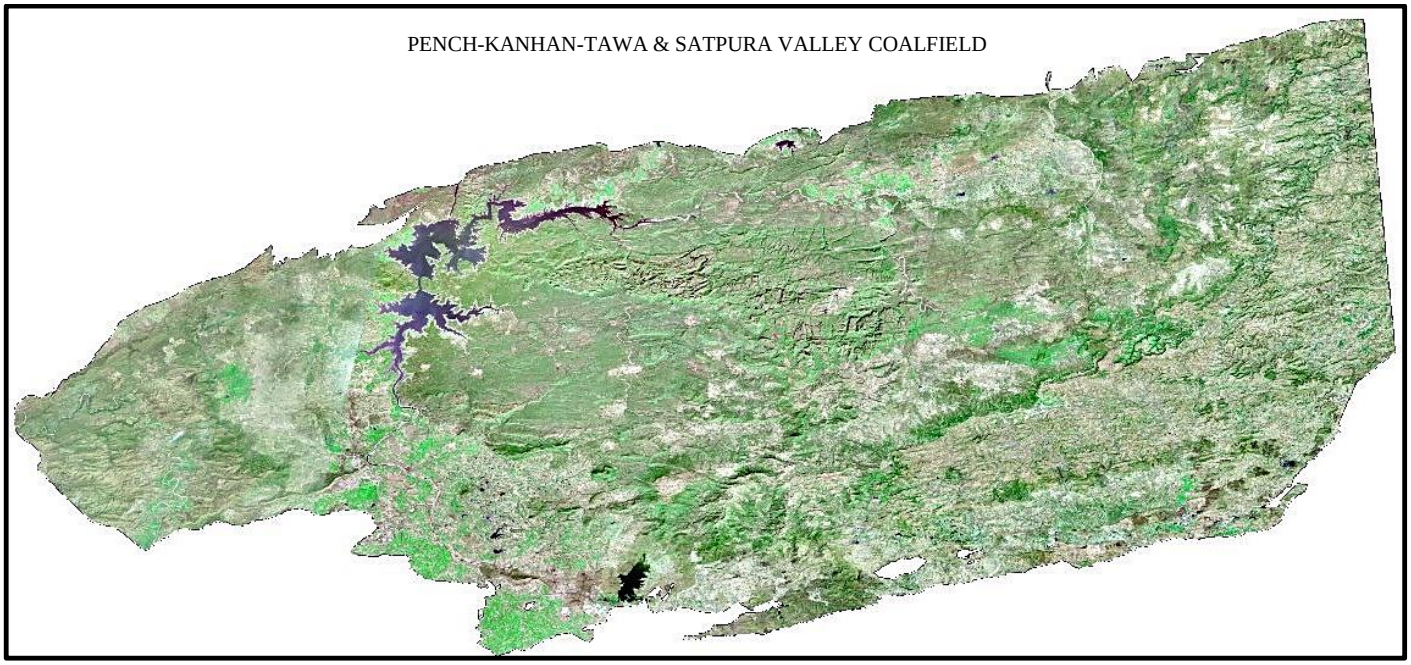
Report on
Land Use/ Vegetation cover Mapping of Pench-Kanhan-Tawa & Satpura Valley Coalfield based on Satellite data for the year 2023



Submitted to

Western Coalfields Limited

Report on
Land Use/ Vegetation cover Mapping of Pench-Kanhan-Tawa & Satpura Valley Coalfield based on Satellite data for the year 2023

March-2024

Remote Sensing Cell
Geomatics Division
CMPDI, Ranchi

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Contents

List of Figures

List of Tables

List of Plates

List of maps/plates prepared on a scale of 1:50,000 are given below:

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 major coalfields for creating the geo-environmental data base and subsequent monitoring of impact of coal mining on land environment at a regular interval of three years. A work order no. CIL/WBP/Env/2009/2428 dated 29.12.2009 was initially issued by CIL initially for three years. Subsequently, a revised work order was issued vide letter no. CIL/WBP/Env/2011/4706 dated 12.10.2012 from Coal India Limited for the period 2012-13 to 2016-17 which was subsequently followed by another work order vide letter no. CIL/WBP/Env/2017/DP/8477 dated 21.09.2017 from Coal India Limited for the period 2017-18 to 2021-22. Furthermore, the work order was again renewed by CIL vide letter no CIL/ENVT/2022-23/W.O./10899 dated 06.07.2022 for continuing the work till 2023-24 for land reclamation monitoring of opencast projects and vegetation cover monitoring of 19 major coalfields including Pench-Kanhan-Tawa and Satpura Valley Coalfield as per a defined plan for monitoring the impact of mining on Vegetation Cover. As follow up to the above work order, land use/vegetation cover mapping of Pench-Kanhan-Tawa & Satpura valley Coalfield taken up based on satellite data of the year 2023.

1.2 Objectives

The objective of the present study is to prepare a regional land use and vegetation cover map of Pench-Kanhan-Tawa & Satpura Valley coalfield on 1:50,000 scale based on satellite data of the year 2023, 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 updation 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 & Accessibility

Pench-Kanhan-Tawa & Satpura Valley Coalfield covering an area of about 8457.74 Sq. Km. lies in the Chhindwara and Betul district of Madhya Pradesh. It forms the southern fringes of Satpura basin. This coalfield has been divided into four parts: Pench, Kanhan , Tawa and Satpura . It is bounded by Latitude 21^0 45' to 22^0 45' and Longitudes 77^0 45' to 79^0 15' and located in the central part of India i,e M.P. The coalfield area is covered under Survey of India open series topo-sheet no. F43L/7, F43L/8, F43L/11, F43L/12, F43L/14, F43L/15, F43L/16, F44G/2, F44G/3, F44G/4, F44G/6, F44G/7, F44G/8, F44G/10, F44G/11, F44G/12, F44G/13, F44G/14, F44G/15, F44G/16, F44H/1 & F44H/2 on RF 1:50000.This coalfield holds a premier position in India for having a considerable share of reserve of thermal grades of non-coking coal.

Pench-Kanhan-Tawa & Satpura Valley coalfield is well connected by rail and road ways. Parasia is the major mining town in the coalfield situated in Pench which is connected to the district town Chhindwara (27Km) in the south east via MP State Highway No.19 and South-Eastern Railway Barkuhi Branch (0.76 m gauge). Parasia is connected to Barkuhi and Chandmeta via SE railway (Barkuhi branch) in the west and Rawanwara (4.0 Km) towards east. Broad gauge line of Central Railways (Amla-Parasia Branch) is passing south of the coalfield connecting Parasia with Amla (87 Km) via Jamai (17 Km). The nearest airport is Nagpur at 160 Km. away from Chhindwara. MP State Highway No. 43 is running through the coalfield connecting Parasia, Chandmeta, Bhamodi, Eklehra in the east; Jamai, Damua in central part (Kanhan Area) and Sarni, Bagdona in the west (Tawa Valley). Satpura Reservoir is situated in the southern edge of Tawa valley connected to Sarni (5 Km.) by an all-weather road built by Madhya Pradesh State Electricity Board. Sarni Thermal Power Station is one of the coal based power plants of MPPGCL situated 18 Km. from Ghora Dongri railway station.

1.4 Drainage

The southern and eastern part of Tawa valley is hilly and rugged with thick forest cover whereas the western and north-western parts are comparatively flat. Tawa river flowing to the west and south is controlling the drainage of Tawa reservoir. Few seasonal nallahs (Latiya Nala, Dagdaga Nala etc.) originating from Kilandev Pahad, Bagdev Pahad, Shri Pahar and other elevated regions discharge in to Tawa river which flows in westerly direction. Satpura dam has been built across Tawa river to store water for Thermal Power Station at Sarni as well as to regulate the flow of water in the downstream of Tawa river. Pench-Kanhan area exhibits a rugged topography covered with Deccan Trap. The terrain comprises of many hills and valleys, structural hills, covered by Gondwanas, are seen in northern part; denotational hills in southern part and dissected Deccan plateau in eastern and north-eastern parts. The area is drained by two major rivers - Pench and Kanhan river (flowing towards south east) and their tributaries namely Gonur, Magrahi, Ghatamai, Sukri river, Bor Nala, Rakhi Nala, Tambiya Nadi, Bardhar Nadi etc. The recent alluvium deposits are found at places along these rivers.

