and cost-effective method for assessing the changes in vegetation cover certain period of time due to its inherited capabilities of being multi-spectral, repetitive and synoptic aerial coverage.

2.4 Data Source

The following data are used in the present study:

- **Primary Data** –Raw satellite data, obtained from National Remote Sensing Centre (NRSC), Hyderabad, was used as primary data source for the study.
  IRS –P6/ (LISS III); Band 2,3,4,5; Path # 102, 103 Row # 027, 028, 029, 030, 002; Date of pass 08.03.2010*. The detail specification of the data is also given in Table 2.2.

- **Secondary Data**
  Secondary (ancillary) and ground data constitute important baseline information in remote sensing, as they improve the interpretation accuracy and reliability of remotely sensed data by enabling verification of the interpreted details and by supplementing it with the information that cannot be obtained directly from the remotely sensed data. **Ib Valley Coalfield** toposheet no. 64N, 64O, 73B & 73C as well as map showing details of location of area boundary, colliery boundary, road and railway lines supplied by MCL were used in the study.

2.5 Characteristics of Satellite/Sensor

The basic properties of a satellite's sensor system can be summarised as:

(a) Spectral coverage/resolution, i.e., band locations/width; (b) spectral dimensionality: number of bands; (c) radiometric resolution: quantisation; (d) spatial resolution/instantaneous field of view or IFOV; and (e) temporal resolution. Table 2.2 illustrates the basic properties of IRS-P6 satellite/sensor that is used in the present study.

Table 2.2 Characteristics of the satellite/sensor used in the present project work

Platform	Sensor	Spectral Bands in µm	Radiometric Resolution	Spatial Resolution	Temporal Resolution	Country
IRS-P6	LISS-III	B2 0.52 - 0.59 Green B3 0.62 - 0.68 Red B4 0.77 - 0.86 NIR B5 1.55 - 1.70 MIR	7-bit (128-grey levels)	23.5 m 23.5 m 23.5 m 70.5 m	24 days	India

NIR: Near Infra-Red MIR: Middle Infra-Red

2.6 Data Processing

The methodology for data processing carried out in the present study is shown in Figure 2.4. The processing involves the following major steps:

(a) Geometric correction, rectification and geo-referencing;
(b) Image enhancement;
(c) Training set selection;
(d) Signature generation and classification;
(e) Creation/overlay of vector database;
(f) Validation of classified image;
(g) Layer wise theme extraction using GIS
(g) Final vegetation map preparation.

