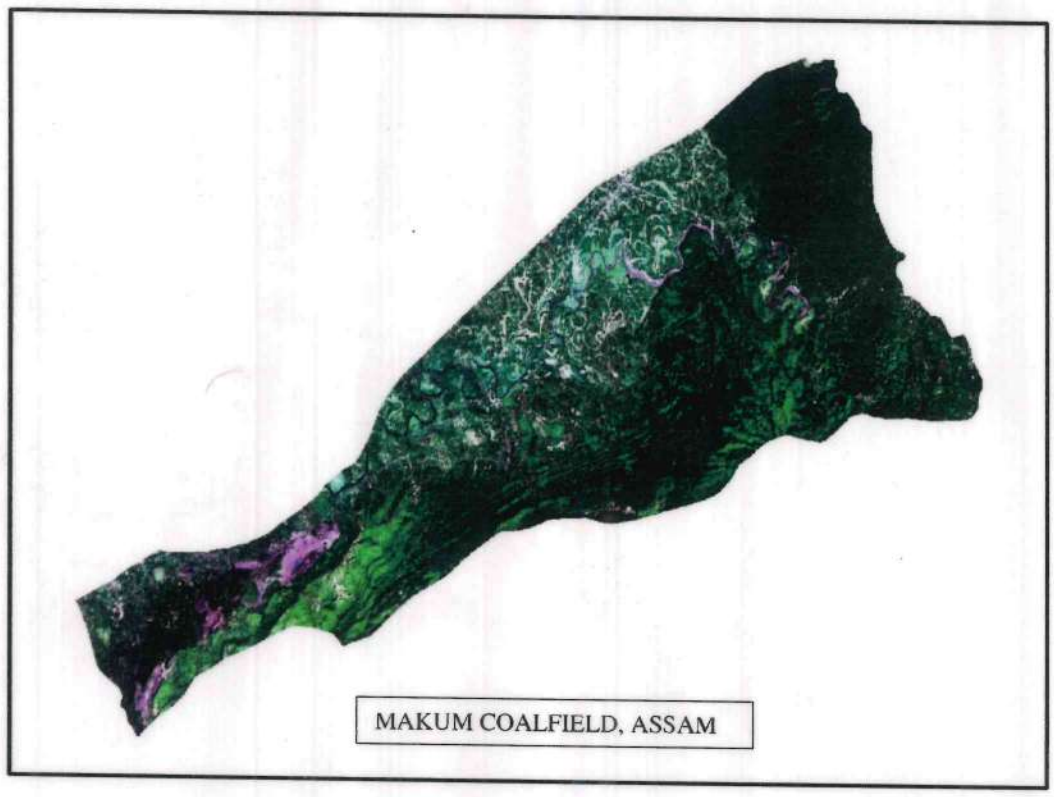
Land Use/ Vegetation Cover mapping of Makum Coalfield based on satellite data of the Year 2022



Submitted to

North Eastern Coalfield
Margherita, Assam

March 2023

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List of Plates

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

1. Plate No. HQ/REM/NEC/A4/01: R-2/ LISS-IV FCC of Makum Coalfield
2. Plate No. HQ/REM/NEC/A4/02: Land use / Vegetation Cover Map of Makum Coalfield based on R-2/ LISS-IV data.

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 19 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. A work order no. CIL/WBP/Env/2009/2428 dated 29.12.2009 was 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 for land reclamation monitoring of opencast projects and vegetation cover monitoring of 19 major coalfields. Further another work order on CIL/ENVT/2022-23/W.O./10899 dated 06.07.2022 for land reclamation monitoring for Land reclamation monitoring and vegetation cover monitoring of 13 major coalfields for the period 2022-2024 including Makum Coalfield, NEC as per a defined plan for monitoring the impact of mining on Vegetation Cover.

1.2 Objectives

The objectives of the present study are to prepare a regional land use and vegetation cover map of Makum Coalfield on 1:50,000 scale based on IRS R2 LISS-IV satellite data of the year 2022, using digital image processing technique for assessing the impact of coal mining and associated industrial activities on the land use/ vegetation cover in the Makum Coalfield area with respect to the earlier study carried out in the year 2019.

1.3 Location & Accessibility

Makum Coalfield falls in the Tinsukia districts of Assam. The nearest railhead is Makum Margherita on the N.E.F. Railway located in the north-western fringe of the coalfield. Makum Coalfield is a part of the Patkai Range which is hilly and rugged terrain, dissected by rivers and streams and is densely forested. The elevation varies from 140 meter at the base of the hill to 400 meter above the mean sea level in the upper hills. The Buri Dihing river with a westerly flow passes along northern part of the coalfield. Namdang, Ledopani, Lekhapani and Tipong rivers traversing through the coalfield discharge into the Buri Dihing river.

The National Highway 38 passes through the northern part of the Makum coalfield. The study area is bounded between North Latitudes $27^0$00'00" to $27^0$30'00" and East longitudes $95^0$30'00" to 96^0 05'00" and is covered by Survey of India (SoI) topo-sheet Nos. 83M/11, 83M/12, 83M/15, 83M/16, The location map of study area is shown in Figure 1.1. The aerial extends ranges 14 km in north-south direction and 36 km in east-west direction encompassing an area of about 240.50 sq. km till year 2019. **The year 2022 onwards the Coalfield boundary has been modified and the net area of Coalfield boundary has been reduced to 216.98 Sq. Km. The vegetation cover mapping for the year 2022 has been exercised on both**

(old and new) boundaries for comparison with previous report and also provide latest land statistics.

1.4 Drainage

The Buri Dihing river with westerly flow passes along northern part of the coalfield. Namdang, Ledopani, Lekhapani and Tipong rivers traversing through the coalfield discharge into the Buri Dihing river.