1.5 Reserved Forests

Sobhapur RF, Ladardev RF are situated in the western part (Tawa) of Pench-Kanhan-Tawa Valley coalfields. Extensive Asir RF in the northern part of Tawa valley and Kanhan area is the main reserved forest in the coalfields. There are number of reserved forests in the Pench area – Bilawar RF, Garadei RF, Kotakhari RF, Dhob RF, Marwa RF, Bhandariya RF, Rawanwara RF, Nawegaon RF, Duddi RF, Thaonri RF, Bardiya RF in the central part; Urdhan RF, Gunor RF, Naheriya RF in the easternmost part & Thesgora RF in the south-eastern part of the coalfields.

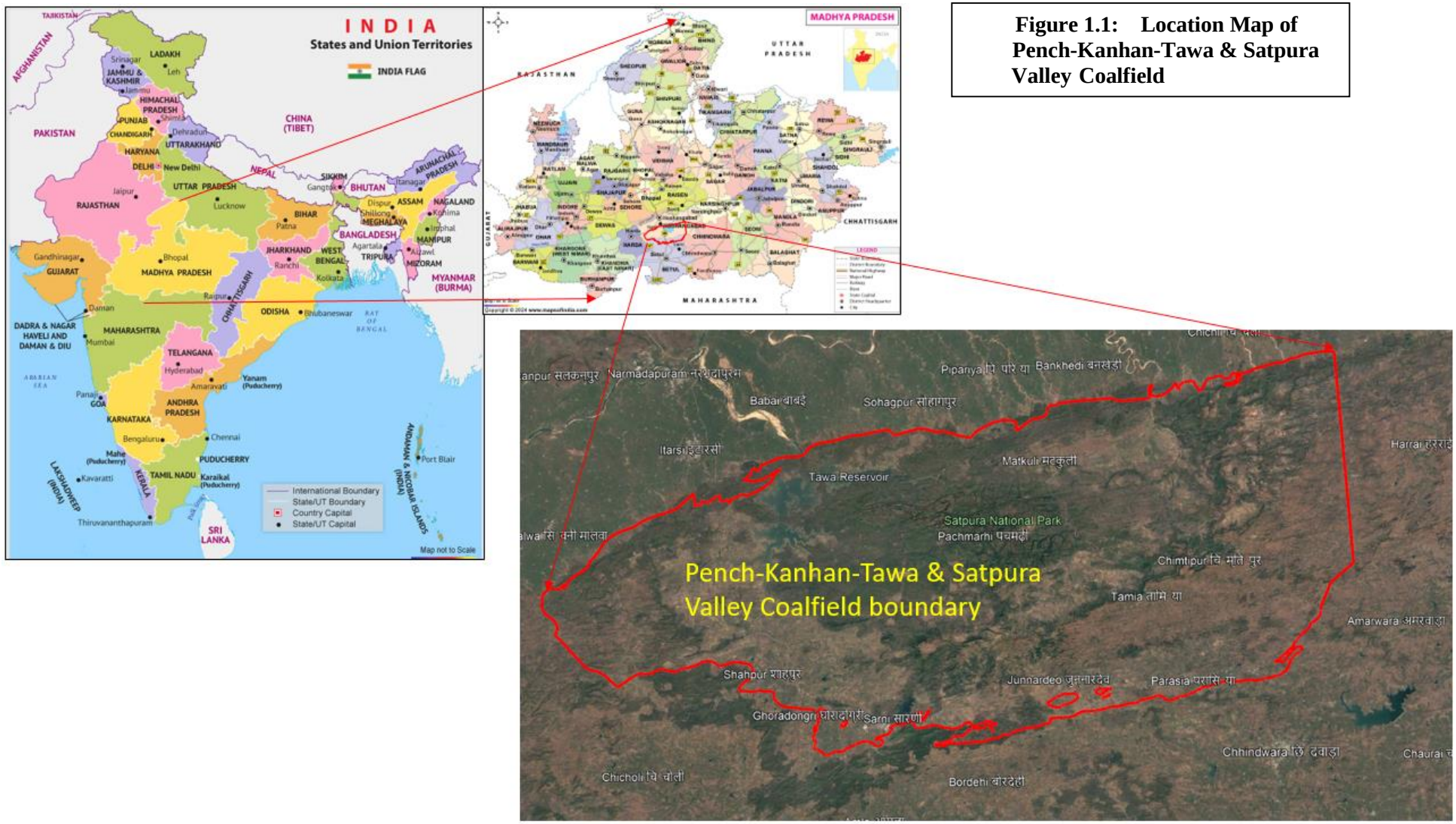


Figure 1.1: Location Map of Pench-Kanhan-Tawa & Satpura Valley Coalfield

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.

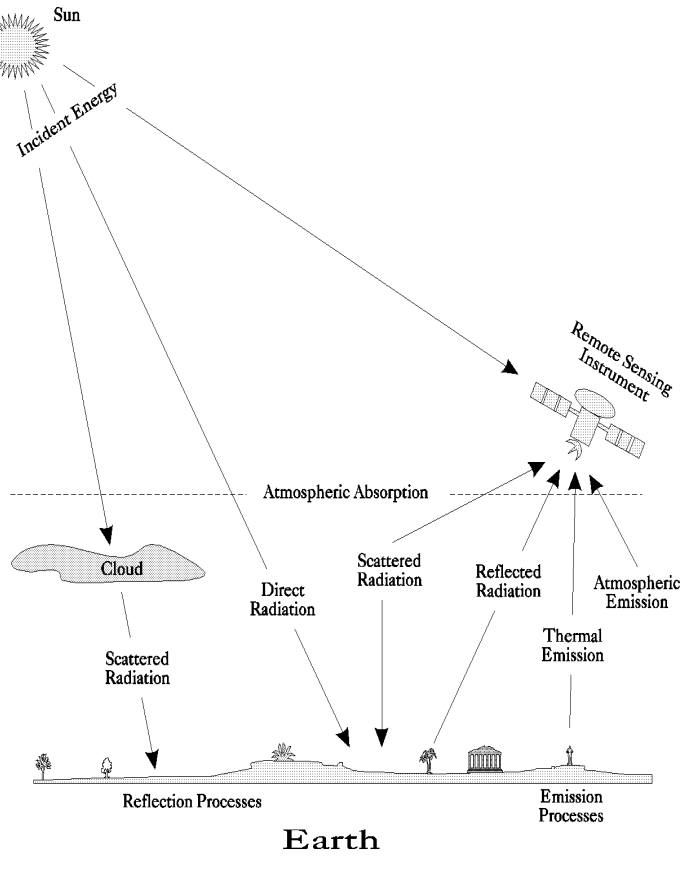


Figure 2.1 Remote sensing radiation system

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.

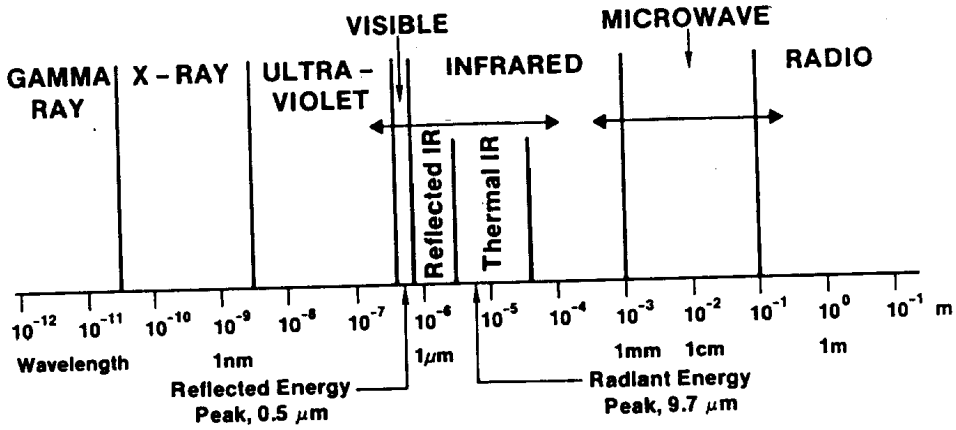


Figure 2.2 Electromagnetic spectrum. Expanded versions of the visible, infrared and microwave regions are shown in Figure 2.3.

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).