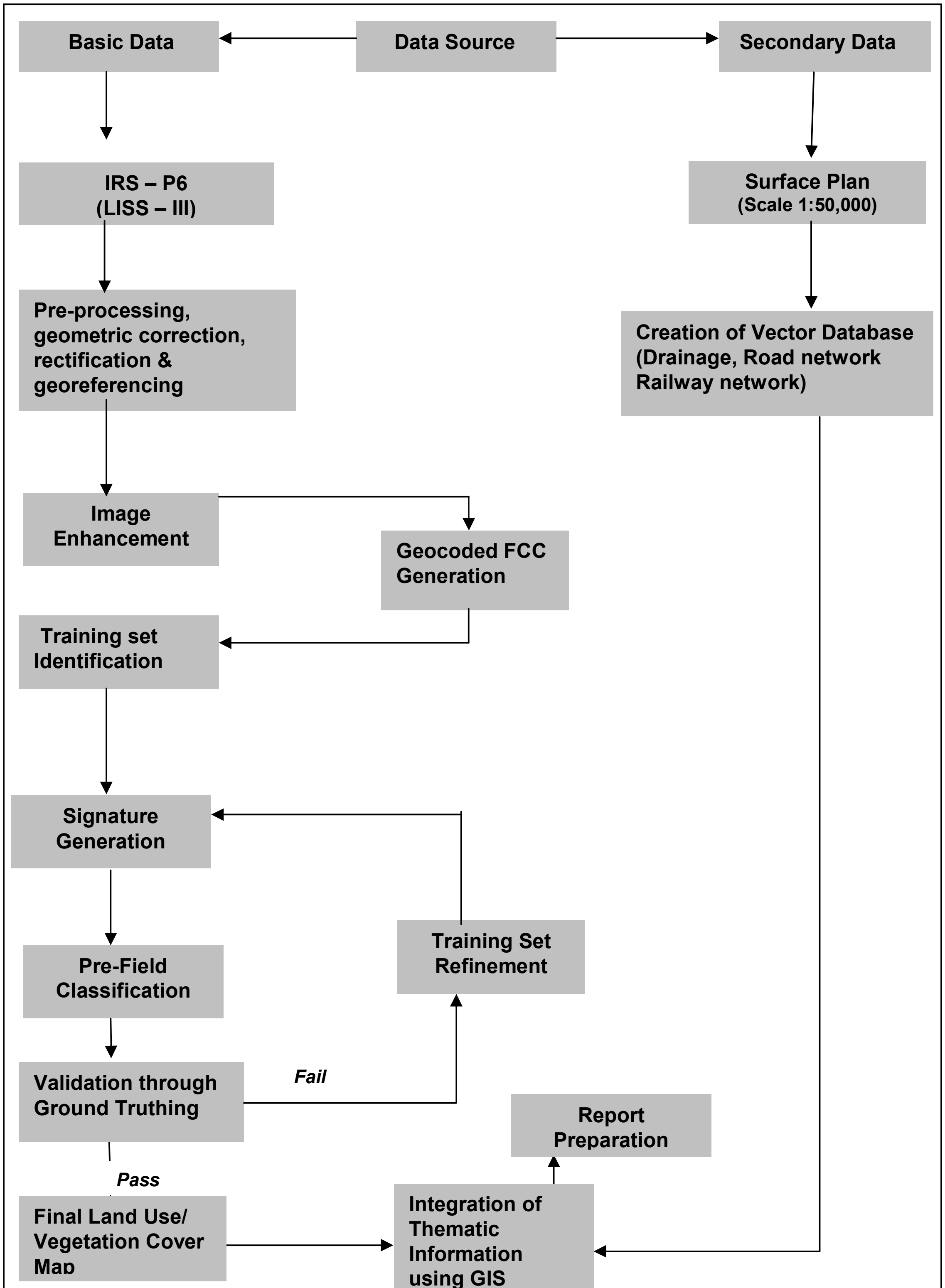


Fig 2.4 : Methodology for Land Use / Vegetation Cover Mapping

2.6.1 Geometric correction, rectification and georeferencing

Inaccuracies in digital imagery may occur due to 'systematic errors' attributed to earth curvature and rotation as well as 'non-systematic errors' attributed to intermittent sensor malfunctions, etc. Systematic errors are corrected at the satellite receiving station itself while non-systematic errors/ random errors are corrected in pre-processing stage.

In spite of 'System / Bulk correction' carried out at supplier end; some residual errors in respect of attitude attributes still remains even after correction. Therefore, fine tuning is required for correcting the image geometrically using ground control points (GCP).

Raw digital images contain geometric distortions, which make them unusable as maps. A map is defined as a flat representation of part of the earth's spheroidal surface that should conform to an internationally accepted type of cartographic projection, so that any measurements made on the map will be accurate with those made on the ground. Any map has two basic characteristics: (a) scale and (b) projection. While *scale* is the ratio between reduced depiction of geographical features on a map and the geographical features in the real world, *projection* is the method of transforming map information from a sphere (round Earth) to a flat (map) sheet. Therefore, it is essential to transform the digital image data from a generic co-ordinate system (i.e. from line and pixel co-ordinates) to a projected co-ordinate system. In the present study geo-referencing was done with the help of Survey of India (SoI) topo-sheets so that information from various sources can be compared and integrated on a GIS platform, if required.

