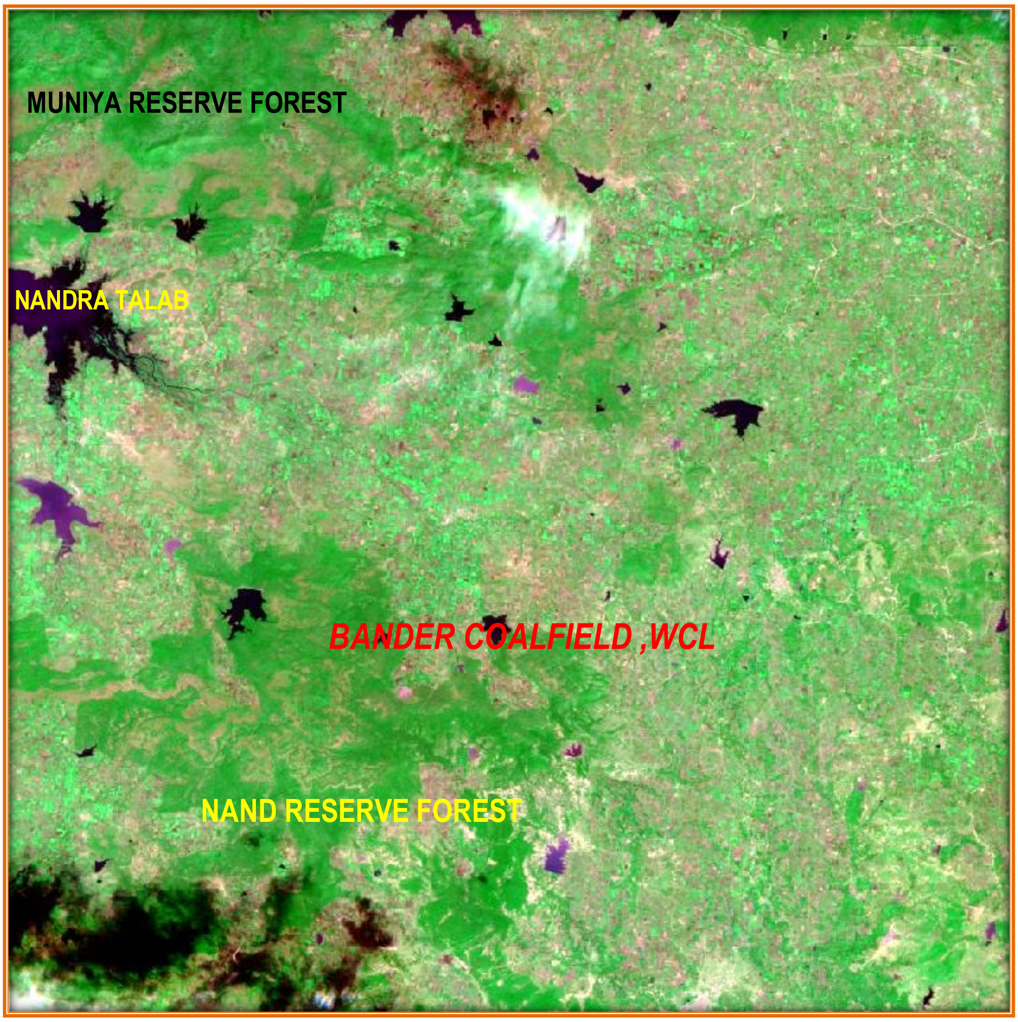
REPORT ON
LAND USE/ COVER MAPPING OF BANDER COALFIELD BASED ON SATELLITE DATA OF THE YEAR 2015 USING DIGITAL IMAGE PROCESSING TECHNIQUE



Submitted to

WESTERN COALFIELD LIMITED

MARCH 2016

cmpdi
A Mini Ratna Company

REPORT ON
LAND USE/COVER MAPPING OF BANDER COALFIELD BASED ON REMOTE SENSING DATA USING DIGITAL IMAGE PROCESSING TECHNIQUE