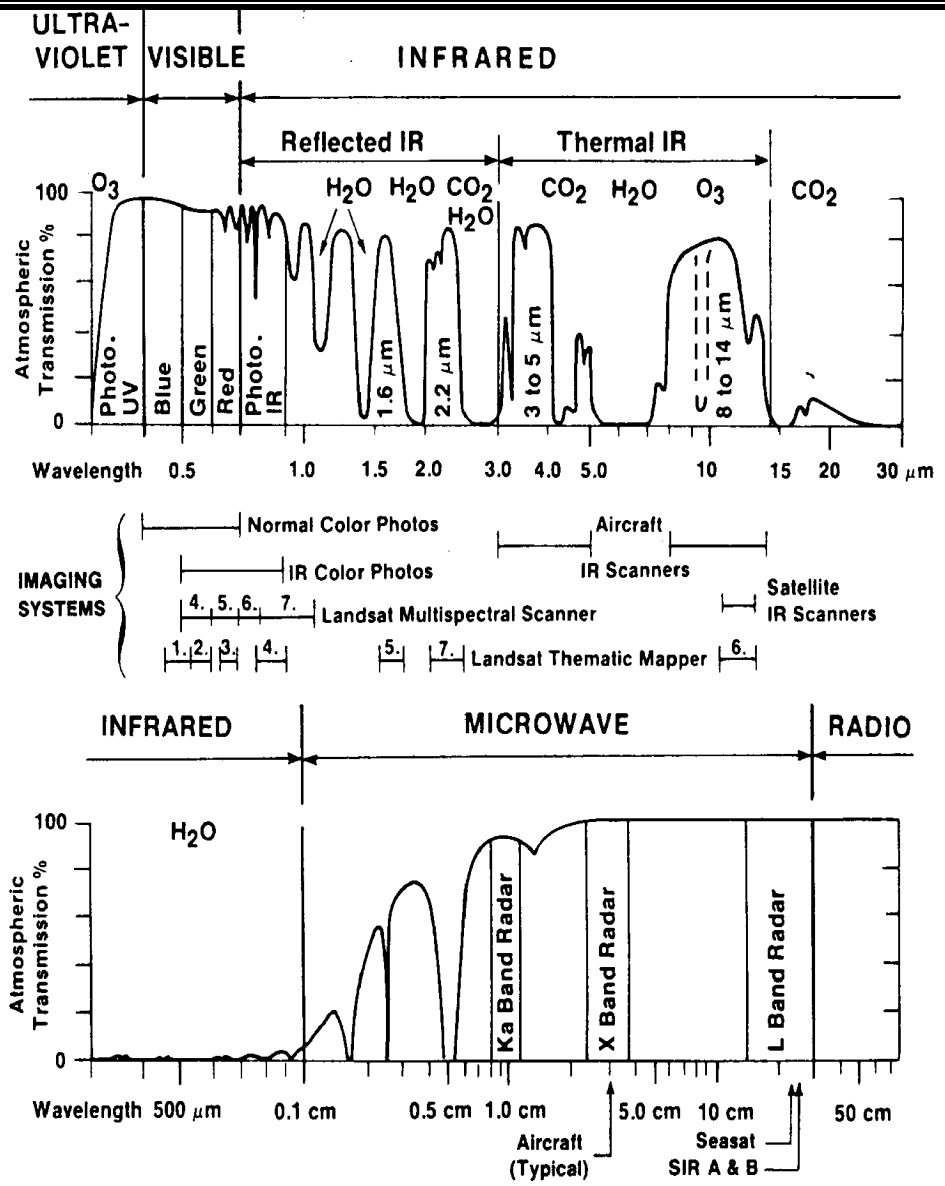


Figure 2.3 Expanded diagrams of the visible and infrared regions (upper) and the microwave regions (lower) showing atmospheric windows. Wavelength bands of commonly used remote sensing systems are indicated. Gases responsible for atmospheric absorption are shown.

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 14.00	**µm** **µm**	Principal atmospheric windows in the thermal region. Images at these wavelengths are acquired by optical-mechanical scanners and special vediocon 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. 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) that 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 (airborne/satellite) in conjunction with traditional techniques harbours in an efficient, speedy and cost-effective method for natural resource management due to its inherited capabilities of being multispectral, repetitive and synoptic areal coverage. Generation of environmental 'Data Base' on land use, soil, forest, surface and subsurface water, topography and terrain characteristics, settlement and transport network, etc., and their monitoring in near real - time is very useful for environmental management planning; this is possible only with remote sensing data.

2.4 Data Source

The following data are used in the present study:

- **Primary Data**

  Remote Sensing Satellite data viz. Resourcesat-IRS-R2A having 5.8 m spatial resolution of the month Mar 2023. spatial resolution was used in the present study. The raw digital satellite data was obtained from NRSC, Hyderabad, through FTP connection via internet.

- **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. For **Pench-Kanhan-Tawa & Satpura Valley Coalfield,** Survey of India open series topo-sheet no. F43L/7, F43L/8, F43L/11, F43L/12, F43L/14, F43L/15, F43L/16, F44G/2, F44G/3, F44G/4, F44G/6, F44G/7, F44G/8, F44G/10, F44G/11, F44G/12, F44G/13, F44G/14, F44G/15, F44G/16, F44H/1 & F44H/2 on RF 1:50000 as well as map showing details of location of area boundary, block boundary and road supplied by WCL 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 Resourcesat satellite/sensor that was 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-R2A	L4/FX	0.52 - 0.59 0.62 - 0.68 0.77 - 0.86	10-bit	5.8 m 5.8 m 5.8 m	24 days	India

2.6 Data Processing

The details of data processing carried out in the present study are shown in Figure 2.4. The processing methodology 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) Final thematic map preparation.

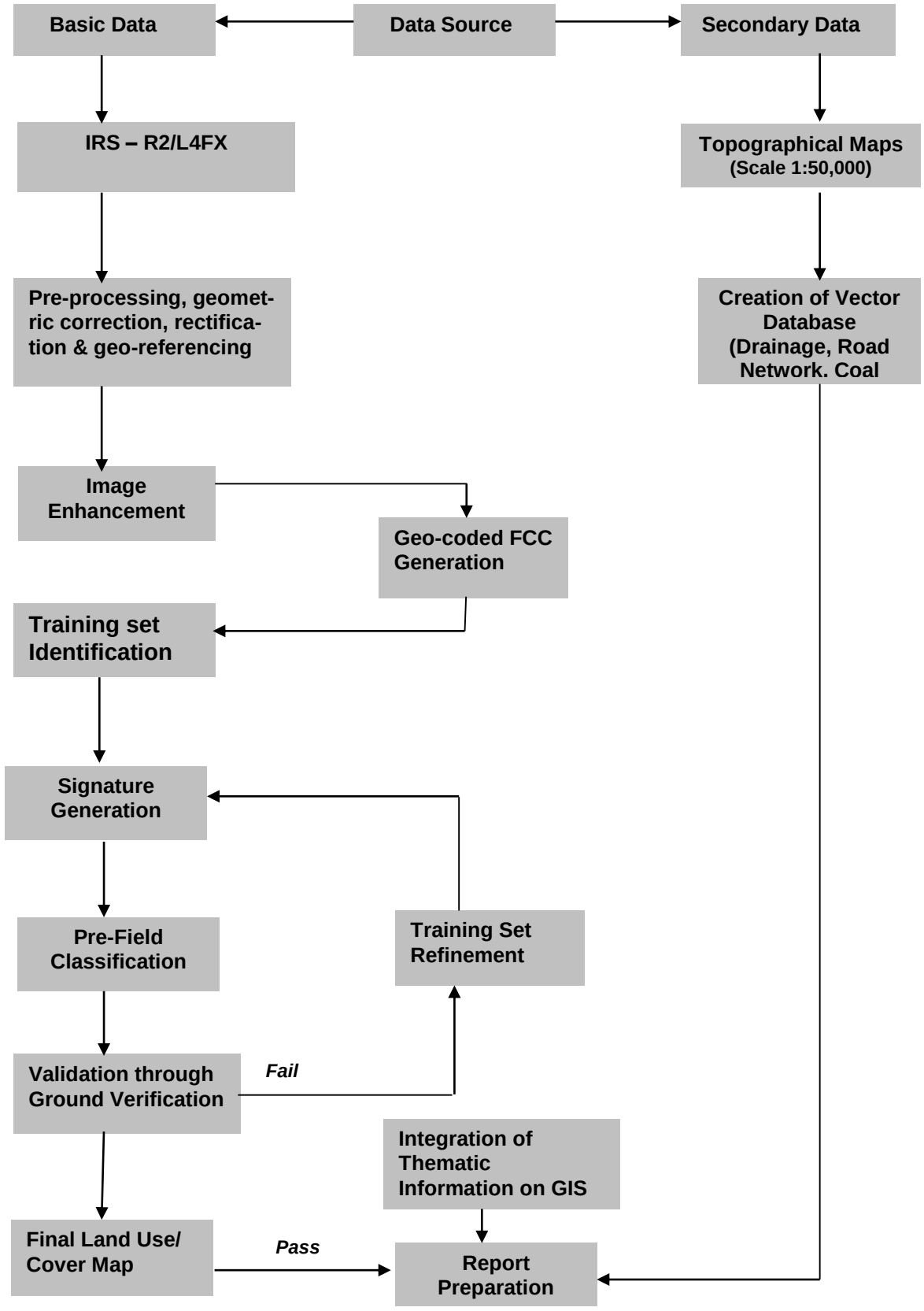


Fig-2.4 –Methodology of Land Use/Vegetation Cover Analysis

2.6.1 Geometric correction, rectification and geo-referencing

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*.

