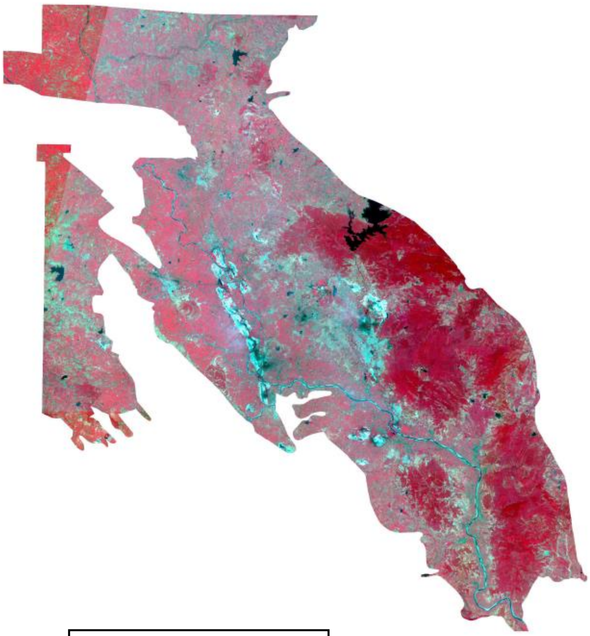
REPORT ON
Land Use / Vegetation Cover Mapping of Wardha Valley Coalfield based on Satellite Data for the Year 2019



Wardha Valley CF

Submitted to

Western Coalfields Limited

Coal India

cmpdi

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Land Use / Vegetation Cover Mapping of Wardha Valley Coalfield based on Satellite Data for the Year- 2019

March-2020

Remote Sensing Cell
Geomatics Division
CMPDI, Ranchi

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Chapter 1

Introduction

1.1 Project Reference

To monitor the regional impact of coal mining on land use pattern and vegetation cover in the 19 major coalfields at regular interval of three years based on remote sensing satellite data, Coal India Ltd. issued a work order to CMPDI vide letter no. CIL/WBP/ENV/2017/DP/8477 dated 21.09.17. Geo-environmental data base for Wardha Valley coalfield based on satellite data was prepared for the first time in the year 2010 under the above project. Impact of coal mining on land environment has to be assessed regularly at interval of three years with respect to the previous data. This report is based on satellite data of 2019 for monitoring the status of land use and vegetation cover in Wardha Coalfield

1.2 Objectives

The objective of the present study is to prepare a regional land use and vegetation cover map of Wardha Valley coalfield on 1:50,000 scale based on satellite data of the year 2019, using digital image processing technique for updation of geo-environmental database and 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

Warda Valley Coalfield covering an area of about 5225.36 sq. Km. lies in the Yavatmal and Chandrapur district of Maharashtra. It is bounded by Latitude 20^0 29’ 06” to 20^0 48’ 22” and Longitudes 79^0 09’ 15” to 79^0 26’ 39”and located in the central part of India. The coalfield area is covered under Survey of India topo-sheet no. 55L/15, 55L/16, 55P/3, 55P/4, 55P/7, 55P/8, 56I/13, 56M/1 and 56M/5 RF 1:50000.

This coalfields holds a premier position in India for having the considerable share of reserve of thermal grades non-coking coal for catering the demand of coal in the western part of country.

Wardha Valley coalfield is well connected by rail and road ways. Chandrapur is the central town in the coalfield which is connected with Nagpur (198 Km) in the north and Wardha (120Km) towards north-west and Kazipet (250) in the south. Chandrapur is connected also via rail with Nagpur in the north and Kazipet in the south, on the main line of South-Central Railways passing through the coalfield.

1.4 Topography & Drainage

The area has almost flat to gently undulating topography developed over Precambrians, Gondwanas and Trap rocks covered with black soil and alluvium. The general slope of the area is towards south. The area is drained mainly by the Wardha, the Penganga and the Erai rivers. The north-eastern Part of the area is drained by Erai river and its tributaries whereas southern part of the area is drained by Penganga flowing along the south boundary of the coalfield

1.5 Reserved Forests

The reserved forests in the Wardha Valley coalfield are Tadoba, Balharsha and Bhandak in the western side, Rajura in the southern side, Satna, Raikot, Pardi and Borgaon in the eastern side.