Submitted to

Western Coalfields Limited (WCL)
Nagpur, Maharashtra

March 2016

Central Mine Planning & Design Institute Ltd.
Gondwana Place, Kanke Road
Ranchi 834 008, India

Contents

Document Control Sheet

(1)	Job No.	561410027
(2)	Publication Date	March 2016
(3)	Number of Pages	29
(4)	Number of Figures	10
(5)	Number of Tables	8
(6)	Number of Plates	1
(7)	Title of Report	Land use/cover mapping of Bander coalfield based on remote sensing data using digital image processing technique.
(8)	Aim of the Report	To prepare land use/cover map of Coalfield area of Bander Coalfield on 1:50,000 scale based on satellite data (R2- L4FX) of the year 2015 using digital image processing technique. To analyse land use/cover pattern within the area of Bander Coalfield and change detection in 2015 over 2012.
(9)	Executing Unit	Remote Sensing Cell, Geomatics Division, Central Mine Planning & Design Institute Limited, Gondwana Place, Kanke Road, Ranchi 834008 India
(10)	User Agency	Western Coalfields Limited (WCL), Nagpur, Maharashtra
(11)	Authors	B.K. Choudhary, Sr. Manager (E&M) Mr. N.P. Singh, General Manager (Geomatics)
(12)	Security Restriction	Restricted Circulation
(13)	No. of Copies	5

(14) Distribution Statement Official

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 Ltd 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, road map for implementation of the project was submitted to Coal India Ltd. for land use and vegetation cover mapping of 28 major coalfields for creating the geo-environmental data base and subsequent monitoring of impact of coal mining land environment at regular interval of three years. A Work order no. CIL/WBP /NV/ 2009 /2428 DATAED 29.12.2009 was issued by CIL initially for three years. Subsequently , revised work order was issued vide letter no. CIL/WBP/Env/2011 /4706 dated 12.10.2012 from Coal India Ltd for the period 2012-2013 to 2016-17 for land reclamation monitoring of all the opencast projects as well as vegetation cover monitoring of 28 major coalfields including Western coalfield as per a defined plan for monitoring the impact of mining on Vegetation Cover.

.

Project Background

Western Coalfield Limited (WCL), is subsidiary of Coal India Ltd ,dedicated for maintaining the ecological balance in the region has initiated a massive plantation programme on backfilled area, OB Dump and wasteland. The advent of high resolution , multispectral satellite data has opened a new avenue in the field of mapping and monitoring of vegetation Cover . The present study has been taken up to access the impact of coal mining on land use and vegetation Cover in the Western Coalfield with respect to earlier study carried out of Western Coalfield in the year 2012.

1.2 Objectives

The objectives of present study to prepare land use/cover map of Bander Coalfields covering an area of 361.09 km^2. on a scale of 1:50,000 based on satellite data of the year 2015,for creating the geo-environmental data base in respect of land use, Vegetation Cover ,Drainage ,mining area, infrastructure etc. and regular up-dation of data base at regular interval of three years to assess the impact of coal mining and other activities on land use and Vegetation Cover in the Coalfield area.

1.3 Location & Accessibility

Bander Coalfield (BCF), situated about 70 km south of Nagpur, consists of part of Nagpur and Chandrapur districts of Maharashtra State. The area is bounded between North Latitudes 20^0 29' 06" to 20^0 48' 22" and East Longitudes 79^0 09' 15" to 79^0 26' 39" and is covered by Survey of India (SoI) toposheet Nos. $55^P/_1$, $55^P/_2$, $55^P/_5$ and $55^P/_6$. The location map and the incidence of study area on toposheets are shown in Figure 1.1. The area extends for about 32 km in north-south direction and 35 km in east-west direction encompassing an area of about 361.09 sq. km.

BCF is approachable by road from Nagpur via Umrer on the northern side and Chandrapur on the southern side. Nand town, situated in the middle of the coalfield region, is connected with Umrer by all-weather tarred road, which in turn connects Bhisi and Bhagawanpur by fair-weather roads.