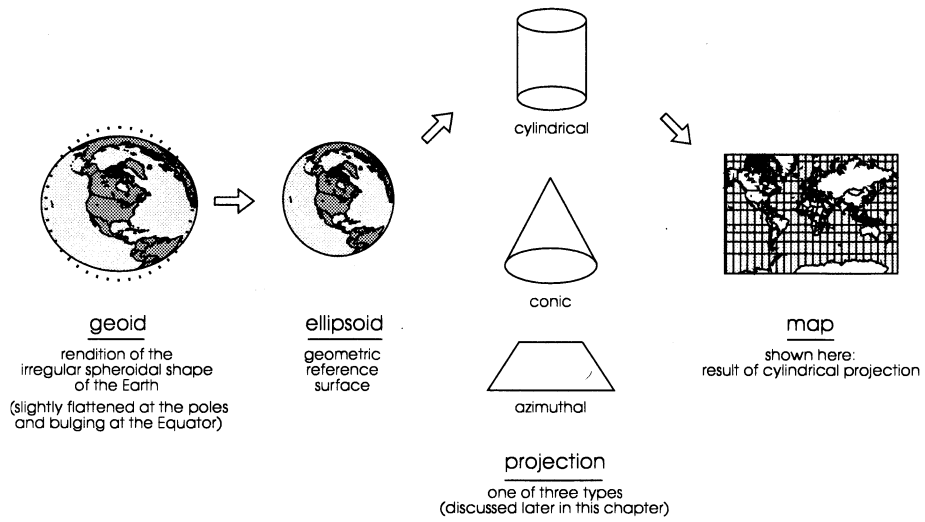


Fig 2.5: Geoid – Ellipsoid – Projection Relationship

In the present study, ***UTM Zone 44 projection*** was used so as to prepare the map compatible with the SoI topo-sheets**.** Image enhancement and other image processing were carried out using Erdas IMAGINE 2022 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 was applied on the image data using Erdas IMAGINE 2022 s/w. The enhanced and geocoded FCC image of Pench-Kanhan-Tawa & Satpura Valley Coalfield is shown in Plate No. 1.

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, 250 points were selected to generate the training sets.

2.6.4 Signature generation and classification

Image classification was carried out using the maximum likelihood 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 Erdas IMAGINE 2022 s/w. The classified image for the year 2023 for Pench-Kanhan-Tawa and Satpura Valley Coalfield is shown in Plate No.2.

2.6.5 Creation/overlay of vector database

Plan showing coal block boundary is superimposed on the image as vector layer in the Arc GIS database. Road and drainage network are also digitised on Arc GIS database and

superimposed on the classified image. Geo-environmental data base created on GIS platform to analyse the impact of mining on land use and vegetation cover at interval of three years.

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 classification accuracy matrix is shown in Table 2.3.

Classification accuracy in case of Plantation on OB Dump, Sand Body and Barren OB Dump was 100%. Classification accuracy in case of Dense Forest and Water Bodies lie between 90% to 100%. In case of open forest, built-up land, the classification accuracy varies from 80.0% to 90.0%. Classification accuracy for scrubs was 73.3% due to poor ***signature separability index***. The overall classification accuracy is 90%.

2.6.7 Final land use/vegetation cover map preparation

Final land use/vegetation cover map (Plate - 2) was generated on 1:50,000 scale & printed in 1: 90,000 scale for handling convenience using HP Design jet T7200 Colour plotter and the same is enclosed in the report. A soft copy in .pdf format is also attached.

Table 2.3: Classification Accuracy Matrix for Pench-Kanhan-Tawa & Satpura Valley Coalfield

Sl. No.	Classes in the Satellite Data	Class	Total Obsrv. Points	Land use classes as observed in the field									
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	Urban Settlement	C1	05	5									
2	Dense Forest	C2	10		8	1	1						
3	Open Forest	C3	10		1	8	1						
4	Scrubs	C4	10		1	1	7	1					
5	Social Forestry	C5	10				1	8	1				
6	Agriculture Land	C6	10					1	9				
7	Waste Upland	C7	10							10			
8	Sand Body	C8	10								10		
9	Quarry Area	C9	10									10	
10	Water Bodies	C10	10										10
Total no. of observation points			**110**	05	10	10	10	10	10	10	10	10	10
% of commission				**00.0**	**20.0**	**20.0**	**30.0**	**20.0**	**10.0**	**0.0**	**0.0**	**0.0**	**0.0**
% of omission				**00.0**	**20.0**	**20.0**	**30.0**	**20.0**	**10.0**	**0.0**	**0.0**	**0.0**	**0.0**
% of Classification Accuracy				**100.0**	**80.0**	**80.0**	**70.0**	**80.0**	**90.0**	**100.0**	**100.0**	**100.0**	**100.0**
Overall Accuracy (%)			**90.000**										

Chapter 3

Land Use/ Vegetation Cover Mapping

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/ vegetation cover.

Remote sensing data with its various spectral and spatial resolution offers comprehensive and accurate information for mapping and monitoring of land use/cover pattern, dynamics of changing pattern and trends 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/Cover Classification

The array of information available on land use/cover requires be arranging or grouping under a suitable framework in order to facilitate the creation of a land use/cover database. Further, to accommodate the changing land use/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. Land use map was prepared on

the basis of image interpretation carried out based on the satellite data for the year 2023 for Pench-Kanhan-Tawa & Satpura Valley coalfield and following land use/cover classes are identified (Table 3.1).

***Table 3.1*:**
Land use/cover classes identified in Pench-Kanha-Tawa & Satpura Valley Coalfield

	Level -I	***Level -II***
1.	**Built-Up Land**	1.1 Urban 1.2 Rural 1.3 Industrial
2.	**Forest/Vegetation Cover**	2.1 Dense Forest 2.2 Open Forest 2.3 Scrub 2.4 Plantation under Social Forestry 2.5 Plantation on OB Dumps 2.6 Plantation on **B**ackfill
3.	**Mining Area**	3.1 Coal Quarry 3.2 Barren OB Dump 3.3 Barren Backfill 3.4 Coal Dump 3.5 Water filled Quarry
4.	**Agricultural land**	4.1 Crop Land 4.2 Fallow Land
5.	**Waste Land**	5.1 Waste upland with/without scrubs 5.2 Fly Ash Pond 5.3 Sand Body 5.4 Gullied Land
6.	**Water bodies**	6.1 River/ Streams /Reservoir/ Ponds

Following maps are prepared on 1:50,000 scale:

Plate No. 1: Drawing No. HQ/REM/ 4/A4/23/01: FCC (IRSR2A-L4FX) data of Pench-Kanhan-Tawa and Satpura Valley Coalfield of the year 2023) with Coalfield boundary and other infrastructural details.

Plate No. 2: Drawing No. HQ/REM/ 4/A4/23/02- Land use/Cover Map of Pench-Kanhan-Tawa Valley Coalfield based on Satellite data (IRSR2A-L4FX) of the year 2023.