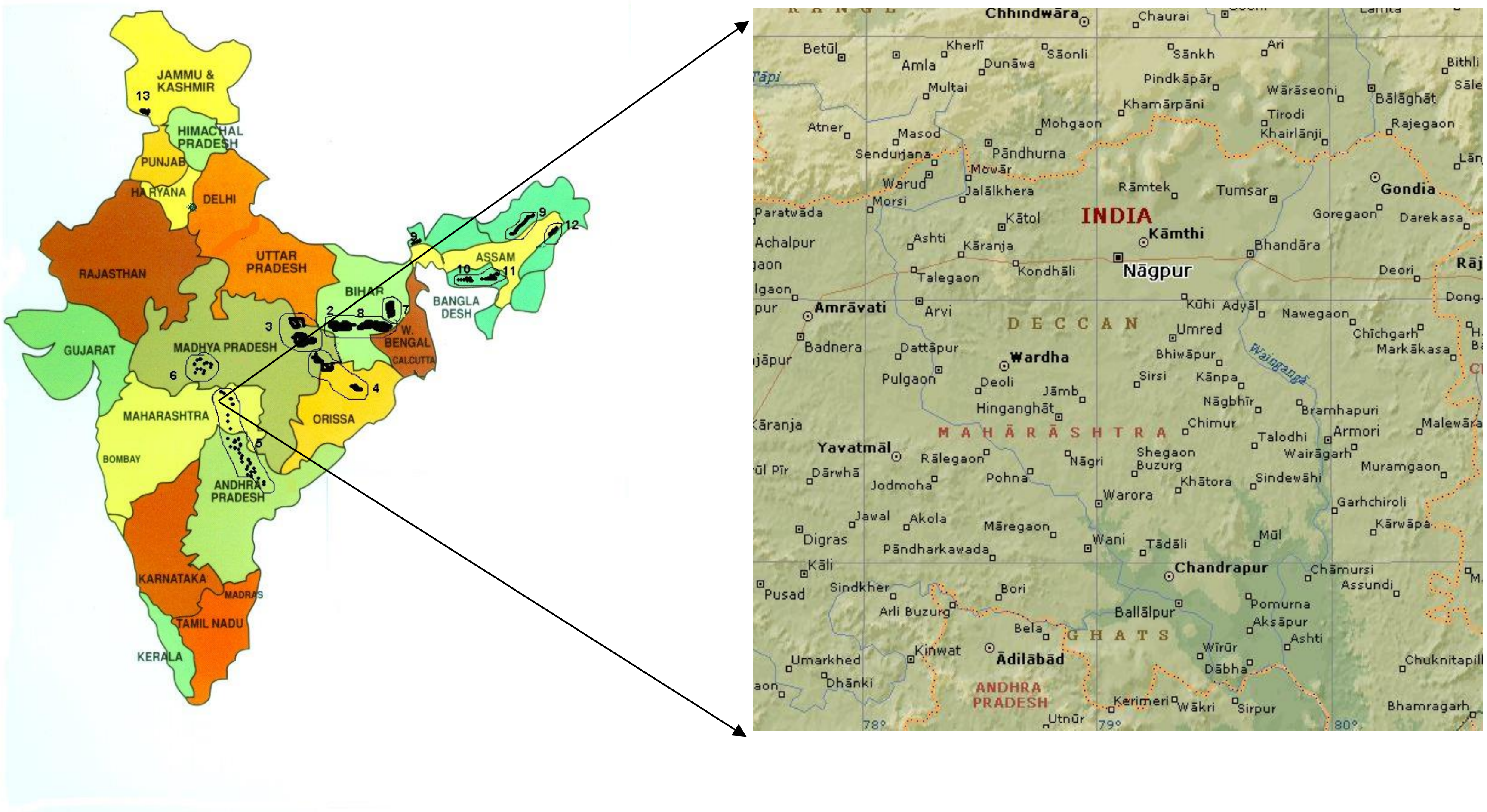

Fig. 1.1 : Location Map of Wardha Valley Coalfield

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.

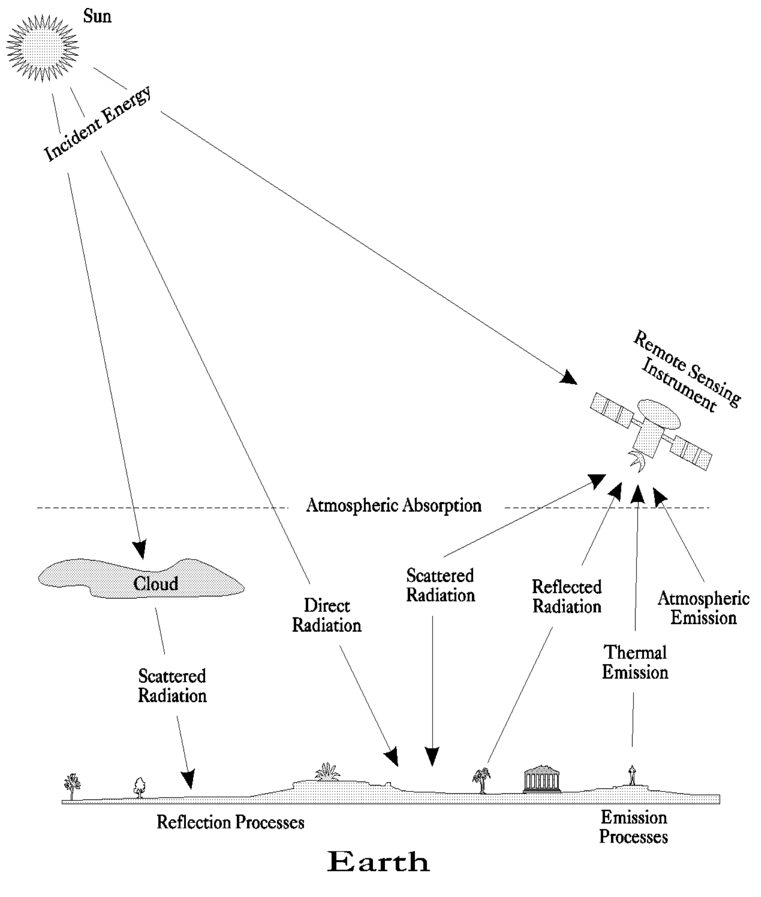

Figure 2.1 Remote sensing radiation system

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.

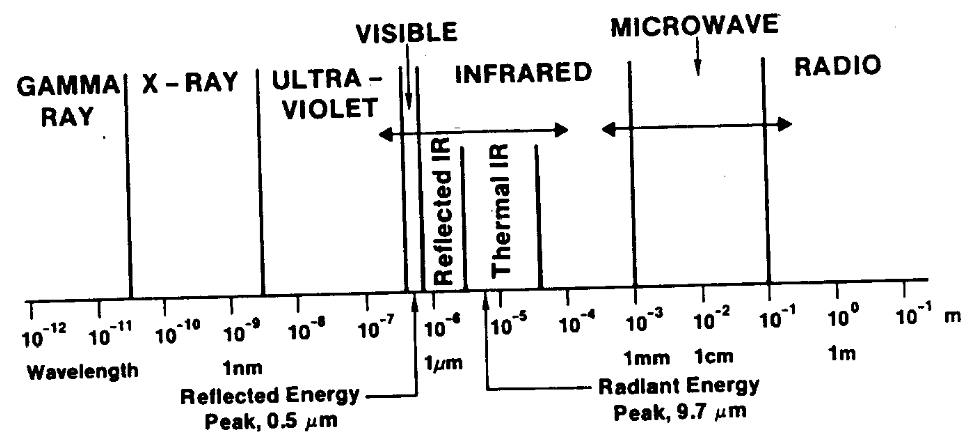

Figure 2.2 Electromagnetic spectrum. Expanded versions of the visible, infrared and microwave regions are shown in Figure 2.3.

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).