An understanding of the basics of projection system is required before selecting any transformation model. While maps are flat surfaces, Earth however is an irregular sphere, slightly flattened at the poles and bulging at the Equator. Map projections are systemic methods for "*flattening the orange peel*" in measurable ways. When transferring the Earth and its irregularities onto the plane surface of a map, the following three factors are involved: (a) geoid (b) ellipsoid and (c) projection. Figure 2.5 illustrates the relationship between these three factors. The *geoid* is the rendition of the irregular spheroidal shape of the Earth; here the variations in gravity are taken into account. The observation made on the geoid is then transferred to a regular geometric reference surface, the *ellipsoid*. Finally, the geographical relationships of the ellipsoid (in 3-D form) are transformed into the 2-D plane of a map by a transformation process called map projection. As shown in Figure 2.5, the vast majority of projections are based upon *cones*, *cylinders* and *planes*.

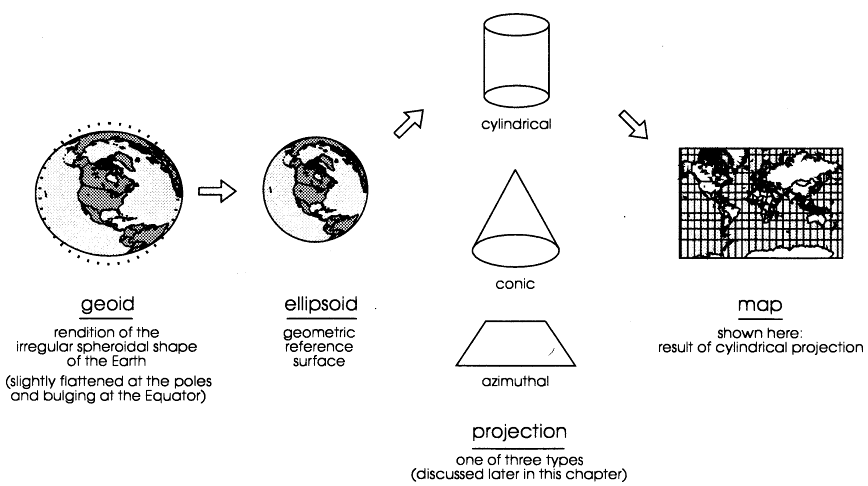


Fig 2.5 : Geoid – Ellipsoid – Projection Relationship

In the present study, ***Polyconic projection*** *along with* ***Modified Everest (1956) Ellipsoidal model*** was used so as to prepare the map compatible with the SoI topo-sheets**.** Polyconic projection is used in SoI topo-sheets as it is best suited for small-scale mapping and larger area as well as for areas with North-South orientation (viz. India). Maps prepared using this projection is a compromise of many properties; it is neither conformal perspective nor equal area. Distances, areas and shapes are true only along central meridian. Distortion increases away from central meridian. Image transformation from generic co-ordinate system to a projected co-ordinate system was carried out using ERDAS Imagine 9.3 digital image processing system.

2.6.2 Image enhancement

To improve the interpretability of the raw data, image enhancement is necessary. Most of the digital image enhancement techniques are categorised as either point or local operations. Point operations modify the value of each pixel in the image data independently. However, local operations modify the value of each pixel based on brightness value of neighbouring pixels. Contrast manipulations/ stretching technique based on local operation were applied on the image data using PCI Geomatica v10.1 software.

2.6.3 Training set selection

The image data were analysed based on the interpretation keys. These keys are evolved from certain fundamental image-elements such as tone/colour, size, shape, texture, pattern, location, association and shadow. Based on the image-elements and other geo-technical elements like land form, drainage pattern and physiography; training sets were selected/ identified for each land use/cover class. Field survey was carried out by taking selective traverses in order to collect the ground information (or reference data) so that training sets are selected accurately in the image. This was intended to serve as an aid for classification. Based on the variability of land use/cover condition and terrain characteristics and accessibility, 90 points were selected to generate the training sets.

2.6.4 Signature generation and classification

Image classification was carried out using the minimum distance algorithm. The classification proceeds through the following steps: (a) calculation of statistics [i.e. signature generation] for the identified training areas, and (b) the decision boundary of maximum probability based on the mean vector, variance, covariance and correlation matrix of the pixels.