3.3 Land use/cover Analysis

Satellite data of the year 2023 was processed using Erdas IMAGINE 2022 image processing s/w in order to interpret the various land use/cover classes present in the study area of Pench-Kanhan-Tawa &Satpura Valley Coalfield covering 8457.74 Km^2. Distribution of various land use classes are shown in the Pie Charts for the year 2023 is given in (Fig. 3.1)

Table-3.2
Land use/ Vegetation Cover in the Pench –Kanhan–Tawa & Satpura Valley Coalfield for the year 2023

Sl. No.	Land Use / Cover Classes		Mar-23 IRS R2/2A LISS-IV	
	Level - I	Level - II	Km^2	%
1	Vegetation Cover	*Dense Forest*	2814.21	33.27
		Open Forest	2056.23	24.31
		Sub -Total	**4870.44**	**57.59**
		Scrubs	566.53	6.70
		Social Forestry	22.57	0.27
		Plantation on OB	5.36	0.06
		Plantation on Backfill	0.49	0.01
		Sub – Total	**28.42**	**0.34**
		Total	**5465.39**	**64.62**
2	Mining Area	*Coal Quarry*	2.59	0.03
		Advanced Quarry Site	0.00	0.00
		Barren OB Dump	3.56	0.04
		Barren Backfill	1.36	0.02
		Coal Dump	1.49	0.02
		Water filled Quarry	2.16	0.03
		Sub – Total	**11.16**	**0.13**
3	Agricultural Land	*Crop Land*	584.62	6.91
		Fallow Land	1469.18	17.37
		Sub – Total	**2053.80**	**24.28**
4	Waste Land	*Waste land with / without Scrubs*	560.68	6.63
		Sand Body	81.99	0.97
		Fly Ash Pond	4.52	0.05
		Gullied Land	1.67	0.02
		Sub-Total	**648.86**	**7.67**
5	Water Body	*River, nallah, pond etc.*	**215.80**	**2.55**
6	Settlement	*Rural*	30.52	0.36
		Urban	28.53	0.34
		Industrial	3.68	0.04
		Sub-Total	**62.73**	**0.74**
		TOTAL	**8457.74**	**100.00**

Table:3.3
Comparison Status of Land Use/Cover Pattern in Pench-Kanhan-Tawa & Satpura Valley Coalfield during the year 2020 & 2023

LAND USE CLASSES	Year-2020		Year-2023		Change w.r.t. Yr 2020		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
SETTLEMENT							
Rural Settlements	11.02	0.14	25.63	0.32	14.61	0.18	Based on image interpretation of current satellite data Settelement area has been updated
Urban Settlements	18.59	0.23	24.50	0.30	5.91	0.07	
Industrial Settlements	8.51	0.11	3.21	0.04	-5.30	-0.07	
Total Settlements	**38.12**	**0.47**	**53.34**	**0.66**	**15.22**	**0.19**	
VEGETATION COVER							
FOREST							
Dense Forest	2798.21	34.73	2798.57	34.74	0.36	0.00	Increase in Forest Area due to aforestation effort
Open Forest	2030.30	25.20	2031.35	25.21	1.05	0.01	
Total Forest (A)	**4828.51**	**59.93**	**4829.92**	**59.95**	**1.41**	**0.02**	
SCRUBS							
Scrubs (B)	407.81	5.06	439.96	5.46	32.15	0.40	Natural scrub grown in many places due to high soil fertility
PLANTATION							
Social forestry	15.39	0.19	18.68	0.23	3.29	0.04	Plantation area has increased. This may be due to plantation being carried out by WCL in many areas as well as increase in Social Forestry area
Plantation on OB	5.35	0.07	5.36	0.07	0.01	0.00	
Plantation on backfill	0.47	0.01	0.49	0.01	0.02	0.00	
Total Plantation (C)	**21.21**	**0.26**	**24.53**	**0.30**	**3.32**	**0.04**	
Total Vegetation (A+B+C)	**5257.53**	**65.26**	**5294.41**	**65.72**	**36.88**	**0.46**	
MINING AREA							
Coal Quarry	1.85	0.02	2.59	0.03	0.74	0.01	Minining area has increased due to mine advance to meet the high production requirement to meet the growing coal demand
Barren OB Dump	2.02	0.03	3.56	0.04	1.54	0.02	
Barren Backfilled	1.33	0.02	1.36	0.02	0.03	0.00	
Coal Dump	3.38	0.04	1.49	0.02	-1.89	-0.02	
Advance Quarry	0.00	0.00	0.00	0.00	0.00	0.00	
Water filled quarry	2.31	0.03	2.16	0.03	-0.15	0.00	
Total Mining Area	**10.89**	**0.14**	**11.16**	**0.14**	**0.27**	**0.00**	
AGRICULTURE							
Crop Land	556.96	6.91	548.61	6.81	-8.35	-0.10	Total agricultue land has increased
Fallow Land	1333.13	16.55	1359.95	16.88	26.82	0.33	
Total Agriculture	**1890.09**	**23.46**	**1908.56**	**23.69**	**18.47**	**0.23**	
WASTELANDS							
Waste land	609.70	7.57	498.69	6.19	-111.01	-1.38	Decrease in Waste Land may be due to interclass conversion as well as identification of new Waste Land class
Sand Body	46.17	0.57	74.17	0.92	28.00	0.35	
Fly Ash Pond	4.22	0.05	4.54	0.06	0.32	0.00	
Gullied Land	4.81	0.06	2.11	0.03	-2.70	-0.03	
Total Wasteland	**664.90**	**8.25**	**579.51**	**7.19**	**-85.39**	**-1.06**	
WATERBODIES							
River, nallah, pond etc.	**195.08**	**2.42**	**209.63**	**2.60**	**14.55**	**0.18**	Due to inclusion of seasonal nala and ponds on interpretation of satellite data
TOTAL	**8056.61**	**100.00**	**8056.61**	**100.00**	**0.00**	**0.00**	

Note: *Comparison of Land use/ Vegetation Cover classes in the Pench-Kanhan-Tawa & Satpura Valley Coal-field has been done using the coalfield boundary that was used for previous study undertaken in the year 2020. It may also be noted that the Coalfield Boundary has been updated for this study from 8056.61 Km^2 (2020) to 8457.74 Km^2 in 2023.*

3.3.1 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 Pench-Kanhan-Tawa & Satpura Valley Coalfield as per the updated coalfield boundary covers an area of 62.73 km^2 (0.74%) out of the total coalfield area. Analysis of the satellite data of the year 2023 indicated that settlement coming under the updated coalfield boundary of Pench-Kanhan-Tawa & Satpura Valley Coalfield is distributed between Urban (28.53 km^2; 0.34%), Rural (30.52 km^2; 0.36%) and Industrial (3.68 km^2; 0.04%) (Refer Table 3.2).

The variation of area statistics of Settlement Area based on the old Coalfield boundary is shown in Table 3.4.

Table:3.4

Status of change in settlement in Pench-Kanhan –Tawa & Satpura Valley Coalfield during the year 2020 & 2023

LAND USE CLASSES	Year-2020		Year-2023		Change w.r.t. Yr 2020		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
SETTLEMENT							
Rural Settlements	11.02	0.14	25.63	0.32	14.61	0.18	Based on image interpretation of current satellite data Settelement area has been updated
Urban Settlements	18.59	0.23	24.50	0.30	5.91	0.07	
Industrial Settlements	8.51	0.11	3.21	0.04	-5.30	-0.07	
Total Settlements	**38.12**	**0.47**	**53.34**	**0.66**	**15.22**	**0.19**	

Settlements in Pench-Kanhan-Tawa & Satpura Valley Coalfield cover an area of 53.34 km^2 (0.66%). Analysis of the satellite data of the year 2023 indicates that settlements coming under the old coalfield boundary of Pench-Kanhan-Tawa & Satpura Valley Coalfield were distributed between *Urban* (24.50 km^2; 0.30%), *Rural* (25.63 km^2; 0.32%) and *Industrial* (3.21 km^2; 0.04%).

3.3.2 Vegetation cover

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 is also included under vegetation cover as social forestry and plantation on backfilled/over-burden dumps respectively.