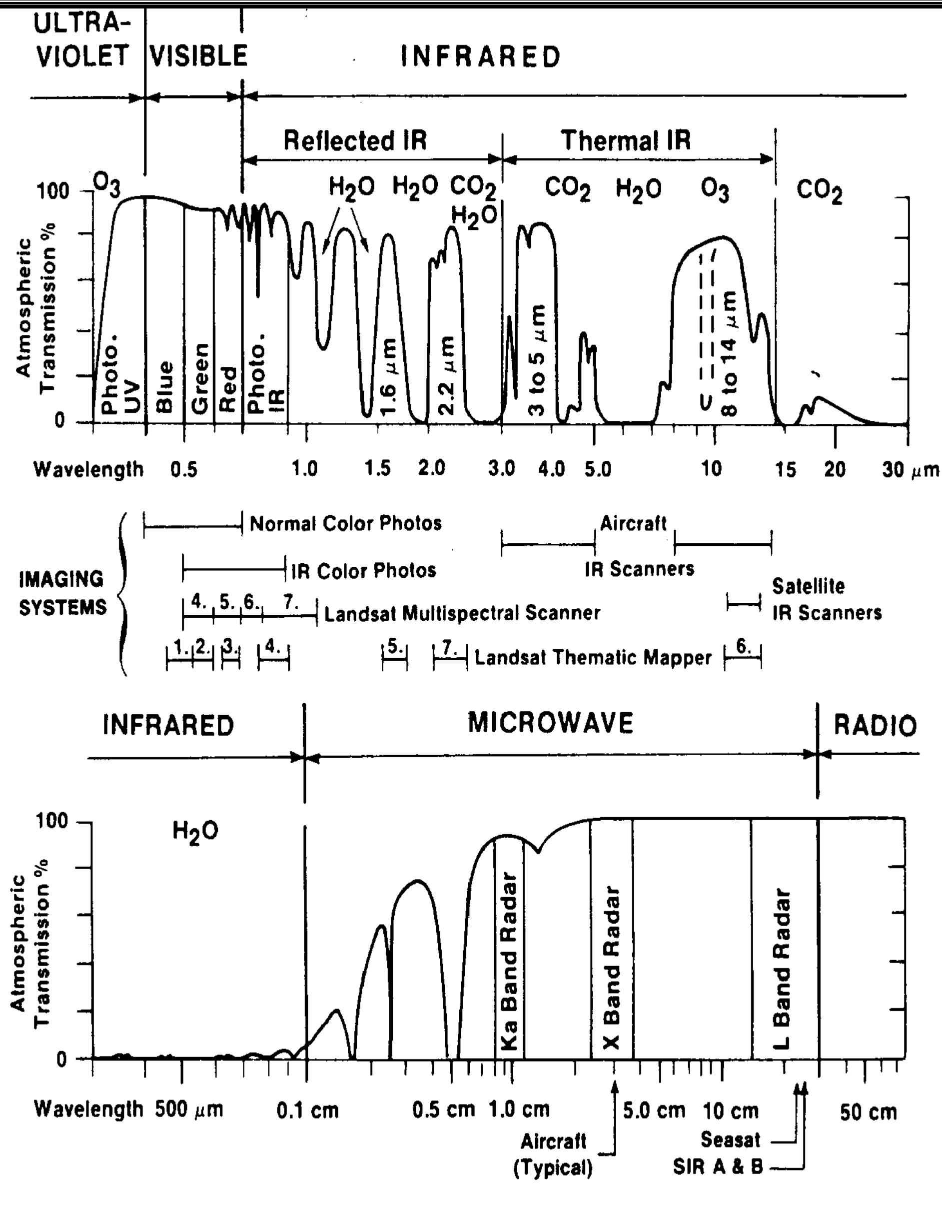

Figure 2.3 Expanded diagrams of the visible and infrared regions (upper) and the microwave regions (lower) showing atmospheric windows. Wavelength bands of commonly used remote sensing systems are indicated. Gases responsible for atmospheric absorption are shown.

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 character-istics, 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. Sentinel 2B of March 2019 having 10 m. spatial resolution was used in the present study.

- **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 **Wardha Valley Coalfield,** Survey of India toposheet no. 55L/15, 55L/16, 55P/3, 55P/4, 55P/7, 55P/8,56I/13, 56M/1 and 56M/5 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 Sentinel 2B 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	Central wavelength in µm			Radiometric Resolution	Spatial Resolution	Temporal Resolution
ESA	Senti-nel 2B	B3	0.56	Green	12-bit (4096-grey levels)	10.0 m	5 days
		B4	0.66	Red		10.0 m	
		B8	0.84 -	NIR		10.0 m	

NIR: Near 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.