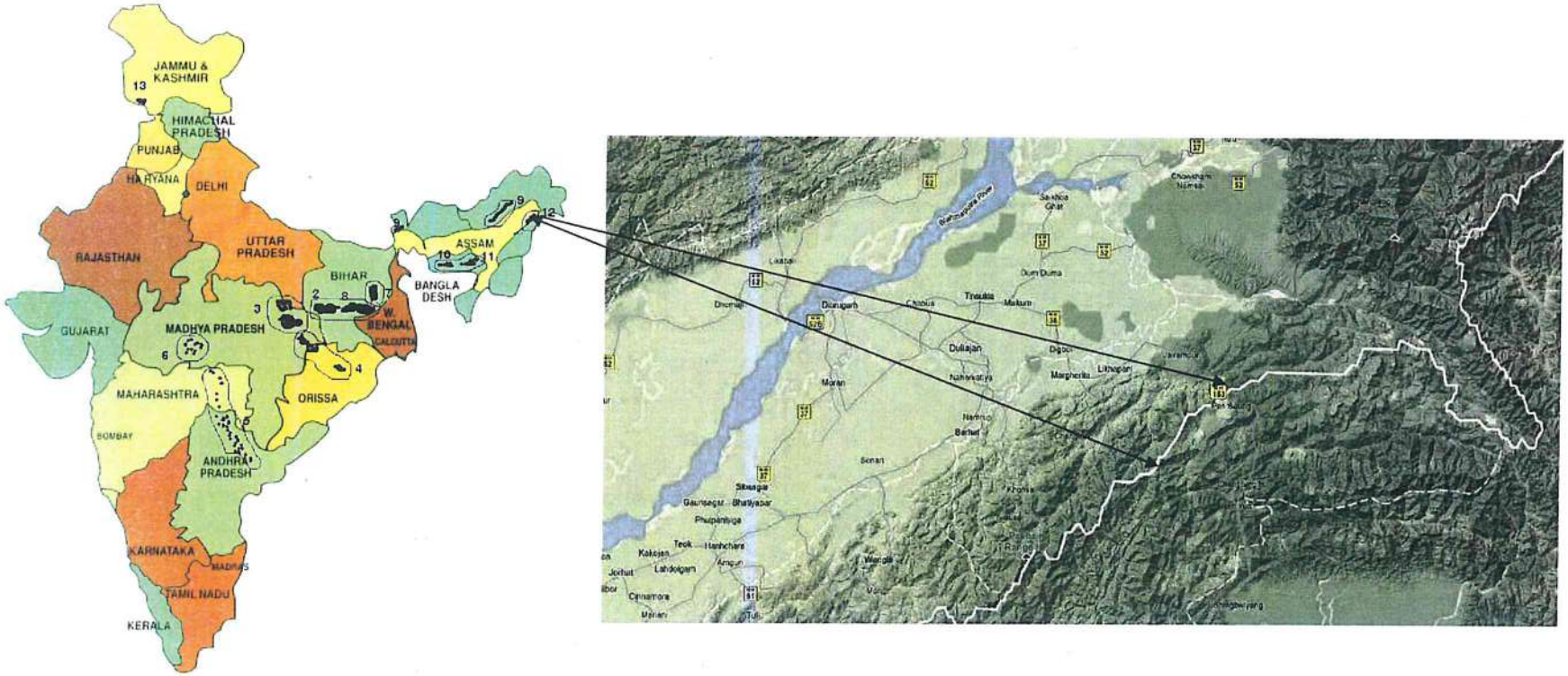

Fig. 1.1: **Location Map of Makum Coalfield, NEC**

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.

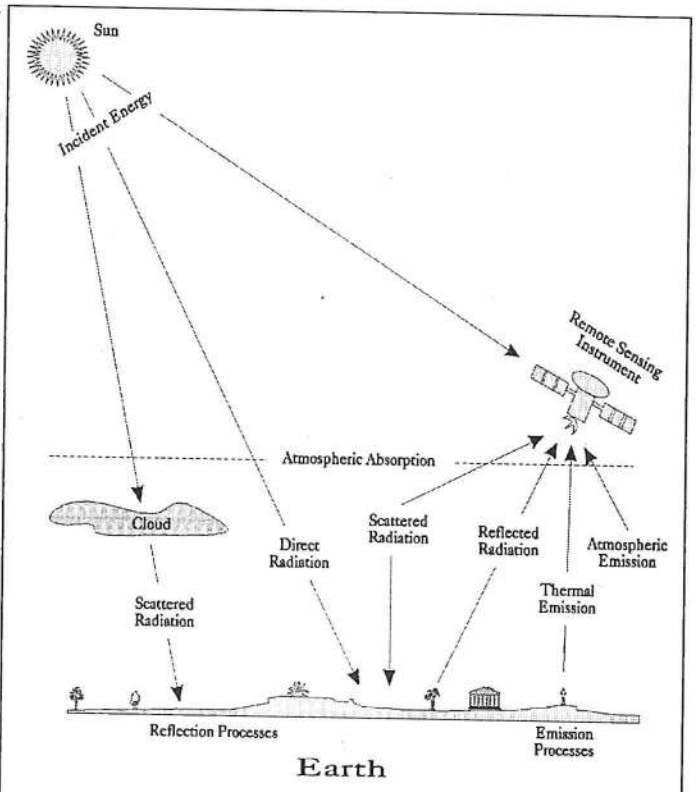

Figure 2.1 Remote sensing radiation system

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.

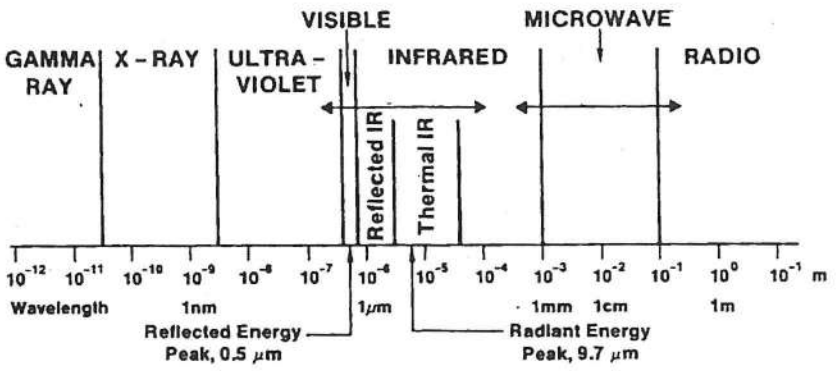

Figure 2.2 Electromagnetic spectrum. Expanded versions of the visible, infrared and microwave regions are shown in Figure 2.3.

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).