Analysis of the satellite data of the year 2023 indicated that vegetation cover in Pench-Kanhan-Tawa & Satpura Valley Coalfield as per the updated coalfield boundary covers an area of 5465.39 Km^2 (64.62%) out of the total coalfield area of 8457.74 Km^2. Vegetation Cover coming under the updated coalfield boundary of Pench-Kanhan-Tawa & Satpura Valley Coalfield is distributed between *Dense Forest* covering area of 2814.21 Km^2 (33.27%), *Open Forest* covers 2056.23 Km^2 (24.31%); *Scrubs* has covered an area of 566.53 km^2 (6.70%), *Plantation under social forestry* occupies area of 22.57 Km^2 (0.27%), *Plantation on OB dumps* occupies 5.36 km^2 (0.06%) and *Plantation over backfilled areas* has 0.49 km^2 (0.01%) area under its influence as per the analysis of Satellite Data of the Year 2023. *(Refer Table 3.2).*

As per the old coalfield boundary that has been used in Vegetation Cover Mapping report for the year 2020, the analysis of the satellite data of the year 2023 is shown in Table 3.5.

Table:3.5

Status of change in Vegetation cover in Pench-Kanhan –Tawa & Satpura Valley Coalfield during the year 2020 & 2023

LAND USE CLASSES	Year-2020		Year-2023		Change w.r.t. Yr 2020		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
VEGETATION COVER							
FOREST							
Dense Forest	2798.21	34.73	2798.57	34.74	0.36	0.00	Increase in Forest Area due to aforestation effort
Open Forest	2030.30	25.20	2031.35	25.21	1.05	0.01	
Total Forest (A)	**4828.51**	**59.93**	**4829.92**	**59.95**	**1.41**	**0.02**	
SCRUBS							
Scrubs (B)	407.81	5.06	439.96	5.46	32.15	0.40	Natural scrub grown in many places due to high soil fertility
PLANTATION							
Social forestry	15.39	0.19	18.68	0.23	3.29	0.04	Plantation area has increased. This may be due to plantation being carried out by WCL in many areas as well as increase in Social Forestry area
Plantation on OB	5.35	0.07	5.36	0.07	0.01	0.00	
Plantation on backfill	0.47	0.01	0.49	0.01	0.02	0.00	
Total Plantation (C)	**21.21**	**0.26**	**24.53**	**0.30**	**3.32**	**0.04**	
Total Vegetation (A+B+C)	**5257.53**	**65.26**	**5294.41**	**65.72**	**36.88**	**0.46**	

Vegetation cover in the coalfield area comprises following six classes:

- Dense Forest
- Open Forest
- Scrubs
- Plantation on Over Burden(OB) Dumps
- Plantation on Backfilled area and
- Social Forestry

Dense forest – Forest having crown density of above 40% comes in this class. In the year 2020 the total area covered by dense forest were estimated to be 2798.21 km^2 area (34.73%) of the total coalfield area. Whereas in year 2023 the estimated area under dense forest has increased to 2798.57 km^2 area (34.74%). This increase in area of dense forest to 0.36 km^2 is due to afforestation efforts in the coalfield region.

Open Forest – Forest having crown density between 10% to 40% comes under this class. Open forest cover over Pench- Kanhan-Tawa & Satpura Valley Coalfield which was estimated to be 2030.30 km^2 (25.20%) in 2020 has increased to 2031.35 km^2 (25.21%) of the total coalfield area in the year 2023. Thus the increase in open forest area of 1.05 km^2 (0.01) % of the total coalfield area. This increase in open forest area is due to afforestation effort**.**

Scrubs – Scrubs are vegetation with crown density less than 10%. Scrubs in the coalfield are seen to be scattered signature all over the area mixed with wastelands. It is observed that Scrubs covered over Pench-Kanhan-Tawa & Satpura Valley Coalfield which was estimated to 407.81 km^2 (5.06%) in the year 2020 has increased to 439.96 km^2 (5.46%) of the total Coalfield area in the year 2023.This increase of 32.15 km^2 area (0.40%) of the total Coalfield area is because of growth of natural scrub due to high soil fertility.

Social Forestry – Plantation which has been carried out on wastelands, along the roadsides and colonies on green belt come under this category. Analysis of satellite based data of the year 2023 reveals that Social Forestry covers 18.68 km^2 area (0.23%) of the Pench-Kanhan-Tawa & Satpura Valley coalfield in 2023 with respect to area covered by social forestry of 15.39 km^2 area (0.19%) in the year 2020. Increase in area covered by social forestry in the year 2023 is estimated to 3.29 km^2 (0.04%). It is due to plantation carried out by WCL in the colony and along road side in the mining area.

Plantation over OB Dump– Analysis of the satellite data of the year 2023 reveals that WCL has carried out plantation on OB dumps during 3 year span of time for maintaining the ecological balance of the area. The plantation on the OB dumps is estimated to be 5.36 km^2 (0.07%) of the coalfield area in the year 2023 as compared to area covered by plantation on OB 5.35 Sq. km, (0.07%) in the year 2020. The increase in area covered by plantation on OB is estimated to be 0.01 Km^2 in the year 2023 with respect to Year 2020. This increase is due to plantation on OB carried out by WCL.

Plantation on Backfilled Area- The plantation on backfilled area in the year 2023 is estimated to 0.49 Km^2 (0.01%) in the year 2023. Whereas planation on backfill in the year 2020 was 0.47 Km^2 (0.01%).

However, it is important to note here that total area under plantation in mining area in the year 2023 is showing increasing trend as compared to the year 2020.

3.3.3 Mining Area

The mining area includes the area of

- Coal Quarry
- Advance Quarry Site
- Barren OB Dumps
- Barren Backfilled Area
- Coal Dumps and
- Water Filled Quarry Area.

Analysis of the satellite data of the year 2023 indicates that mining area coming under the updated Pench-Kanhan-Tawa & Satpura valley coalfield boundary is distributed between Coal quarry constituting 2.59 Km^2 (0.03%), Coal dumps constituting 1.49 Km^2 (0.02%), Barren over burden dumps covering an area of 3.56 Km^2 (0.04%), Barren Backfilled areas constituting 1.36 Km^2 (0.02%) and Water Filled Quarry constituting 2.16 km^2 (0.03%). Total area under mining activities is 11.16 km^2 (0.13%) (Refer Table 3.2).

As per the old coalfield boundary that has been used in Vegetation Cover Mapping report for the year 2020, the analysis of the satellite data of the year 2023 is shown in Table 3.6.

Table:3.6 Status of change in Mining area in Pench- Kanhan –Tawa & Satpura Valley Coalfield during the year 2020 & 2023

LAND USE CLASSES	Year-2020		Year-2023		Change w.r.t. Yr 2020		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
MINING AREA							
Coal Quarry	1.85	0.02	2.59	0.03	0.74	0.01	Minining area has increased due to mine advance to meet the high production requirement to meet the growing coal demand
Barren OB Dump	2.02	0.03	3.56	0.04	1.54	0.02	
Barren Backfilled	1.33	0.02	1.36	0.02	0.03	0.00	
Coal Dump	3.38	0.04	1.49	0.02	-1.89	-0.02	
Advance Quarry	0.00	0.00	0.00	0.00	0.00	0.00	
Water filled quarry	2.31	0.03	2.16	0.03	-0.15	0.00	
Total Mining Area	**10.89**	**0.14**	**11.16**	**0.14**	**0.27**	**0.00**	

Total mining area covers 11.16 km^2 (0.14%) in the year 2023, out of which coal quarry covers 2.59 km^2 (0.03%), barren OB dump covers 3.56 km^2 (0.04%), backfill covers 1.36 km^2 (0.02%), coal dump covers 1.49 km^2 (0.02%), and water filled quarry covers 2.16 km^2 (0.03%). Mining

area has increased to 11.16 Km^2 (0.14%) in the year 2023 as compared to 10.89 Km^2 (0.14%) in the year 2020.This increase of 0.27 Km^2 in mining area during span of three years is due to mine advancement to meet the high production requirement.

3.3.4 Agricultural Land

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.

Analysis of the satellite data of the year 2023 indicated that agriculture coming under the updated Pench- Kanhan – Tawa & Satpura Valley Coalfield boundary is distributed between Crop Land (584.62 km^2; 6.91%), and Fallow Land (1469.18 km^2; 17.37%). Agricultural land in Pench- Kanhan –Tawa & Satpura Valley Coalfield covers an area of 2053.80 km^2 (24.28%). (Refer Table 3.2)

As per the old coalfield boundary that has been used in Vegetation Cover Mapping report for the year 2020, the analysis of the satellite data of the year 2023 is shown in Table 3.7.