1.4 Drainage

The Bander Coalfield region is drained by Nand river and its tributaries in the central, Kalhai river and its tributaries in the eastern and Uma river in the southern region. The general flow direction of the Nand river is from west to east and is locally characterized by open and closed meanders. Some of the tributaries pass through the Nand reserved forest in the western part of the coalfield. Kalhai river, though do not pass through the coalfield region, its tributaries are passing through the southern side of Bhisi village. Uma river in Bander area originate from the Nand reserved forest and flow in the south-east direction.

1.5 Reserved Forests

The reserved forests in the Bander coalfield are Muniya and Chichala in the northern side, Wadhona in the central and Nand, Kesarbodi in the south western side.

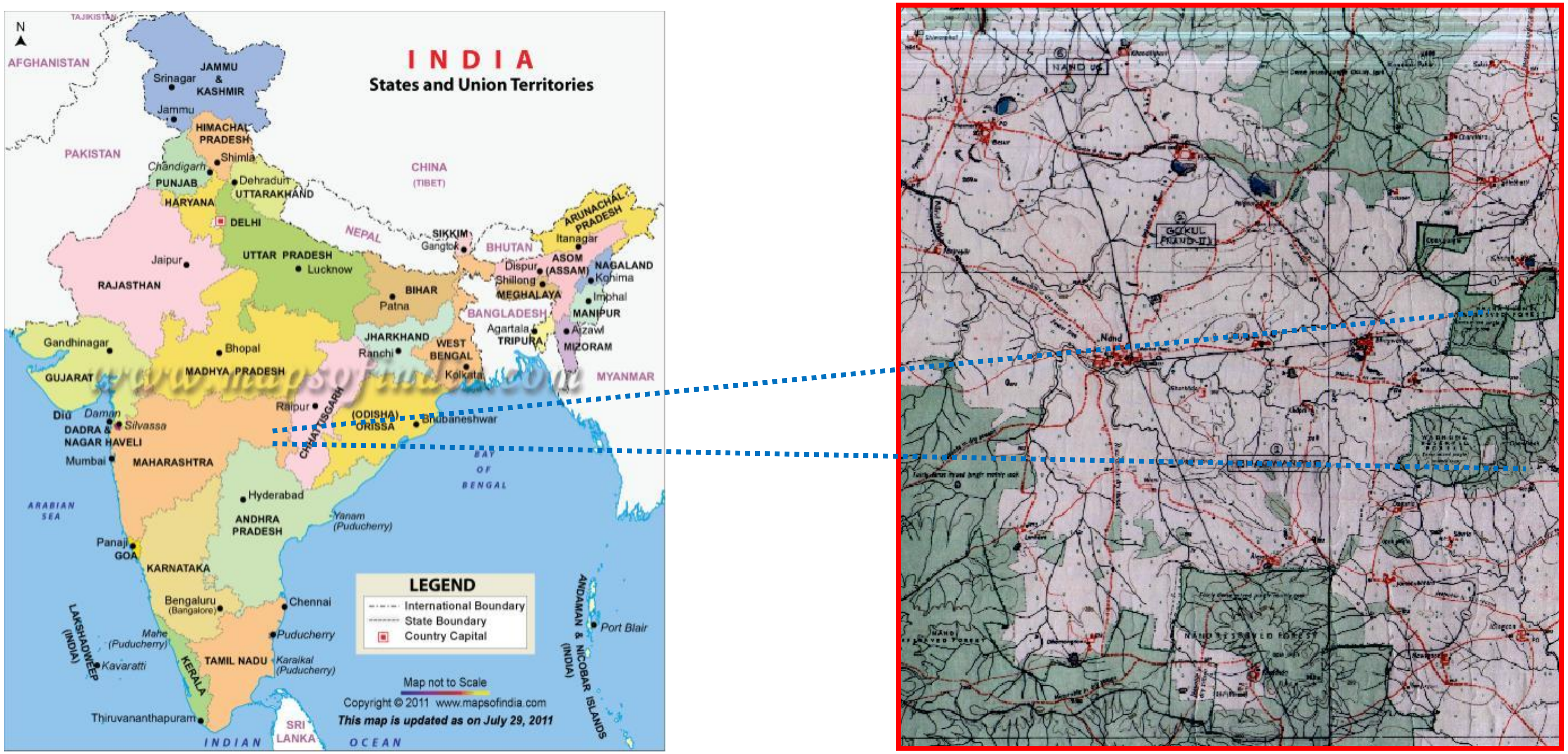


Fig. 1.1 : Location Map of Bander Coalfield, WCL, Nagpur

Chapter 2

Methodology

2.1 Data Source

The following data are used in the present study:

- **Primary Data** - Raw satellite data, obtained from National Remote Sensing Centre (NRSC), Hyderabad, as follows, was used as primary data source for the study.

  RESOURCESAT-2 L4FX; Band 1,2,3 Path # 100, Row # 58A; Date of pass 21.10.2014.
  The detailed specification of the data is also given in Table 2.1

- **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.. Survey of India topo sheet no. $55^{P}/_{1}$, $55^{P}/_{2}$, $55^{P}/_{5}$ and $55^{P}/_{6}$ as well as map showing details of location of area boundary, block boundary and road supplied by WCL were used in the study.

2.2 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 2.1 illustrates the basic properties of IRS-P6 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
Re-source-sat-2	L4FX	B2 B3 B4	0.52 0.62 0.77	- - -	0.59 0.68 0.86	Green Red NIR	10-bit	5.8 m 5.8 m 5.8 m	5 days	India
NIR: Near Infra-Red										

2.3 Data Processing

The details of data processing carried out in the present study are shown in Figure 2.1. 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.