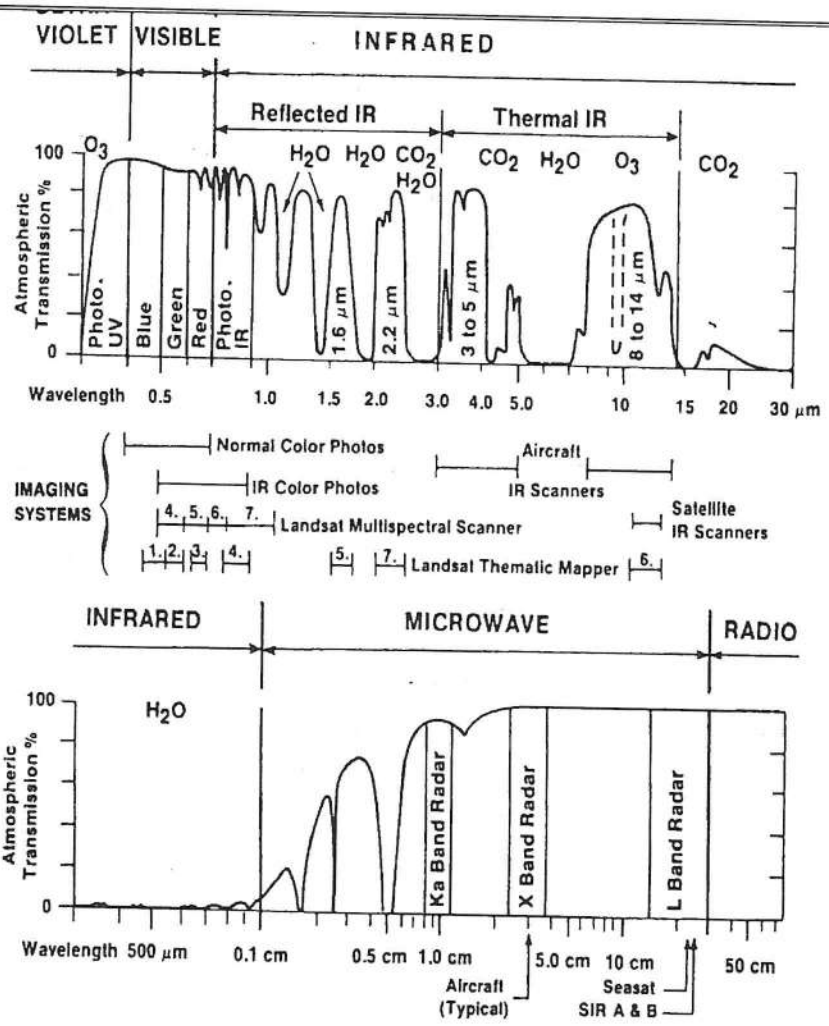

Figure 2.3 Expanded diagrams of the visible and infrared regions (upper) and the microwave regions (lower) showing atmospheric windows. Wavelength bands of commonly used remote sensing systems are indicated. Gases responsible for atmospheric absorption are shown.

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. 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-2/LISS-IV of March 2022 having 5 m. spatial resolution was used in the present study. The path and Row of satellite data is 114/52/C. The raw digital satellite data was obtained from NRSC, Hyderabad, on CD-ROM media.

- **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 **Makum Coalfield,** Survey of India Topo-Sheet nos. $83^{M}/_{11}$, $83^{M}/_{12}$, $83^{M}/_{15}$, $83^{M}/_{16}$, as well as map showing location of coal blocks supplied by Geology Department (HQ) 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-R2	L4FX	B2 0.52 - 0.59 Green B3 0.62 - 0.68 Red B4 0.77 - 0.86 NIR	16-bit (256-grey levels)	5.8 m	24 days	India

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

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.

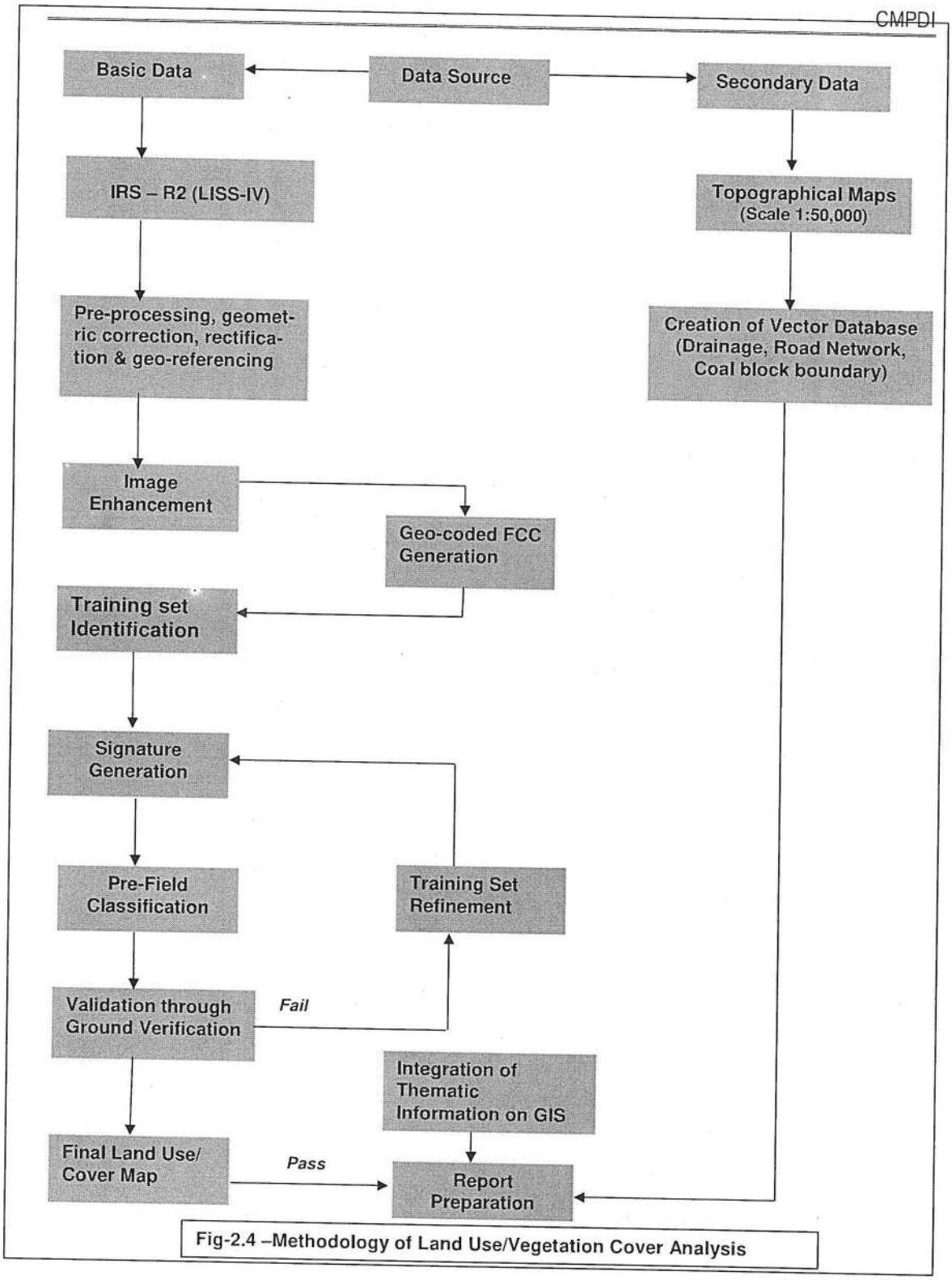

Fig-2.4 –Methodology of Land Use/Vegetation Cover Analysis

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*.