After evaluating the statistical parameters of the training sets, reliability test of training sets was conducted by measuring the statistical separation between the classes that resulted from computing divergence matrix. The overall accuracy of the classification was finally assessed with reference to ground truth data. The aerial extent of each land use class in the coalfield was determined using PCI Geomatica v10.1 s/w. The classified image for the year 2010 for Ib Valley Coalfield is shown in Drawing No. R7GMT100001.

2.6.5 Creation/overlay of vector database in GIS

Plan showing leasehold areas of mining projects supplied by MCL are superimposed on the image as vector layer in the GIS database. Road network, rail network and drainage network are digitised on different vector layers in GIS database. Layer wise theme extraction was carried out using ArcGIS s/w and imported the same on GIS platform for further analysis.

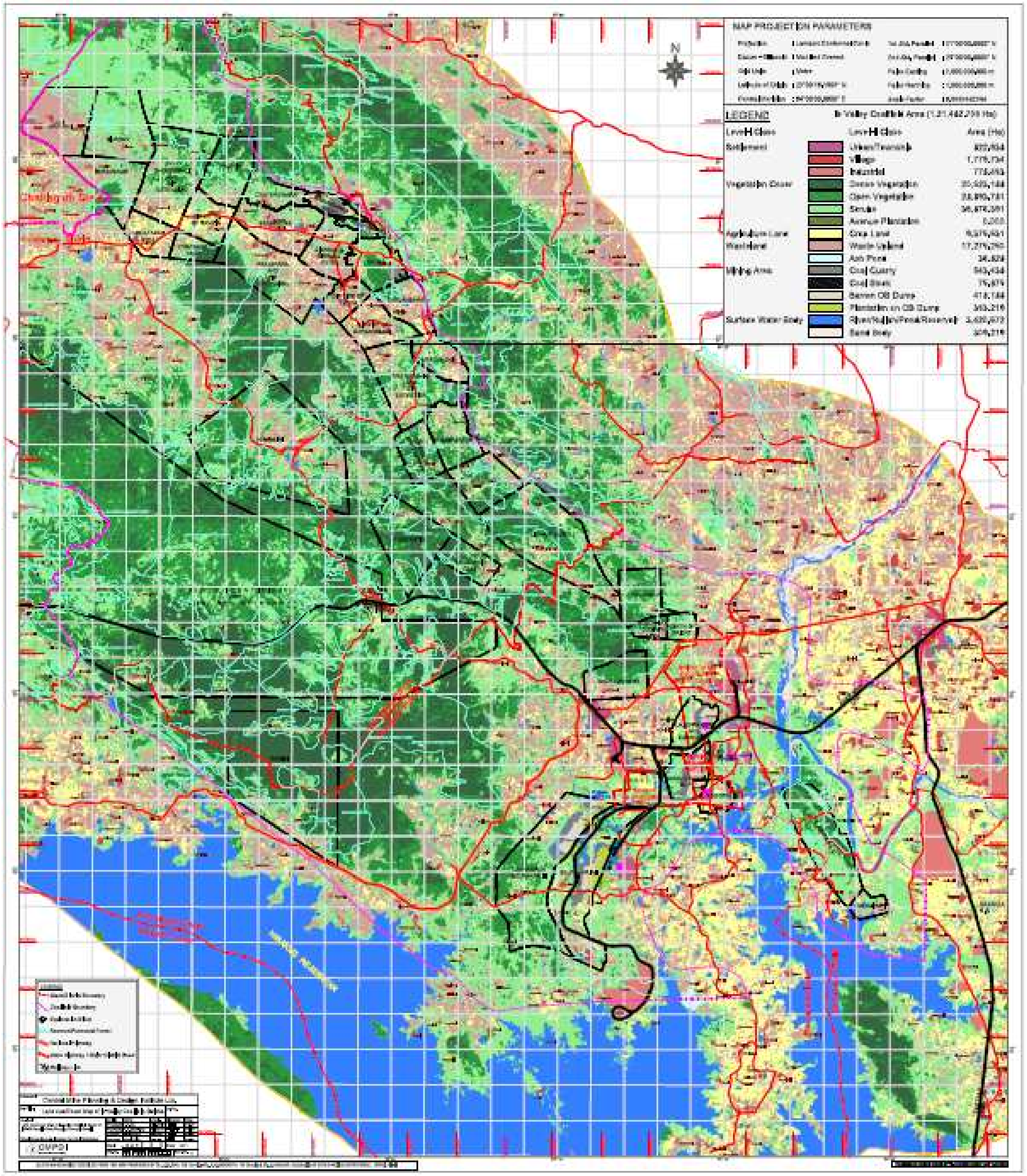
2.6.6 Validation of classified image

Ground truth survey was carried out for validation of the interpreted results from the study area. Based on the validation, classification accuracy matrix was prepared. The overall classification accuracy for the year 2010 was found to be 88.59%.

Final Land Use/vegetation cover maps were printed using HP Design jet 4500 PS Colour Plotter.

Table 2.3: Classification Accuracy Matrix for Ib Valley Coalfield in the year 2010

Sl.#	Vegetation\Land use classes as observed in the field	Built-up land	Vegetation Cover	Agriculture	Wasteland	Mining Area	Water Bodies	Total no. of observation points (Z)	% of observation points	% of classification accuracy	% of omission
		Land use/vegetation cover Classes based on Satellite Data									
(b)	Vegetation Cover		16	2	+`			18	20.00	**88.89**	11.12
(g)	Mining Area				1	7		8	8.89	**87.5**	12.5
(c)	Agriculture		2	18				20	22.22	**90.00**	10.00
(d)	Wasteland	1			24		1	26	28.89	**92.31**	7.69
(a)	Built-up land	13			1			14	15.56	**92.86**	7.14
(h)	Water Bodies					1	4	5	5.56	**80.0**	20.0
Total no. of observation points (X)		14	18	20	26	8	5	90	-	**88.59**	-
% of Commission		7.14	11.11	10.00	7.69	12.5	20.0				


MAP PROJECTION PARAMETERS
N
LEGEND
Settlement
Urban/Township
Village
Industrial
Vegetation Cover
Dense Vegetation
Open Vegetation
Scrubs
Avenue Plantation
Agriculture Land