Table:3.7 Status of change in Agriculture area in Pench- Kanhan –Tawa & Satpura Valley Coalfield during the year 2020 & 2023

LAND USE CLASSES	Year-2020		Year-2023		Change w.r.t. Yr 2020		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
AGRICULTURE							
Crop Land	556.96	6.91	548.61	6.81	-8.35	-0.10	Total agricultue land has increased
Fallow Land	1333.13	16.55	1359.95	16.88	26.82	0.33	
Total Agriculture	**1890.09**	**23.46**	**1908.56**	**23.69**	**18.47**	**0.23**	

Area under agriculture land has increased from 1890.09 Km^2 (23.46%) in the year 2020 to 1908.56 Km^2 (23.69%) in the year 2023. This increase of 18.47 Km^2 (0.23%) area under agriculture land in the year 2023 is due to conversion of some waste land in fallow land and crop land.

3.3.5 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). This also includes fly ash pond, gullied land and sand body formed on the banks of the river owing to the non flow of water there.

Analysis of satellite data of 2023 reveals that waste land in the updated Pench- Kanhan –Tawa & Satpura Valley Coalfield boundary, occupies 648.86 Km^2 (7.67%) out of which Waste upland with or without scrubs occupies 560.68 Km^2 (6.63%), Fly Ash Ponds / Sludge Ponds constitute 4.52 Km^2 (0.05%), Gullied land constitutes 1.67 Km^2 (0.02%) and Sand bodies constitute 81.99 km^2 (0.97%). (Refer Table 3.2).

As per the old coalfield boundary that has been used in Vegetation Cover Mapping report for the year 2020, the analysis of the satellite data of the year 2023 is shown in Table 3.8.

Table:3.8

Status of change in Waste Land in Pench- Kanhan –Tawa & Satpura Valley coalfield during the year 2020 & 2023

LAND USE CLASSES	Year-2020		Year-2023		Change w.r.t. Yr 2020		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
WASTELANDS							
Waste land	609.70	7.57	498.69	6.19	-111.01	-1.38	Decrease in Waste Land may be due to interclass conversion as well as identification of new Waste Land class
Sand Body	46.17	0.57	74.17	0.92	28.00	0.35	
Fly Ash Pond	4.22	0.05	4.54	0.06	0.32	0.00	
Gullied Land	4.81	0.06	2.11	0.03	-2.70	-0.03	
Total Wasteland	**664.90**	**8.25**	**579.51**	**7.19**	**-85.39**	**-1.06**	

Analysis based on satellite data of the year 2023 reveals that in Pench-Kanhan-Tawa & Satpura Valley Coalfields, wasteland covers an area of 579.51 Km^2 (7.19%). out of which waste upland is 498.69 Km^2 (6.19%), fly ash pond is 4.54 Km^2 (0.06%), Gullied land is 2.11 Km^2 (0.03%) and sand body is 74.17 Km^2 (0.92%).

3.3.6 Surface Water bodies

It is the area of impounded water includes natural lakes, rivers/streams and man made canal, reservoirs, tanks etc.

Analysis of satellite data of 2023 reveals that surface water bodies in the updated Pench-Kanhan –Tawa & Satpura Valley Coalfield boundary, occupies 215.80 Km^2 (2.55%).

As per the old coalfield boundary that has been used in Vegetation Cover Mapping report for the year 2020, the analysis of the satellite data of the year 2023 is shown in Table 3.9.

Table-3.9

Status of change in Water Body in Pench-Kanhan –Tawa & Satpura Valley coalfield during the year 2020 & 2023

LAND USE CLASSES	Year-2020		Year-2023		Change w.r.t. Yr 2020		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
WATERBODIES							
River, nallah, pond etc.	195.08	2.42	209.63	2.60	14.55	0.18	Due to inclusion of seasonal nala and ponds on interpretation of satellite data

The water bodies in the study area had been estimated to be 195.08 Km^2 which was 2.42% in the year 2020. While in the year 2023, it has increased to 209.63 Km^2 which is 2.60% of the total Coalfield area. So there is an increase of area 14.55 Km^2 (0.18%) in water bodies. This increase in water body is due to inclusion of seasonal nala and ponds on interpretation of satellite data.

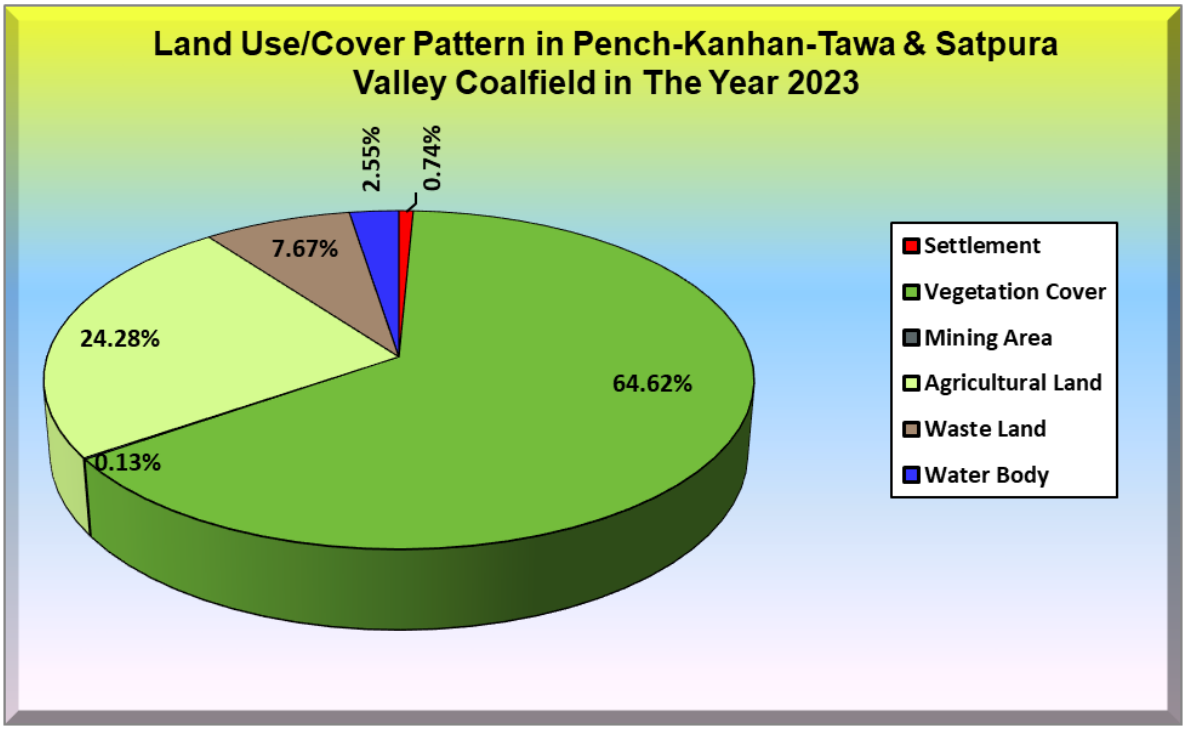


Figure-3.1 Land Use/Cover Pattern in
Pench-Kanhan-Tawa & Satpura Valley Coalfield in The Year 2023

Plate:1 FCC for Pench –Kanhan –Tawa & Satpura Valley CF Based on Satellite Data of the Year 2023