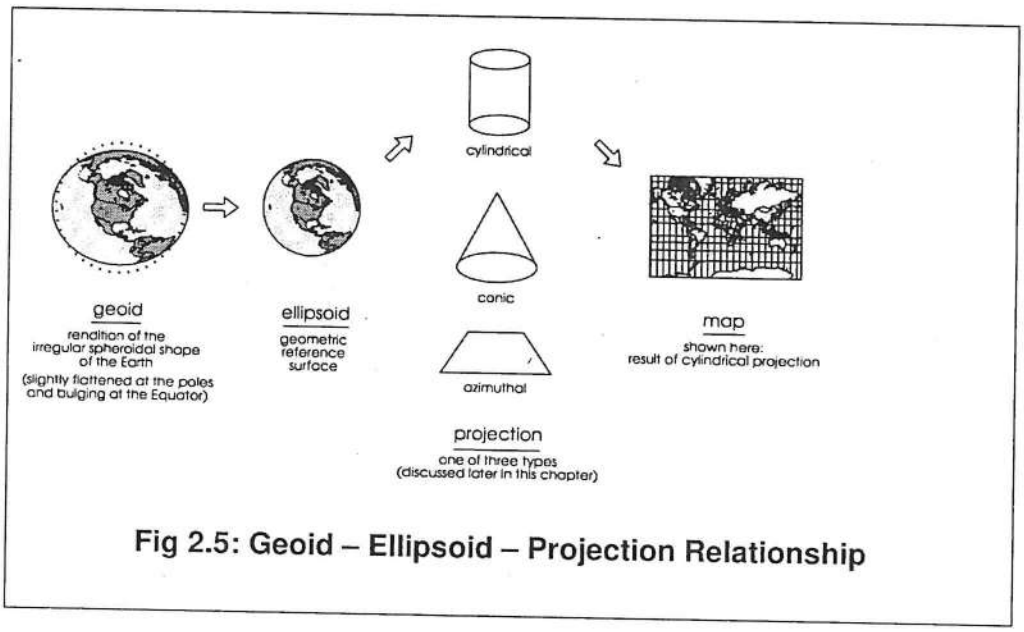

Fig 2.5: Geoid – Ellipsoid – Projection Relationship

In the present study, ***UTM projection*** *along with* ***WGS 1984 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 v 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 IMAGINE s/w. The enhanced and geocoded FCC image of Makum 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 s/w. The classified image for the year 2022 for Makum 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 network, rail network and drainage network are also digitised on Arc GIS database and superimposed on the classified image.

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 printed using HP Design jet 7200 Colour Plotter. The maps are prepared on 1:50,000 scale and enclosed as drawing No. 2 along with the report. A soft copy in pdf format is also enclosed.

Table 2.3: Classification Accuracy Matrix for Makum 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	Tea Plantation	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	Coal Quarry	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/ Cover Mapping

3.1 Introduction

The need for information on land use/ vegetation cover has gained importance due to the all-round concern on environmental impact of mining. The information on land use/cover inventory that includes 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. Moreover, with passage of time, demand for coal has increased many folds and therefore production from the mines has also increased and hence the mining areas also kept on increasing. Therefore, it is important to know the existing land use pattern and the changes that have occurred during previous years, so as to predict the possible changes due to mining in future around the existing coal mines.

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 is determined.

Realising the need of regular monitoring of land use/ vegetation cover in Makum coalfield; Coal India Limited entrusted CMPDI to prepare land use/ vegetation cover map for assessing the impact of coal mining on land use pattern and vegetation cover using remote sensing data at a regular interval of three years, which will help in formulating the mitigative measure, if any required for environmental protection in the coal mining areas.

The present study incorporates the findings on Land use / Vegetation Cover pattern in the Makum Coalfield, NEC based on satellite data of the year 2022. Similar study has also been done previously in the year 2013, 2016 and 2019.

3.2 Land Use/Cover Classification

The array of information available on land use/cover requires to be arranged or grouped 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 Agency, Hyderabad. Land use map was prepared on the basis of image interpretation carried out based on the satellite data for the year 2022 for Makum coalfield and following land use/cover classes are identified (Table 3.1).

Table 3.1:
Land use/cover classes identified in Makum Coalfield

	Level -I	*Level -II*
1	**Built-Up Land**	1.1 Urban 1.2 Rural 1.3 Industrial
2	**Agricultural Land**	2.1 Crop Land 2.2 Fallow Land
3	**Forest/Vegetation Cover**	3.1 Dense Forest 3.2 Open Forest 3.3 Scrub 3.4 Tea Plantation 3.5 Plantation under Social Forestry 3.5 Plantation on OB Dumps
4	**Wasteland**	4.1 Waste Upland 4.2 Waste upland with/without scrubs 4.3 Sand body
5	**Mining**	5.1 Coal Quarry 5.2 Quarry filled with water 5.3 Barren OB Dump 5.4 Wasteland due to mining 5.5 Advance Quarry Site 5.6 Coal Stock
6	**Water bodies**	6.1 River/Streams /Reservoir

3.3 Data Analysis

Satellite data of the year 2022 for Makum Coalfield, NEC was processed using ERDAS Imagine v 2022 Digital Image Processing s/w in order to interpret the various land use and vegetation cover classes present in the Makum Coalfield. Table 3.2 shows the comparison of land use / vegetation cover classes in Makum Coalfield based on the coalfield boundary measuring 216.98 Km^2. The following maps were prepared for Makum Coalfield on 1:50,000 scale:

1. ***Plate No. 1***: Drawing No: HQ/REM/NEC/A4/22/01 -Land use/Vegetation Cover FCC Map of Makum Coalfield based on R-2/ LISS-IV data.
2. ***Plate No. 2***: Drawing No: HQ/REM/NEC/A4/22/02 Land use/Cover Map of Makum Coalfield based on R-2/ LISS-IV data.