Crop Land
Wasteland
Waste Upland
Ash Pond
Mining Area
Coal Quarry
Coal Stack
Barren OB Dump
Plantation on OB Dump
Surface Water Body
River/Nallah/Pond/Reservoir
Sand Body
CMPDI

Chapter 3

Land Use/ Vegetation Cover Monitoring

3.1 Introduction

Land is one of the most important natural resource on which all human activities are based. Therefore, knowledge on different type of lands as well as its spatial distribution in the form of map and statistical data is vital for its geospatial planning and management for optimal use of the land resources. In mining industry, the need for information on land use/ vegetation cover pattern has gained importance due to the all-round concern on environmental impact of mining. The information on land use/ cover inventory that includes type, spatial distribution, aerial extent, location, rate and pattern of change of each category is of paramount importance for assessing the impact of coal mining on land use/ cover.

Remote sensing data with its various spectral and spatial resolutions, offers comprehensive and accurate information for mapping and monitoring of land use/cover over a period of time. By analysing the data of different cut-off dates, impact of coal mining on land use and vegetation cover can be determined.

3.2 Land Use / Vegetation Cover Classification

The array of information available on land use/ vegetation cover requires be arranging or grouping under a suitable framework in order to facilitate the creation of database. Further, to accommodate the changing land use/vegetation cover pattern, it becomes essential to develop a standardised classification system that is not only flexible in nomenclature and definition, but also capable of incorporating information obtained from the satellite data and other different sources.

The present framework of land use/cover classification has been primarily based on the '***Manual of Nationwide Land Use/ Land Cover Mapping Using Satellite Imagery***' developed by National Remote Sensing Centre, Hyderabad, which has further been modified by CMPDI for coal mining areas. Land use/vegetation cover map was prepared on the basis of image interpretation carried out based on the satellite data for the year 2010. Following land use/cover classes are identified in the Ib Valley coalfield region (Table 3.1).