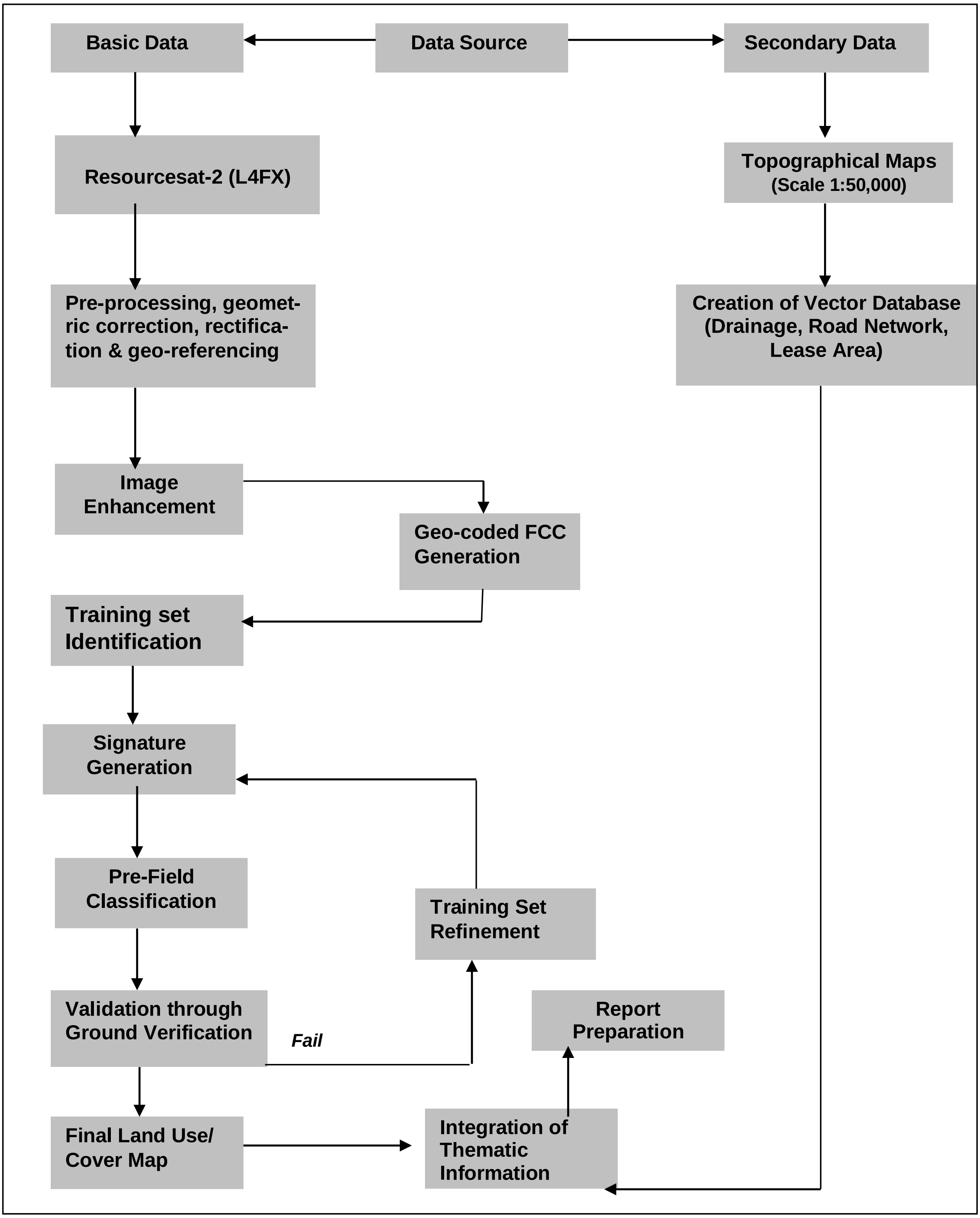


Fig. 2.1 Methodology for Land use/Cover Analysis

2.3.1 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 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 2.2 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 2.2, the vast majority of projections are based upon *cones*, *cylinders* and *planes*.

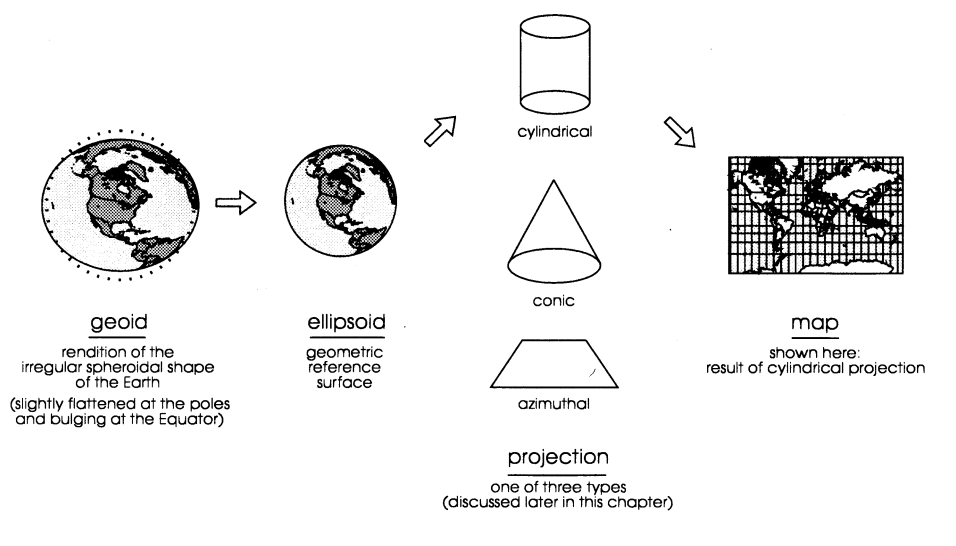


Fig 2.2 : Geoid – Ellipsoid – Projection Relationship

In the present study, ***Polyconic projection*** along with ***Modified Everest 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 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.

2.3.2 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 IMAGINE20014 s/w. The enhanced and geocoded FCC image of Bander Coalfield is shown in Plate No. 1.

2.3.3 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, 100 points were selected to generate the training sets.

2.3.4 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 IMAGINE2014 s/w. The classified image for the year 2015 for Bander Coalfield is shown in Plate No. 1.