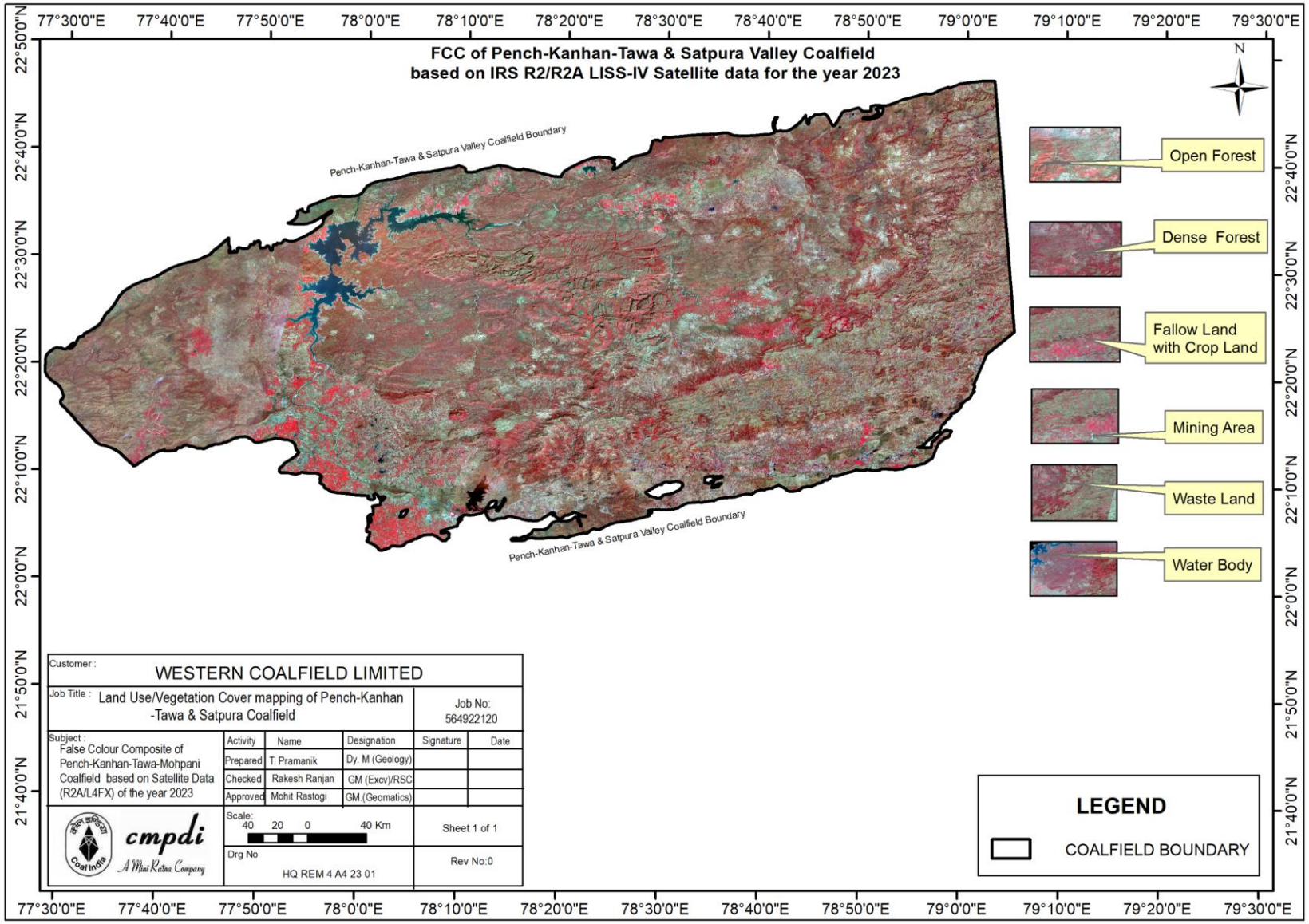
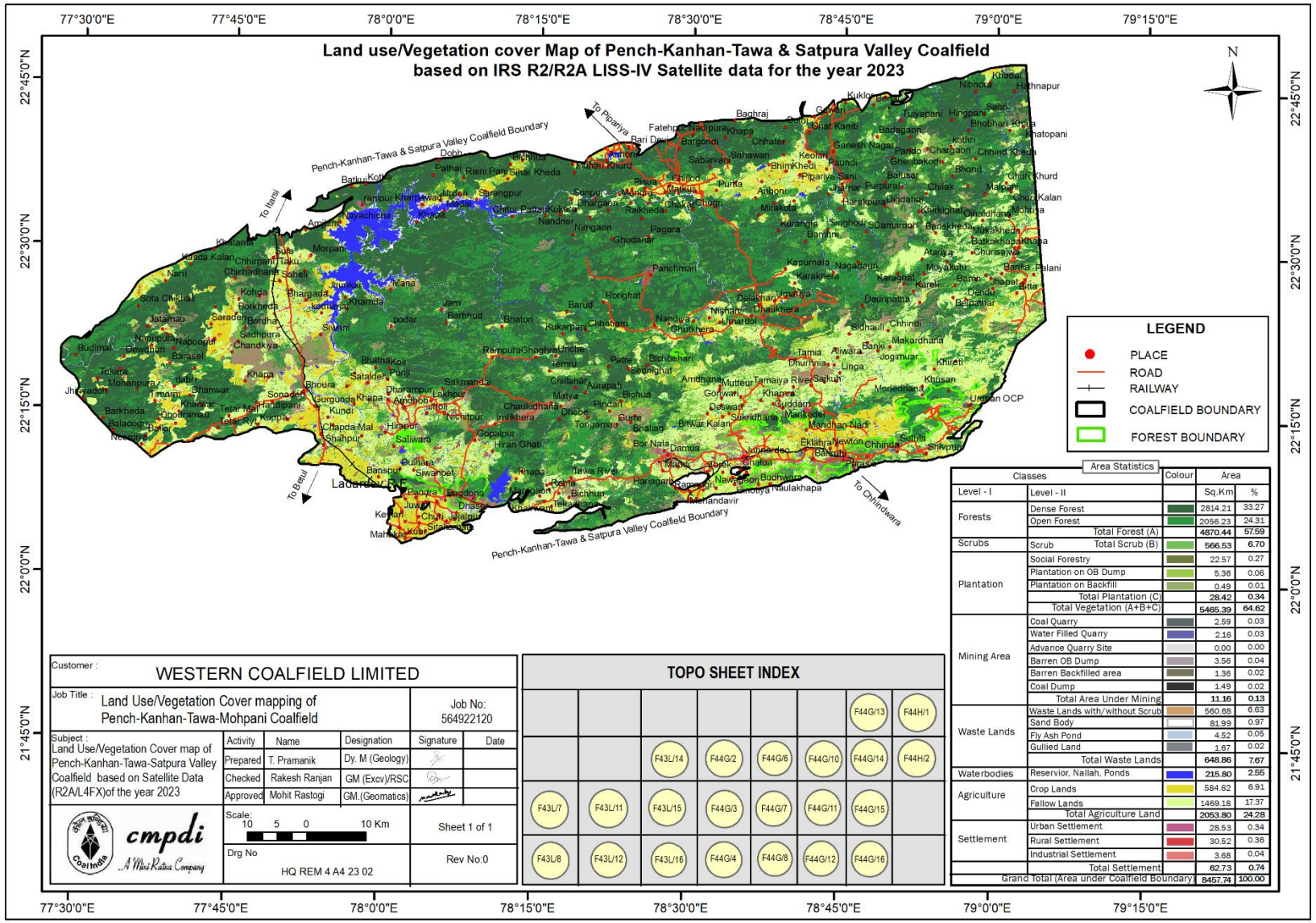


Plate:2 Land use/Vegetation cover Map of Pench-Kanhan-Tawa & Satpura Valley Coalfield based on IRS R2/R2A LISS-IV Satellite data for the year 2023



Chapter 4

Conclusion & Recommendation

4.1 Conclusion

In the present study, land use/ vegetation cover mapping has been carried out, based on IRS R2/2A, LISS4 satellite data of 2023 in order to generate the geo-environmental database on land use/vegetation cover in Pench-Kanhan-Tawa & Satpura valley Coal-field for monitoring the impact of coal mining on land environment. Change analysis in land use pattern may helps in formulating the mitigation measures required, if any.

Study reveals that the settlements in the Pench-Kanhan-Tawa & Satpura Valley Coalfields are a mix of urban, rural and industrial which covers an area of 62.73 km^2 (0.74%). Forest cover occupies 4870.44 km^2 (57.59%) and total vegetation cover including dense forests, open forests, scrubs & plantation areas occupies an area of 5465.39 km^2 (64.62%). The study further indicates that total agricultural land which includes crop and fallow land covers an area of 2053.80 km^2 (24.28%). Waste land covered an area of 648.86 km^2 (7.67%). Surface water bodies, mainly rivers, reservoir and ponds covered an area of 215.80 km^2 (2.55%).

4.2 Recommendation

The aim of this study is to incorporate the temporal changes based on satellite data to identify the pattern of vegetation cover and consequently enhance the interpretation capabilities. Keeping this in view, for the sustainable development of proposed coal mining in the area, it is recommended that;

- Similar study should be carried out regularly at interval of three years to monitor the change in land use/vegetation cover in the coalfield.
- Efforts for afforestation should be given thrust in the coalfield on wasteland and mined out area to maintain the ecological balance in the region.
- If any deforestation takes place, then it may be restored back by planting of suitable trees that grow in this region easily.

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