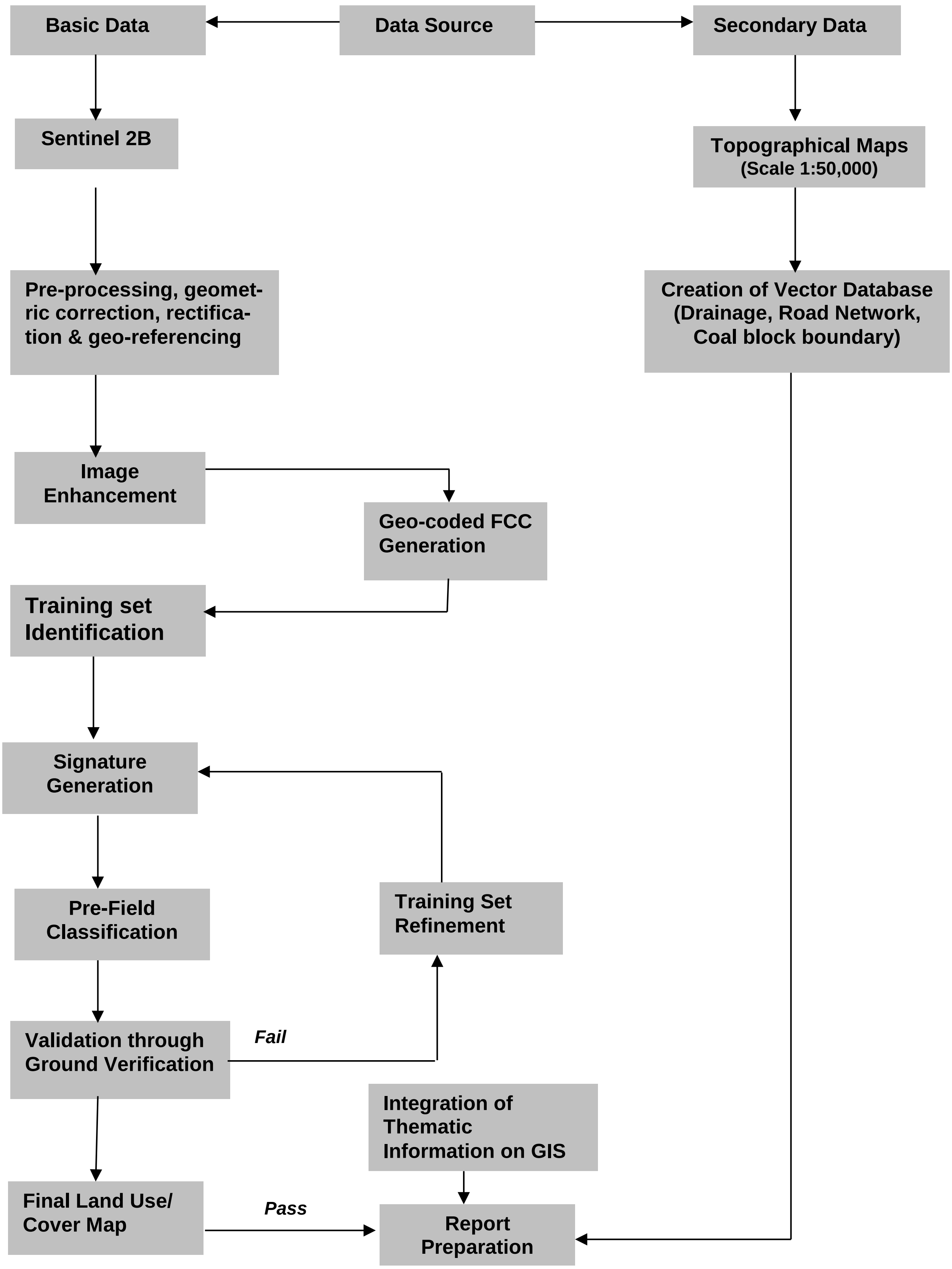

Fig-2.4 –Methodology of Land Use/Vegetation Cover Analysis

2.6.1Geometric 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 georeferencing 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*.

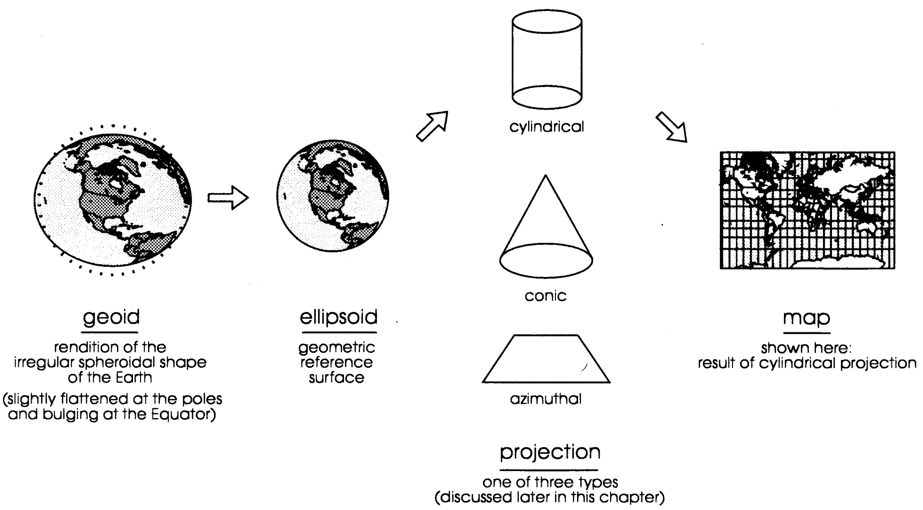

Fig 2.5 : Geoid – Ellipsoid – Projection Relationship

In the present study, ***UTM projection*** along with ***WGS 1984 Coordinate system*** 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 these projections are 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 IMAGINE v.2014 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 Wardha Valley Coalfield 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 2019 for Wardha Valley Coalfield is shown in Plate No. 2.

2.6.5 Creation/overlay of vector database

Plan showing coal block boundary are 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 4500 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 Wardha 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	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/ 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/ 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/Vegtation 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 Centre, Hyderabad. Land use map was prepared on the basis of image interpretation carried out based on the satellite data for the year 2019 for Wardha Valley coalfield and following land use/cover classes are identified (Table 3.1).

***Table 3.1*:**
Land use/cover classes identified in Wardha Valley 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 Plantation under Social Forestry 3.5 Plantation on OB Dumps
4	**Wasteland**	4.1 Waste upland with/without scrubs 4.2 Sand body
5	**Mining**	5.1 Coal Quarry 5.2 Barren OB Dump 5.3 Back Filled
6	**Water bodies**	6.1 River/Streams /Reservoir

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

3. Plate No. 1 : Drawing No. HQ/REM/ 01: FCC (ESA – Sentinel 2B data of Wardha Valley coalfield of the year 2019) with Coalfield boundary and other infrastructural details.
4. Plate No. 2 : Drawing No. HQ/REM/ 02 - Land use/Cover Map of Wardha Valley Coalfield based on Sentinel 2B data..

3.3 Data Analysis & Change Detection

Satellite data of the year 2019 were processed using ERDAS IMAGINE 2014 image processing s/w in order to interpret the various land use/cover classes present in the study area of Wardha Valley Coalfield covering 5225.36 sq.kms. The area of each land use/cover class for Wardha Valley coalfield were calculated using ERDAS IMAGINE s/w and tabulated in Table 3.2. Comparison of various land use classes between years 2016 & 2019 are shown in the Bar Chart (Fig. 3.1).