Table 3.1
Land use / Vegetation Cover classes identified in Ib Valley Coalfield

	LEVEL –I	LEVEL-II
1	**Vegetation Cover**	1.1 Dense Forest 1.2 Open Forest 1.3 Scrub 1.4 Avenue Plantation 1.5 Plantation on OB Dumps
2	**Mining Area**	2.1 Coal Quarry 2.2 Barren OB Dump 2.3 Coal Stock / Dump
3	**Agricultural Land**	3.1 Crop Land
4	**Wasteland**	4.1 Waste upland with/without scrubs 4.2 Fly Ash Pond 4.3 Sand Body
5	**Settlements**	5.1 Urban/Township 5.2 Village / Rural 5.3 Industrial
6	**Water Bodies**	6.1 River/Streams /Reservoir

3.3 Data Analysis

Satellite data of the year 2010 was processed using PCI Geomatica v.10.1 image processing s/w in order to interpret the various land use and vegetation cover classes present in the Ib Valley coalfield. The analysis was carried out for entire coalfield covering about 1214.83 sq. km.

The area of each class was calculated and analysed using PCI Geomatica *Digital Image Processing* s/w and *ArcGIS* s/w. Analysis of land use / vegetation cover pattern in Ib Valley Coalfield for the year 2010 was carried out and details of the analysis are and shown in table 3.2.

TABLE – 3.2

STATUS OF LAND USE & VEGETATION COVER PATTERN IN IB VALLEY COALFIELD IN THE YEAR 2010

Area in Sq km

LAND USE / COVER CLASSES	AREA STATISTICS FOR THE YEAR 2010	
	AREA	% of TOTAL
VEGETATION COVER		
Dense forest	205.23	16.89
Open Forest	288.94	23.78
Scrubs	368.76	30.36
Avenue Plantation	0.00	0.00
Plantation on OB Dump	3.53	0.29
Sub Total	**866.47**	**71.32**
MINING AREA		
Coal Quarry/Active Mining Area	5.43	0.45
Coal Stock / Dump	0.76	0.06
Barren OB Dump	4.19	0.34
Sub Total	**10.38**	**0.85**
AGRICULTURAL LAND		
Crop Land	94.57	7.79
Sub Total	**94.57**	**7.79**
WASTELAND		
Waste upland	171.93	14.15
Fly-Ash Pond	0.37	0.03
Sand Body	3.09	0.25
Sub Total	**175.39**	**14.43**
SETTLEMENTS		
Urban	8.23	0.68
Rural	17.80	1.47
Industrial	7.78	0.64
Sub Total	**33.81**	**2.79**
WATER BODIES	**34.21**	**2.82**
TOTAL	**1214.83**	**100.00**

3.3.1 Vegetation cover Analysis

Vegetation cover is an association of trees and other vegetation type capable of producing timber and other forest produce. It is also defined as the percentage of soil which is covered by green vegetation. Leaf area index (LAI) is an alternative expression of the term vegetation cover which gives the area of leaves in m^2 corresponding to an area of one m^2 of ground. Primarily vegetation cover is classified into the following three sub-classes based on crown density as per modified FAO-1963 (Food & Agricultural Organisation of United Nations) norms: (a) dense forest (crown density more than 40%), (b) open/degraded forest (crown density between 10% to 40%), and (c) scrubs (crown density less than 10%). The plantation that has been carried out on wasteland along the roadside and on the overburden dumps / Backfilled areas is also included under vegetation cover as social forestry and plantation on over-burden dumps respectively. The percentage of vegetation cover shown in the analysis here are in terms of total land use / cover only.

Analysis of the satellite data of the year 2010 reveals that vegetation cover in the Ib Valley Coalfield occupies 866.47 km^2 (71.32%). Out of which, *dense forest* covers an area of 205.23 km^2 (16.89%), *open forest* covers area of 288.94 km^2 (23.78%); *Scrubs* has covered 368.77 km^2 (30.36%) and Plantation on OB dumps has an area of 3.53 km^2 in the coalfield in 2010 *(Refer Table 3.2)*.