2.3.5 Creation/Overlay of Vector Database

Plan showing areas and block boundaries are superimposed on the image as vector layer in the ArcGIS database. Road network, forest boundary and district boundary are digitised on different vector layers of ArcGIS 10.2.2

2.3.6 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 built-up land, waste land and water bodies lie between 90% - 100%. In case of open forest, dense forest, the classification accuracy varies from 90.0% to 92.0%. Classification for scrubs was 91.7%. It was mostly due to poor *signature separability index*. The overall classification accuracy in case **Bander Coalfield** was 93.10%.

2.3.7 Final thematic map preparation

Final land use/cover map (Plate - 1) was printed using HP Design jet 4500 Colour Plotter. The maps are prepared and printed on a scale of 1:50000 and is given in Drawing No. 1 along with the report. However, a soft copy in .pdf format is also enclosed for printing on any desired scale.

	Table 2.2 : Classification Accuracy Matrix for Bander 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**
1	Rural Settle-ment	**C1**	**05**	5							
2	Dense Forest	**C2**	**12**		11	1					
3	Open Forest	**C3**	**10**		1	9	1				
4	Scrubs	**C4**	**12**				11	1			
5	Agriculture Land	**C5**	**10**					9	1		
6	Fallow Land	**C6**	**10**						9	1	
7	Waste Upland	**C7**	**12**							11	
8	Water Bodies	**C8**	**5**								5
Total no. of observation points			**76**								
% of commission				**0.0**	**8.3**	**10.0**	**8.3**	**10**	**10**	**0**	**0**
% of omission				**0.0**	**8.3**	**10.0**	**8.3**	**10**	**10**	**8.3**	**0**
% of Classification Accuracy				**100.0**	**91.7**	**90.0**	**91.7**	**90**	**90**	**91.7**	**100**
Overall Accuracy (%)				**93.10**							

Chapter 3

Land Use/ Vegetation Cover Monitoring

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 vegetation cover. Remote sensing data with its various spectral and spatial resolutions, offers comprehensive and accurate information for mapping and monitoring of land use/cover over a period of time. Since production from the mines are increasing and the mining areas also keep on increasing, it has become very important to reclaim the areas where the mining operations have been completed to reclaim the surface of the earth to its original form along with the vegetation cover.

Realising the need of monitoring of land use/ vegetation cover and land reclamation in major coalfields; CIL requested the services of CMPDI to prepare land use/vegetation cover map of all coalfields at an interval of 3 years, including Bander coalfield for assessing the possible impact of coal mining on land use pattern and vegetation cover using remote sensing data. The first report in this series was prepared in year 2008 to analyse the existing land use/ vegetation cover, which will serve as the base data for future purposes.

The present study incorporates the findings on Land use/Cover pattern in Western Coalfield WCL based on satellite data of the year 2015. Similar study has also been done previously in the year 2008 and 2012.Currently the findings of analysis of the data of the year 2015 is now compared with respect to year 2012 for temporal change in land use/ Vegetation Cover during the 3 year interval .This will help in formulating the mitigative measures, if any required for environmental protection in the coal mining area.

3.2 Land Use / Vegetation 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 database. Further, to accommodate the changing land use/vegetation cover pattern, it becomes essential to develop a standardised classification system that is not only flexible in nomenclature and definition, but also capable of incorporating information obtained from the satellite data and other different sources.

The present framework of land use/cover classification has been primarily based on the '***Manual of Nationwide Land Use/ Land Cover Mapping Using Satellite Imagery***' developed by National Remote Sensing Centre, Hyderabad, which has further been modified by CMPDI for coal mining areas. Land use/vegetation cover map was prepared on the basis of image interpretation carried out based on the satellite data for the year 2015. Following land use/cover classes are identified in the Bander coalfield region (Table 3.1).