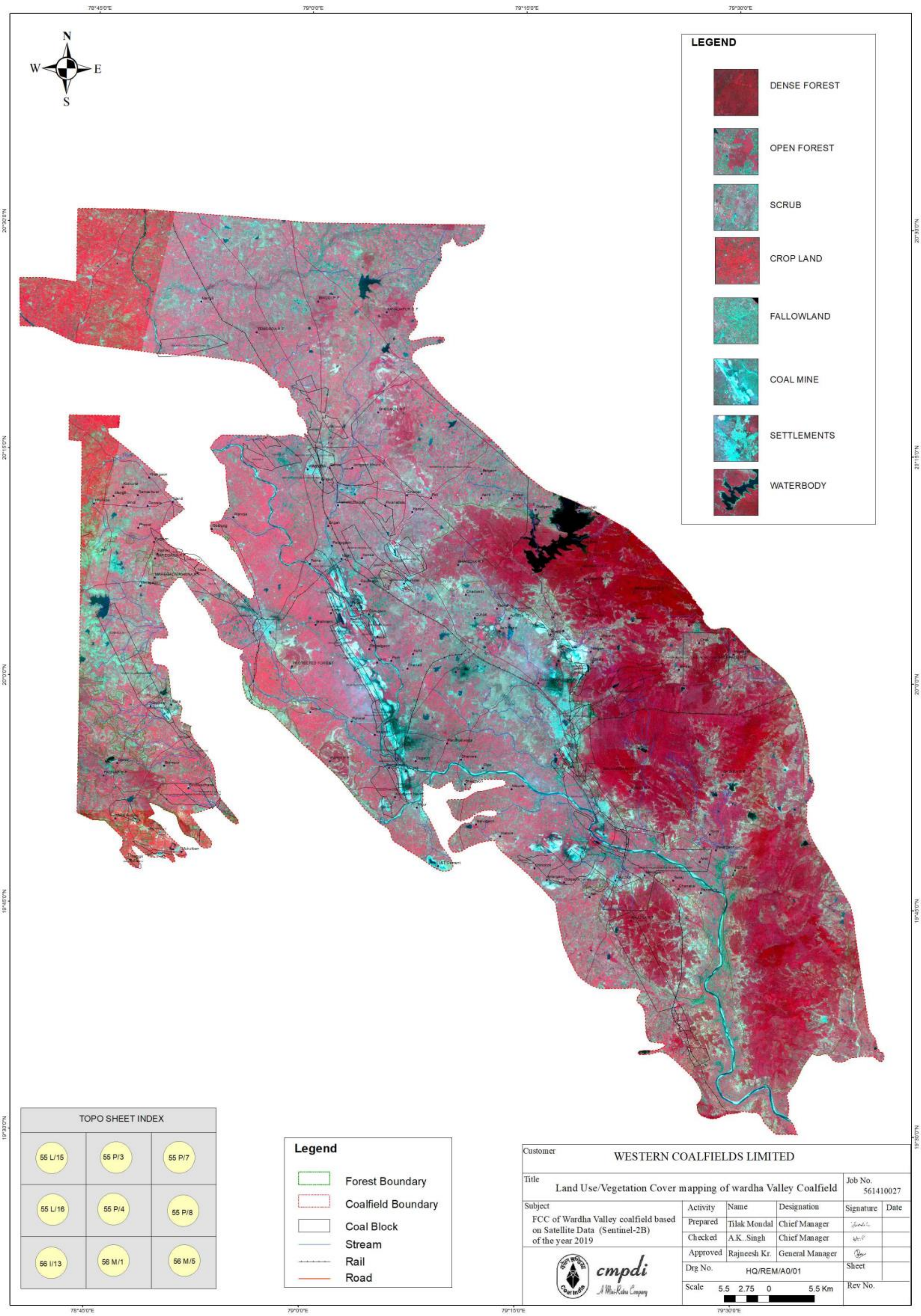

Plate 1 : FCC (Band 8,4,3) of Wardha Valley CF based on ESA (Sentinel-2B) Data of Year – 2019