3.3.2 Mining

The mining area includes the area of existing quarry, old quarries filled with water, advance quarry sites, Coal Stock/Dumps, Coal Faces, Barren Backfilled areas, Barren over-burden dumps and allied activities. The mining area in Ib Valley Coalfield covers 10.38 km^2 (0.85%) in the year 2010. *Coal quarry* constitutes 5.43 km^2 (0.45%), *Coal dumped/stocks* constitutes 0.76 km^2 (0.06%) and *Barren over burden dumps* constitutes 4.19 km^2 (0.34%).

3.3.3 Agriculture

Land primarily used for farming and production of food, fibre and other commercial and horticultural crops falls under this category. It includes crop land and fallow land. *Crop lands* are those agricultural lands where standing crop occurs on the date of satellite imagery or land is used for agricultural purposes during any season of the year. Crops may be either kharif or rabi. *Fallow lands* are also agricultural land which is taken up for cultivation but temporarily allowed to rest, un-cropped for one or more season. In this study, both crop land and fallow land has been combined in single class namely agricultural land.

Agricultural land in Ib Valley Coalfield covers an area of 94.57 km^2 (7.79%). *(Refer Table 3.2)*

3.3.4 Wasteland

Wasteland is a degraded and under-utilised class of land that has deteriorated on account of natural causes or due to lack of appropriate water and soil management. Wasteland can result from inherent/imposed constraints such as location, environment, chemical and physical properties of the soil or financial or other management constraints (NWDB, 1987).

Analysis of data reveals that wasteland in the Ib Valley Coalfield occupies 175.39 km^2 (14.51%) out of which *Waste upland with or without scrubs* occupies 172.75 km^2 (14.43%), *Fly Ash Ponds* constitute 0.37 km^2 (0.03%) and *Sand bodies* constituted 3.09 km^2 (0.25%) in 2010.

3.3.5 Settlement/ Built-up land

All the man-made constructions covering the land surface are included under this category. Built-up land has been divided in to rural, urban and industrial classes based on availability of infrastructure facilities. In the present study, industrial settlement indicates only industrial complexes excluding residential facilities. The percentage of settlement shown in the analysis here is in terms of total land use/ cover only.

Settlements in Ib Valley Coalfield covers an area of 33.81 km^2 (2.79%) out of the total coalfield area of 1214.83 km^2. Analysis of the satellite data of the year 2010 indicates that settlement coming under the coalfield boundary of Ib Valley was distributed between *Urban* (8.23 $km^{2;}$ 0.68%), *Rural* (17.80 $km^{2;}$ 1.47%) and *Industrial* (7.78 $km^{2;}$ 0.64%) *(Refer Table 3.2)*.

3.3.6 Surface Water bodies

Analysis of data reveals that water bodies in Ib Valley Coalfield occupy an area of 34.21 km^2 (2.82%).

Chapter 4

Conclusion & Recommendations

4.1 Conclusion

In the present study, land use/vegetation cover map of Ib Valley coalfield is prepared based on IRS-P6/ LISS III of the year 2010 in order to generate the geo-environmental database on vegetation cover and land use pattern for the year 2010 for effective natural resource management and its planning. The Land use/vegetation cover analysis at an interval of three years will help to analyse and monitor the impact of mining and other industrial activities in the area.

Study reveals that Ib Valley Coalfield covers an area of about 1214.83 km^2. Vegetation cover constitutes 866.47 km^2 (71.32%), Mining activities is on 10.38 km^2 area which is 0.85% of the total coalfield area whereas agriculture and wasteland are on 94.58 km^2 (7.79%) and 175.39 km^2 (14.43%).Settlements coming under the coalfield boundary cover area of 33.81 km^2 which is 2.79% of the total coalfield area. Water bodies cover an area of 34.21 km^2 (2.78%)

The detail data analysis is given under Table-3.2.

4.2 Recommendations

Keeping in view the sustainable development together with coal mining in the area, it is recommended that;

a) Similar study should to be carried out regularly at interval of 3 years to monitor the change in land use/vegetation cover in the coalfield for assessing the impact of coal mining and take the remedial measures required, if any.

b) Efforts for afforestation should be given thrust in the coalfield on wasteland and mined out area to maintain the ecological balance in the region.

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