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. Total area of settlements in Makum CF covers 5.41 km^2 (2.49%) Which are basically urban in nature *(Refer Table 3.2).*

3.3.2 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 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. Details of area statistics of the vegetation cover in Makum Coalfield area is given in Table 3.2.

Analysis of data reveals that vegetation cover in Makum CF occupies an area of 162.40 km^2 (74.85%). Out of which dense forest occupies 91.51 km^2 (42.17%), open forest cover occupies 23.97 km^2 (11.05%), scrub covers 14.90 km^2 (6.87%) of the area and plantation under Tea plantation 29.75 km^2 (13.71%), Plantation on Over burden dump covers an area of 2.08 km^2 (0.96%) of area under its coverage and plantation on backfill covers 0.19 km^2 (0.09) area.

3.3.2 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.

Analysis of data reveals that agriculture that covers in Makum occupies an area of 36.28 km^2 (16.72%). Out of which crop land is 27.75 km^2 (12.79%) and fallow land covers an area of 8.53 km^2 (3.93%).

3.3.4 Mining

The mining area includes the area of existing quarry, old quarries filled with water, advance quarry sites, wasteland due to mining and allied activities, coal stock/dumps and overburden (OB) dumps.

The mining area in Makum Coalfield covers 4.23 km^2 (1.95%) in the year 2022. *Coal quarry* constitutes 0.95 km^2 (0.44%), *Quarry filled with water* constitutes 0.07 km^2 (0.03%), *Coal dumps / stocks* constitute 0.08 km^2 (0.04%), *Barren backfilled constitutes 0.80* km^2 *(0.37%)* and *Barren over burden dumps* constitutes 2.33 km^2 (1.07%) *(Refer Table 3.2).*

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). Analysis of data reveals that the area wasteland in Makum is 6.35 km^2 (2.93%).

3.3.5 Surface Water bodies

Analysis of data reveals that surface water bodies in Makum covers an area of 2.31 km^2 (1.06%).

TABLE – 3.2

STATUS OF LAND USE & VEGETATION COVER PATTERN IN MAKUM COALFIELD IN THE YEAR 2022

(Area in Km²)

LAND / VEGETATION COVER CLASSES	Area Statistics	
VEGETATION COVER	**Area**	**% of total**
Dense forest	91.51	42.17
Open Forest	23.97	11.05
Scrubs	14.90	6.87
Tea Plantation/ Social Forest	29.75	13.71
Plantation over OB Dump	2.08	0.96
Plantation on backfill	0.19	0.09
Sub Total	**162.40**	**74.85**
MINING AREA		
Coal Quarry/ Active Mining Area	0.95	0.44
Advance Quarry Site	0.00	0.00
Coal Dump	0.08	0.04
Barren Backfilled Area	0.80	0.37
Barren OB Dump	2.33	1.07
Water Filled Quarry	0.07	0.03
Sub Total	**4.23**	**1.95**
AGRICULTURAL LAND		
Crop Land	27.75	12.79
Fallow Land	8.53	3.93
Sub Total	**36.28**	**16.72**
WASTELAND		
Waste upland	6.35	2.93
Fly-Ash Pond / Alumina Sludge Pond	0.00	0.00
Sand Body	0.00	0.00
Barren Rocky Land	0.00	0.00
Sub Total	**6.35**	**2.93**
SETTLEMENTS		
Urban	4.63	2.13
Rural	0.62	0.29
Industrial	0.16	0.07
Sub Total	**5.41**	**2.49**
WATER BODIES	2.31	1.06
TOTAL	**216.98**	**100.00**

Table 3.3

COMPARATIVE STATUS OF LAND USE & VEGETATION COVER IN MAKUM COALFIELD IN THE YEAR 2019 & 2022

Sl. No.	Land Use / Cover Classes		2019		2022		Change w.r.t. year 2019		Remarks
			Resourcesat-2/ LISS – IV Data		Resourcesat-2/ LISS – IV Data				
	Level - I	Level - II	Km^2	%	Km^2	%	Km^2	%	
1	Settlement	Urban	4.44	1.85	5.35	2.22	0.91	0.37	Change due to mining allied industries and socio economic reasons.
		Rural	0.83	0.35	0.79	0.33	-0.04	-0.02	
		Industrial	0.02	0.01	0.11	0.05	0.09	0.04	
		Sub – Total	**5.29**	**2.21**	**6.25**	**2.60**	**0.96**	**0.39**	
2	Vegetation Cover	*Dense Forest*	94.86	39.43	107.24	44.59	12.38	5.16	Open Forest changed to Dense forest during the period of 3 years as Coal Mining activities are suspended in NEC due to EC/FC. Also Scrub area has been converted into Crop land and Fallow land. Major Social Forestry is Tea Plantation.
		Open Forest	40.64	16.90	31.13	12.94	-9.51	-3.96	
		Scrubs	30.71	12.77	15.59	6.48	-15.12	-6.29	
		Plantation on OB Dump	0.33	0.14	2.06	0.86	1.73	0.72	
		Plantation on Backfill	0.00	0.00	0.19	0.08	0.19	0.08	
		Tea Plantation (Social Forestry)	29.42	12.23	29.30	12.18	-0.12	-0.05	
		Sub – Total	**195.96**	**81.47**	**185.51**	**77.13**	**-10.45**	**-4.34**	
3	Agricultural Land	Crop Land	17.46	7.26	26.29	10.93	8.83	3.67	Increase in agriculture land
		Fallow Land	6.51	2.71	8.51	3.54	2.00	0.83	
		Sub – Total	**23.97**	**9.97**	**34.80**	**14.47**	**10.83**	**4.50**	
4	Wasteland	Waste up land with / without Scrubs	8.37	3.48	7.59	3.16	-0.78	-0.32	Change due to conversion of waste land to Built up area.
		Sub – Total	**8.37**	**3.48**	**7.59**	**3.16**	**-0.78**	**-0.32**	
5	Mining Area	Coal Quarry	1.41	0.59	0.95	0.40	-0.46	-0.19	Mining activities has been suspended due to EC/FC for past few years.
		Coal Dump	0.07	0.03	0.08	0.03	0.01	0.00	
		Barren OB Dump	2.76	1.15	2.13	0.89	-0.63	-0.26	
		Barren Backfilled	0.18	0.07	0.80	0.33	0.62	0.26	
		Water Filled Quarry	0.13	0.05	0.07	0.03	-0.06	-0.02	
		Sub – Total	**4.55**	**1.89**	**4.03**	**1.68**	**-0.52**	**-0.21**	
6	Water Body		2.35	0.98	2.32	0.96	-0.03	-0.02	
7	Sand Body		0.01	0.00	0.00	0.00	-0.01	0.00	
		TOTAL	240.50	100.00	240.50	100.00	0.00	0.00	