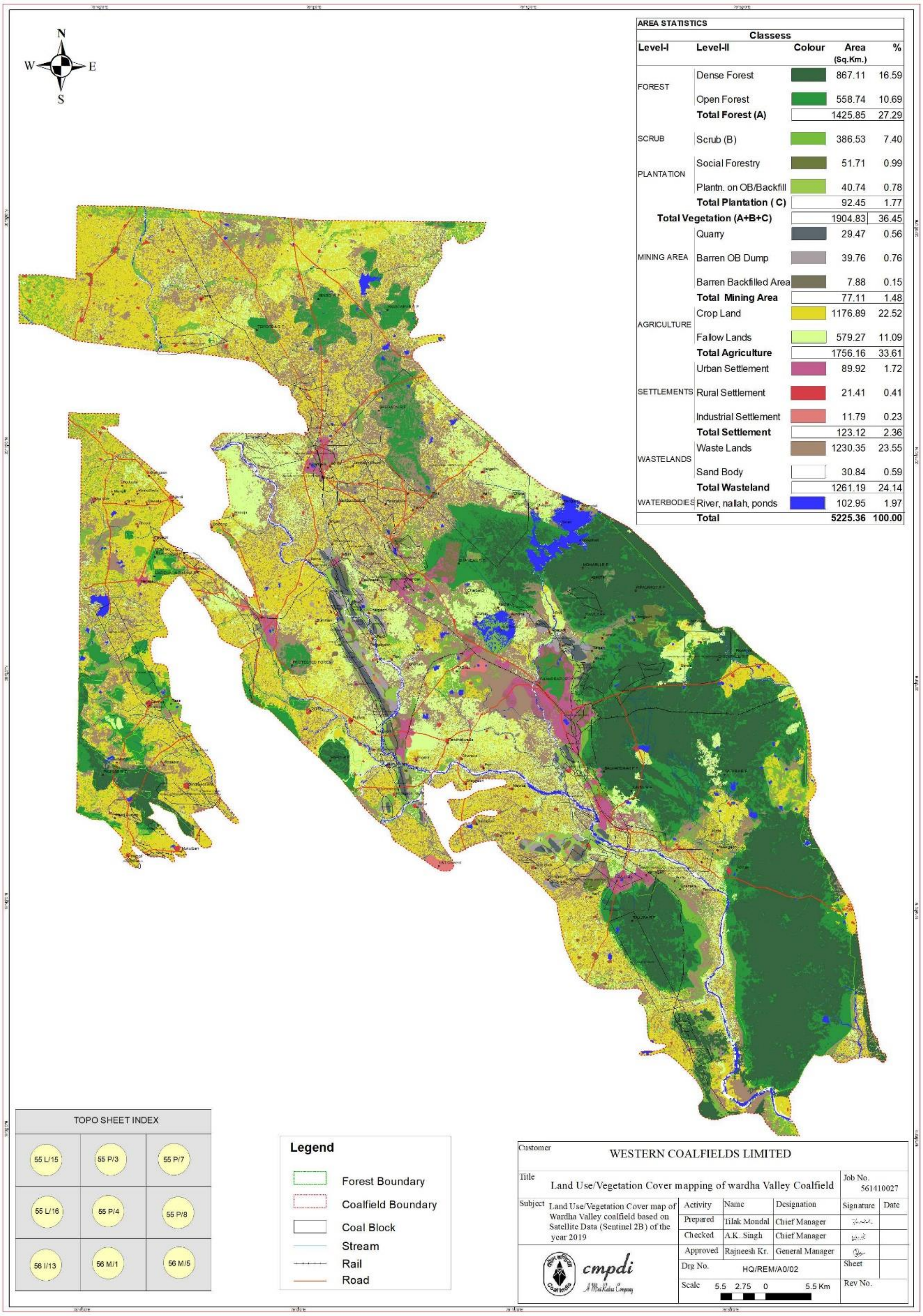

Plate 2 : LU / LC Map of Wardha Valley CF based on ESA (Sentinel-2B) Data of Year 2019

TABLE – 3.2: STATUS OF LAND USE/COVER PATTERN IN WARDHA VALLEY COALFIELD DURING YEAR 2016 & 2019

LAND USE CLASSES	Year-2016		Year-2019		Change w.r.t. Yr 2016		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
SETTLEMENTS							
Rural Settlements	13.05	0.25	21.41	0.41	8.36	0.16	More rural area has been identified in the year 2019 as compared to in the year 2016. Urban settlements have been increased due to more industrilization.
Urban Settlements	85.50	1.64	89.92	1.72	4.42	0.08	
Industrial Settlements	9.30	0.18	11.79	0.23	2.49	0.05	
Total Settlements	**107.85**	**2.06**	**123.12**	**2.36**	15.27	0.29	
VEGETATION COVER							
FOREST							
Dense Forest	810.26	15.51	867.11	16.59	56.85	1.09	Dense forest have been increased as open forest have been classified into dense forest as per open series toposheet of SOI.
Open Forest	596.30	11.41	558.74	10.69	-37.56	-0.72	
Total Forest (A)	**1406.56**	**26.92**	**1425.85**	**27.29**	19.29	0.37	
SCRUBS							
Scrubs (B)	419.37	8.03	386.53	7.40	-32.84	-0.63	As per open series toposheet of SOI, some scruby area comes under open forest area.
PLANTATION							
Social forestry	20.46	0.39	51.71	0.99	31.25	0.60	Social Forestry have been increased due plantation around settlements stemmed from afforestation drive by Govt. Increase in plantation on OB/Backfill
Plantation on OB/Backfill	36.00	0.69	40.74	0.78	4.74	0.09	
Total Plantation (C)	**56.46**	1.08	**92.45**	1.77	35.99	0.69	
Total Vegetation (A+B+C)	**1882.39**	**36.02**	**1904.83**	**36.45**	22.44	0.43	
MINING AREA							
Coal Quarry	23.41	0.45	29.47	0.56	6.06	0.12	Quarry increased due to mining
Barren OB Dump	37.07	0.71	39.76	0.76	2.69	0.05	OB dump increased due to mining
Barren Backfilled	11.09	0.21	7.88	0.15	-3.21	-0.06	Backfilled are planted.
Total Mining Area	**71.57**	**1.37**	**77.11**	**1.48**	5.54	**0.11**	
AGRICULTURE							
Crop Land	1060.47	20.29	1176.89	22.52	116.42	2.23	Waste land have been converted into agricultural land.
Fallow Land	569.95	10.91	579.27	11.09	9.32	0.18	
Total Agriculture	**1630.42**	**31.20**	**1756.16**	**33.61**	125.74	**2.41**	
WASTELANDS							
Waste land	**1394.90**	26.69	**1230.35**	23.55	-164.55	-3.15	Waste land have been converted into agricultural land.
Sand Body	**34.18**	0.65	**30.84**	0.59	-3.34	-0.06	
Total Wasteland	**1429.08**	**27.35**	**1261.19**	**24.14**	-167.89	**-3.21**	
WATERBODIES							
River, nallah, pond etc.	**104.05**	1.99	**102.95**	1.97	-1.10	-0.02	
TOTAL	**5225.36**	**100.00**	**5225.36**	**100.00**	**0.00**	**0.00**	

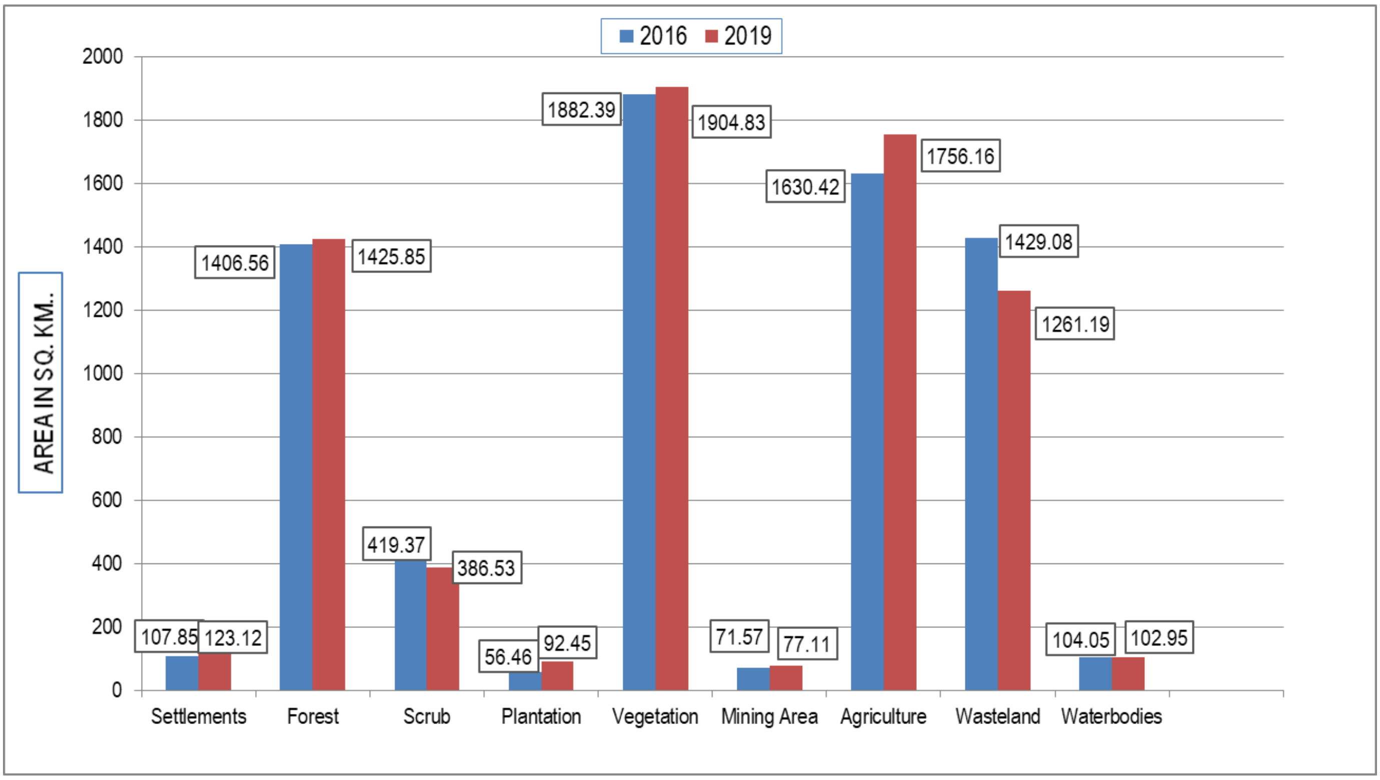

Fig. 3.1 : Year-wise Comparison of Land use / Vegetation Cover in Wardha Valley Coalfield

3.3.1 Settlements

All the man-made constructions covering the land surface are included under this category. Built-up land has been further divided in to rural, urban and industrial classes. In the present study, industrial settlement indicates only industrial complexes excluding residential facilities. In the year 2016 the total area covered by settlements were estimated to be 107.85 sq. km(2.06%). In year 2019 the estimated area under settlements has grown to 123.12 sq. km (2.36%). There is an increase in Settlements by 15.27 sq. km. which is about 0.29% of the total area. This increase is due to more urbanisation in mining and around small town..

The details of the land use under this category are shown in Table 3.3 as follows:

TABLE – 3.3

STATUS OF CHANGE IN SETTLEMENTS IN WARDHA VALLEYCOALFIELD DURING YEAR 2016 & 2019

LAND USE CLASSES	Year-2016		Year-2019		Change w.r.t. Yr 2016		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
SETTLEMENTS							
Rural Settlements	13.05	0.25	21.41	0.41	8.36	0.16	More rural area has been identified in the year 2019 as compared to in the year 2016. Urban settlements have been increased due to more industrilization.
Urban Settlements	85.50	1.64	89.92	1.72	4.42	0.08	
Industrial Settlements	9.30	0.18	11.79	0.23	2.49	0.05	
Total Settlements	**107.85**	**2.06**	**123.12**	**2.36**	15.27	0.29	

3.3.2 Vegetation cover Analysis

Vegetation cover in the coalfield area comprises following five classes:

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

There has been significant variation in the land use under the vegetation classes within the area as shown below in Table 3.4.

TABLE – 3.4

STATUS OF CHANGE IN VEGETATION IN WARDHA VALLEYCOALFIELD DURING YEAR 2016 & 2019

LAND USE CLASSES	Year-2016		Year-2019		Change w.r.t. Yr 2016		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
VEGETATION COVER							
FOREST							
Dense Forest	810.26	15.51	867.11	16.59	56.85	1.09	Dense forest have been increased as open forest have been classified into dense forest as per open series toposheet of SOI.
Open Forest	596.30	11.41	558.74	10.69	-37.56	-0.72	
Total Forest (A)	**1406.56**	**26.92**	**1425.85**	**27.29**	19.29	0.37	
SCRUBS							
Scrubs (B)	419.37	8.03	386.53	7.40	-32.84	-0.63	As per open series toposheet of SOI, some scruby area comes under open forest area.
PLANTATION							
Social forestry	20.46	0.39	51.71	0.99	31.25	0.60	Social Forestry have been increased due plantation around settlements stemmed from afforestation drive by Govt. Increase in plantation on OB/Backfill
Plantation on OB/Backfill	36.00	0.69	40.74	0.78	4.74	0.09	
Total Plantation (C)	**56.46**	1.08	**92.45**	1.77	35.99	0.69	
Total Vegetation (A+B+C)	**1882.39**	**36.02**	**1904.83**	**36.45**	22.44	0.43	

Dense forest – Forest having crown density of above 40% comes in this class. In the year 2016 the total area covered by dense forest were estimated to be 810.26 sq. km.(15.51%). In year 2019 the estimated area under dense forest has been 867.11 sq. km. (16.59%). There is an increase in dense forest by 56.84 sq. km as open forest being converted into dense forest which is about 1.09% of the total area.

Open Forest – Forest having crown density between 10% to 40% comes under this class. Open forest cover over Wardha Valley coalfield which was estimated to be 596.30 sq. km (11.41%) in 2016 has been decreased to 558.74 sq. km, i.e.10.69 % of the coalfield area in 2019. Thus the decrease in open forest is 37.56 sq. km which is 1.50 % of the total coalfield area. This reduction in open forest is attributed to conversion to dense forest.

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. There is 386.53 sq km. of scrubs, i.e. 7.40% of the coalfield area in 2019. In year 2016 the scrubs covered 419.37 sq km which were 8.03% of the coalfield area. There is an decrease of 32.84 sq. km which is 0.63% of the coalfield area .The decrease is taken place because some area of scrubs has been classified as open forest as per open series Toposheets of SOI. .

Social Forestry – Plantation which has been carried out on wastelands, along the roadsides and colonies on green belt come under this category. Analysis of data reveals Social Forestry covers 20.46 sq. km, which is 0.39% of the coalfield area in 2016. In 2019 the area covered under social forestry was 51.71 sq. km (0.99%). There is an increase of 31.25 sq. km (0.60%). This increase is due to plantation around settlements stemmed from afforestation drive of Govt.