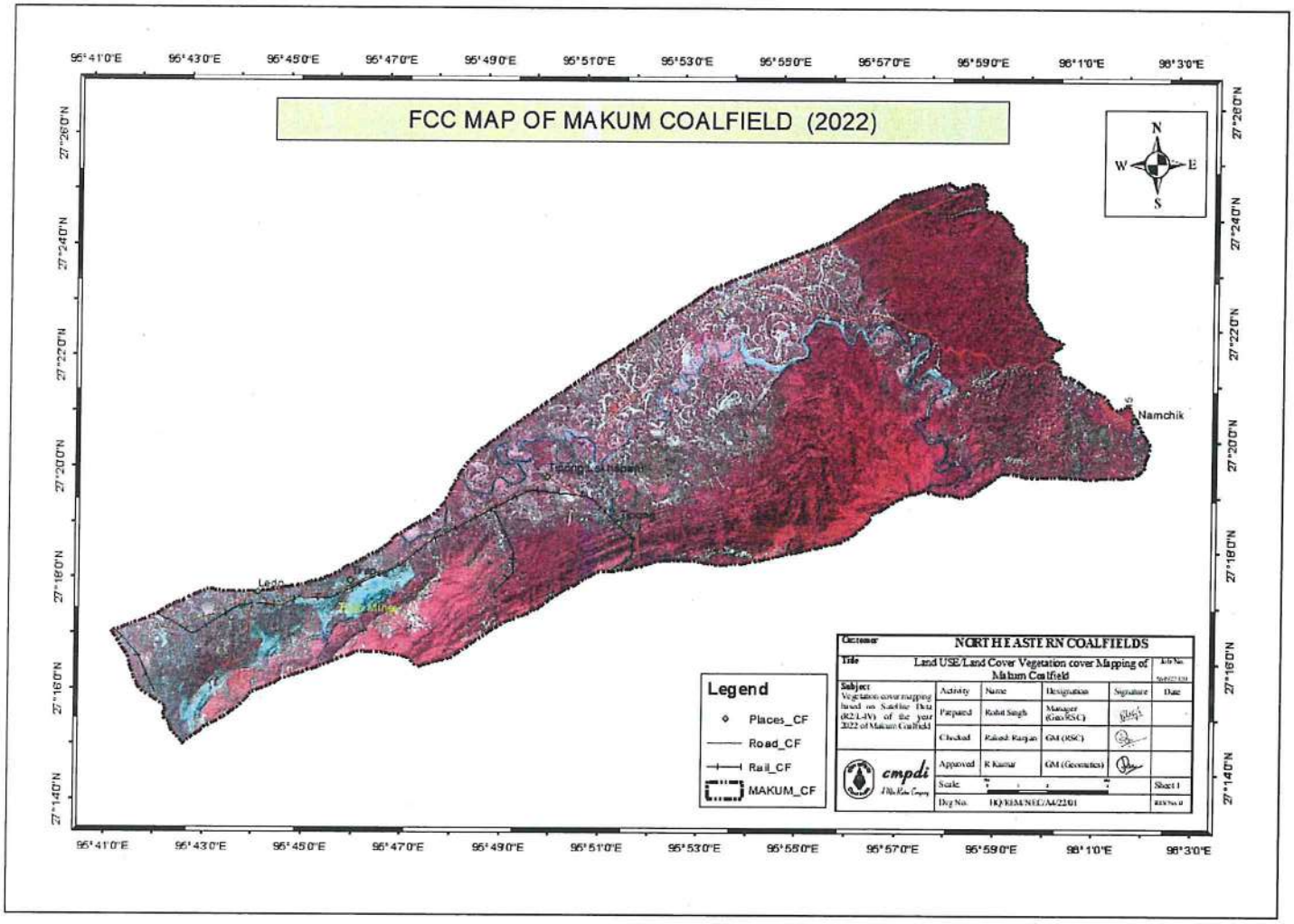

Plate 1 : Geocoded FCC (Band 3, 2, 1) of Makum CF based on R-2 (LISS – IV) Satellite Data of Year – 2022

(Resourcesat-2-LISS-IV Data)