Plantation over OB Dump and backfilled area – Analysis of the data reveals that WCL has carried out significant plantation on OB dumps as well as backfilled areas during the period for maintaining the ecological balance of the area. The plantation on the OB dumps and backfilled areas were estimated to be 36.00 sq. km, i.e. 0.69% of the coalfield area in 2016. In year 2019 the plantation on OB Dumps is estimated to cover an area of 40.74 sq. km which was 0.78% of the coalfield area. There is an increase of 4.74 sq. km (0.09%) in plantation over OB dumps. This is due to plantation done on OB dumps and backfill.

3.3.3 Mining Area

The mining area was primarily been categorized as.

- Coal Quarry
- Barren OB Dump

To make the study more relevant and to give thrust on land reclamation, in the current study some more classes have been added as follows:

- Barren Backfilled Area
- Coal Dumps
- Water filled Quarry

In the year 2016 the coal quarry was estimated to be 23.41 sq. km (0.45%) which has increased to 29.47 sq. km (0.56%) in the year 2019. This increase is due to increase in production of coal from Open cast areas. In the year 2016 the barren OB dump was estimated to be 37.07 sq. km (0.71%) which has been increased to 39.76 sq. km

(0.76%) in the year 2019. This increase is due to increase in mining activity. In the year 2016 the barren backfilled area was estimated to be 11.09 sq. km (0.21%) which has been decreased to 7.88 sq. km (0.15%) in the year 2019 due to plantation on backfill. The status of land Use in the mining area over the Wardha Valley Coalfield is shown in the table 3.5 below.

TABLE – 3.5

Status of change in Mining Area in Wardha Valley Coalfield during the year 2016 & 2019

LAND USE CLASSES	Year-2016		Year-2019		Change w.r.t. Yr 2016		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
MINING AREA							
Coal Quarry	23.41	0.45	29.47	0.56	6.06	0.12	Quarry increased due to mining
Barren OB Dump	37.07	0.71	39.76	0.76	2.69	0.05	OB dump increased due to mining
Barren Backfilled	11.09	0.21	7.88	0.15	-3.21	-0.06	Backfilled are planted.
Total Mining Area	**71.57**	**1.37**	**77.11**	**1.48**	5.54	**0.11**	

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 (irrigated and unirrigated) and fallow land (land used for cultivation, but temporarily allowed to rest)

Crop land is 1060.47 sq. km in year 2016, which is 20.29 % of the coalfield area. In year 2019 the crop land was estimated to be 1176.89 sq. km which was 22.52% of the coalfield area. There is an increase of 116.42 sq. km which is 2.23% of the coalfield due to conversion of fallow land in crop land and waste land into agricultural land. The details are shown below in Table 3.6.

TABLE – 3.6

Status of change in Agricultural land in Wardha Valley Coalfield during the year 2016 & 2019

LAND USE CLASSES	Year-2016		Year-2019		Change w.r.t. Yr 2016		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
AGRICULTURE							
Crop Land	1060.47	20.29	1176.89	22.52	116.42	2.23	Waste land have been converted into agricultural land.
Fallow Land	569.95	10.91	579.27	11.09	9.32	0.18	
Total Agriculture	**1630.42**	**31.20**	**1756.16**	**33.61**	125.74	**2.41**	

3.3.5 Wasteland

Wasteland is degraded and unutilised class of land which is deteriorating 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 management constraints.

The land use pattern within the area for waste lands is shown below in Table – 3.7. the waste land was estimated to be 1394.9 sq. km (26.69%) in the year 2016. In the year of 2019, waste land is estimated to be 1230.35 sq. km (23.55%). So there is a decrease of 164.55 sq. km i.e. (3.15%) of the total coalfield area. This is due to conversion of waste land into agricultural land. The details are shown below in Table 3.7.

TABLE – 3.7

Status of Change in Wastelands in Wardha Valley Coalfield during the year 2016 & 2019

LAND USE CLASSES	Year-2016		Year-2019		Change w.r.t. Yr 2016		Remarks
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%	
WASTELANDS							
Waste land	**1394.90**	26.69	**1230.35**	23.55	-164.55	-3.15	Waste land have been converted into agricultural land.
Sand Body	**34.18**	0.65	**30.84**	0.59	-3.34	-0.06	
Total Wasteland	**1429.08**	**27.35**	**1261.19**	**24.14**	-167.89	**-3.21**	

3.3.6 Water bodies

It is the area of impounded water includes natural lakes, rivers/streams and manmade canal, reservoirs, tanks etc. The water bodies in the study area had been estimated to be 104.05 sq. km in year 2016, which is 1.99% of the coalfield area. In 2019 it have been estimated to be 102.95 sq. km which is 1.97% of the total area. So there is an decrease of 1.10 sq. km. in water bodies which is 0.02% of the total coalfield area.

Chapter 4

Conclusion & Recommendation

4.1 Conclusion

In the present study, land use/ vegetation cover mapping has been carried out based on Sentinel 2B satellite sensor data of March, 2019 in order to monitor the impact of coal mining on land environment which may help in formulating the mitigation measures required, if any.

Study reveals that the total area of settlements which includes urban, rural and industrial settlements in the Wardha Valley coalfields covers 123.12 km^2 (2.36%) area. There is an increase in settlements by 15.27 sq.km over the 2016 study primarily on account of more urbanisation in mining area and around small town. Vegetation cover which includes dense forests, open forests, scrubs, avenue plantation & plantation on over-burden dumps, covers an area of 1904.83 km^2 (36.45%). As compared to 2016 study there is an increase in overall vegetation cover by 22.44 km^2 (0.43%) this is mainly because there is a marginal increase in forest area and plantation. The analysis further indicates that total agricultural land which includes both crop and fallow land has increased by 125.74 km^2 (2.41 %) because of conversion of waste land into agricultural land due to good monsoon over the last few years in Wardha Valley coalfield. The mining area which includes coal quarry, barren OB dump, barren backfilled area, covers 77.11 km^2 (1.48%). As compared to 2016 there is an increase in areas under mining operations due to more production of coal. Wasteland covers 1261.19 km^2 (24.14%) in 2019 and 1429.08 km^2 (27.35%) in 2016. Waste lands have reduced because some wastelands has been converted in fallow land due to good monsoon.

The detail statistical analysis is given under Table-3.2.

4.2 Recommendation

It is essential to maintain the ecological balance for sustainable development of the area together with coal mining in Wardha Valley Coalfield. It is recommended that land reclamation of the mining area should be taken up on Top Priority by WCL. Such study should be carried out regularly 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.

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