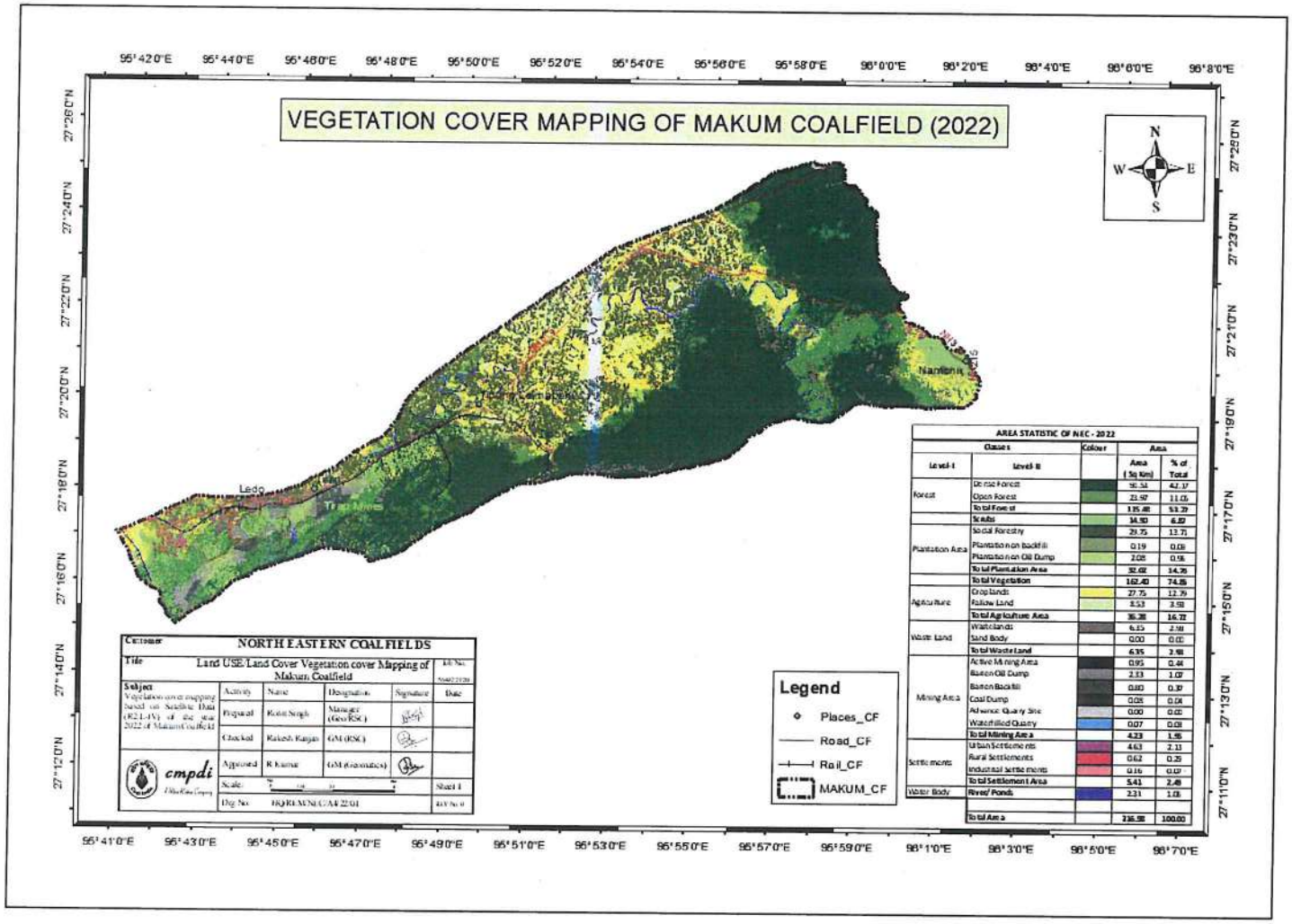

Plate 2: Land Use/ vegetation Cover Map of Makum CF based on R2 (LISS-IV) Satellite Data of the Year 2022

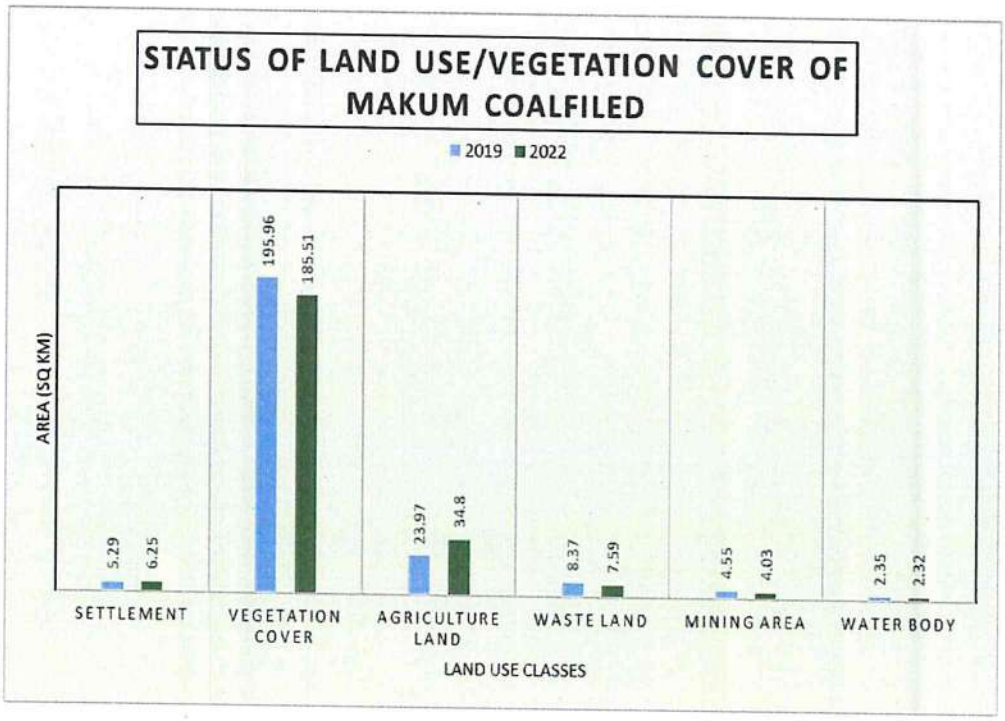

Fig 3.1: Bar Chart Showing Status of Land Use/ Cover Classes in Makum Coalfields, NEC

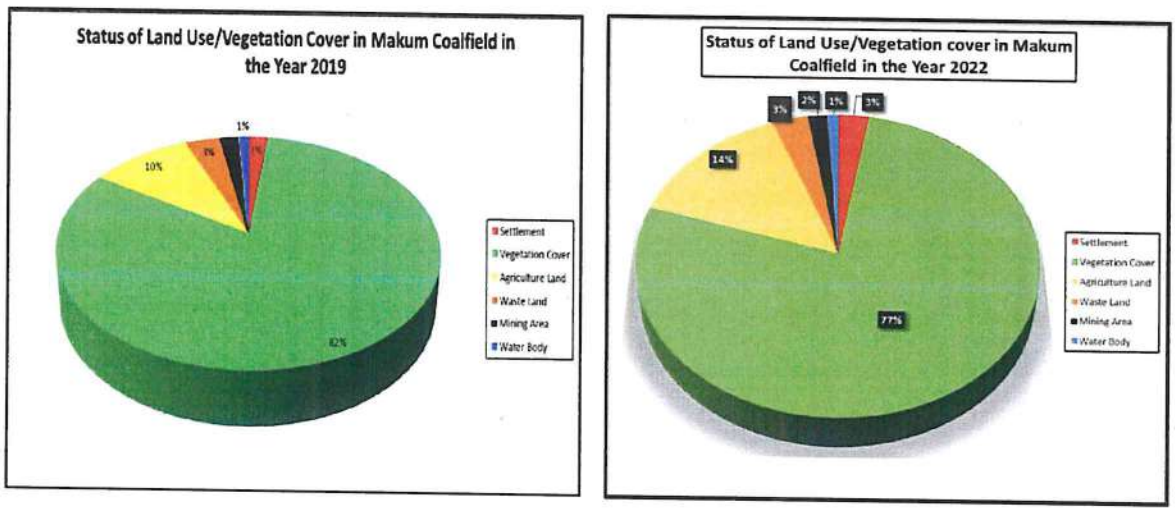

Fig. 3.2

Chapter 4

Conclusion & Recommendation

4.1 Conclusion

In the present study, land use/ vegetation cover mapping has been carried out based on R-2/ LISS IV satellite data of March, 2022 in order to generate the database on land use/vegetation cover in Makum Coalfield for monitoring the impact of coal mining on land environment. The land use/cover data will help in assessing the impact of coal mining on land environment and helps in formulating the mitigation measures required, if any.

Study reveals that the total area of settlements which includes urban, rural and industrial settlements is very scanty in the Makum and covers only 5.41 km^2 (2.49%) area. Vegetation cover which includes dense forests, open forests, scrubs, avenue plantation & plantation on over-burden dumps, covers an area of 162.40 km^2 (74.85%). The analysis further indicates that total agricultural land which includes both crop and fallow land covers an area of 36.28 km^2 (16.72%). The mining area which includes coal quarry, advance quarry site, barren OB dump covers 4.23 km^2 (1.95%) and wasteland covers 6.35 km^2 (2.93%), and surface water bodies covered area of 2.31 km^2 (1.06%) area.

4.2 Recommendation

Keeping in view the eco-fragile hilly terrain in the area, it is essential to maintain the ecological balance for sustainable development of the area together with coal mining. It is recommended that similar study should be carried out regularly at an interval of three years to assess the impact of coal mining on land use pattern and vegetation cover in the coalfield to formulate the remedial measures, if any, required for mitigating the adverse impact of coal mining on land environment. Such regional study will also be helpful in assessing the environmental degradation /upgradation carried out by different industries operating in the coalfield area.

ABBREVIATIONS

SoI	Survey of India
MoEF&CC	Ministry of Environment, Forest & Climate Change
CIL	Coal India Limited
ECL	Eastern Coalfields Limited
BCCL	Bharat Coking Coal Limited
CCL	Central Coalfields Limited
WCL	Western Coalfields Limited
SECL	South Eastern Coalfields Limited
NCL	Northern Coalfields Limited
MCL	Mahanadi Coalfields Limited
NEC	North Eastern Coalfields
CMPDIL	Central Mine Planning & Design Institute Ltd
NRSC	National Remote Sensing Centre
R2/ R2A	ResourceSat Satellites
LISS - 4	Linear Imaging and Self Scanning Sensor (High Resolution Multi Spectral Satellite Data)
FCC	False Colour Composite (Raw Satellite Data)
OCP	Opencast Project
UGP	Underground Project
OB	Over Burden
GCP	Ground Control points
GIS	Geographic Information System
WGS-84	World Geodetic System (Datum for Map Projection)
UTM	Universal Transverse Mercator (Map Projection System)
Arc GIS	GIS Software used for Map preparation
ERDAS IMAGINE	Satellite Image Data Classification Software

GLOSSARY

Sl.	Term	Definition
1.	Land Reclamation	To manage, reclaim and restore mined out/ degraded land as close as possible to its original stage
2.	Over Burden	The material that lies above the coal seam/ deposit
3.	Monitoring	A process of evaluation to check or keep record for a period of time.
4.	Opencast Coal Mine	Open-pit mining, also known as opencast mining, is a surface mining technique that extracts minerals from an open pit in the ground.
5.	Social Forestry	Social forestry is the management and protection of forests and afforestation of barren and deforested lands with the purpose of helping environmental, social and rural development. Plantation (Social/ Avenue or other) carried out outside mining area.
6.	Biological Reclamation	Plantation on Backfilled areas (Stablised Internal Dumps)
7.	Technical Reclamation	Area under backfilling (Over burden dumped inside the mine voids) in mining area.
8.	Green Cover Generated	Total Plantation carried out in the lease area of Project. This includes Plantation on Backfill, Plantation on OB and Social Forestry
9.	Leasehold Area	The area, for which lease is granted for the purpose of undertaking mining and allied operations
10.	Excavated area	Mined out area which includes active mining, area under backfilling and plantation on backfilled areas
11.	Active Mining	Mining areas which include Coal Quarry, Advance Quarry, Quarry Filled with Water etc.
12.	Environmental Protection	It is the practice of protecting the natural environment by individuals, organizations and governments. Its objectives are to conserve natural resources and the existing natural environment and, where possible, to mitigate damage and reverse trends.
13.	Remedial Measure	Any measure or action required or undertaken to investigate, monitor, clean up, remove, treat, prevent, contain or otherwise remediate the presence or release of any hazardous substance or activity.
14.	Systematic Error	Every measurement differing from the true measurement in the same direction, and even by the same amount in some cases

15.	Geometric Distortion	It refers to the improper positioning of any image with respect to their true geographic position when viewed in a properly scaled common image display plane.
16.	Land Use/ Cover Class	Land cover is what covers the surface of the earth and land use describes how the land is used.
17.	Accuracy	The closeness of agreement between a measured quantity value and a true quantity value.
18.	Environmental Clearance	Environmental Clearance (EC) for any developmental projects like coal mining projects etc. has been made mandatory by the Ministry of Environment, Forests and Climate Change (MoEF&CC) through its Notification issued on 27.01.1994 under the provisions of Environment (Protection) Act, 1986.
19.	Rectification and Geo-referencing	Geo-referencing is the assigning of absolute location of a data point or data points. Geo-rectification refers to the removal of geometric distortions between sets of data points, most often the removal of terrain, platform, and sensor induced distortions from remote sensing imagery
20.	Image Enhancement	It is the process of modifying digital images so that the results are more suitable for processing or further image analysis.
21.	Training set selection	It is a portion of a data set used to fit or train a model for prediction or classification of values that are known in the training set, but unknown in other (future) data
22.	Image Classification	It refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps.
23.	Temporal Changes	The 'temporal change' means the change in any entity with a period of time.
24.	Ground Truthing	Collection of primary/ basic information from ground realities for satellite image interpretation and thematic mapping.
25.	Cluster	Group of opencast and/ or underground mines clubbed together for administrative purposes.