Table 3.1
Land use / Vegetation Cover classes identified in Bander Coalfield

	LEVEL –I	LEVEL-II
1	**Vegetation Cover**	3.1 Dense Forest 3.2 Open Forest 3.3 Scrubs
2	**Agricultural Land**	2.1 Crop Land 2.2 Fallow Land
3	**Wasteland**	3.1 Waste upland with/without scrubs 3.2 Sand Body
4	**Settlements**	4.1 Urban 4.2 Rural
5	**Water Bodies**	5.1 River/Streams /Reservoir

-

3.3 Data Analysis & Change Detection

Satellite data of the year 2015 was processed using ERDAS Imagine v.2014 image processing s/w in order to interpret the various land use and vegetation cover classes present in the Bander coalfield. The analysis was carried out for entire coalfield covering about 361.09 sq. km.

The area of each class was calculated and analysed using *ERDAS Digital Image Processing* s/w and *ArcGIS* s/w. Analysis of land use / vegetation cover pattern in Bander Coalfield and changes there in the year 2015 over 2012 was carried out, details are and shown in table 3.2.

TABLE – 3.2

STATUS OF VEGETATION COVER & LANDUSE PATTERN IN BANDER COALFIELD DURING YEAR 2012 & 2015

Area in Sq km

Land Use Classes	Year 2012		Year 2015		Change		Reasons
	Area	% of total	Area	% of total	Area	% of total	
VEGETATION COVER							
Dense forest	43.18	11.96	43.85	12.14	0.67	0.18	
Open Forest	49.32	13.66	49.50	13.71	0.18	0.05	
Total Forest	92.50	25.62	93.35	25.85	0.85	0.23	
Scrubs	58.65	16.24	59.01	16.34	0.36	0.10	Scrubs increased due to good monsoon.in the area.
Total Vegetation Cover	151.15	41.86	152.36	42.19	1.21	0.33	Minor Vegetation cover increased due to less biotic interference by local people.
AGRICULTURE LAND							
Crop Lnad	88.05	24.38	88.08	24.39	0.03	0.01	Crop Land increased due to fallow Land converted into Crop Land.
Fallow Land	107.67	29.82	100.05	27.71	-7.62	-2.11	Fallow Land decreased due to presence of nala, reservoir and some fallow land converted into wasre land and crop land also.
Total Agriculture	195.72	54.20	188.13	52.10	-7.59	-2.10	
WASTE LAND							
Waste land	9.85	2.73	10.35	2.87	0.50	0.14	Waste land incresed due to conversion of fallow land into waste land and sand body.
Sand Body	0	0	0.49	0.14	0.49	0.14	
Total Waste Land	9.85	2.73	10.84	3.01	0.99	0.28	
SETTLEMENTS							
Urban	0.69	0.19	0.70	0.19	0.01	0.00	
Rural	1.12	0.31	1.14	0.32	0.02	0.01	
Total Settlement	1.81	0.50	1.84	0.51	0.03	0.01	Minor increase in settlement due to increse in population .
WATER BODIES							
Water Body	2.56	0.71	7.92	2.19	5.36	1.48	
TOTAL	**361.09**	**100.00**	**361.09**	**100.00**	**0.00**	**0.00**	No change

3.3.1 Vegetation Cover

Vegetation cover in the coalfield area has been found to be predominantly of three classes.

- Dense Forest
- Open Forest

Scrubs have been put into a separate class.

There has been no significant variation in the land use under the vegetation classes within the area as shown in in Table 3.3

. **TABLE – 3.3**

Changes in Agricultural Land in Bander Coalfield during the year 2012 & 2015

Land Use Classes	Year 2012		Year 2015		Change	
	Area	% of total	Area	% of total	Area	% of total
VEGETATION COVER						
Dense forest	43.18	11.96	43.85	12.14	0.67	0.18
Open Forest	49.32	13.66	49.50	13.71	0.18	0.05
Total Forest	**92.50**	**26.52**	**93.35**	**25.85**	**0.85**	**0.23**
Scrubs	**58.65**	**16.24**	**59.01**	**16.34**	**0.36**	**0.10**
Total Vegetation Cover	**151.15**	**41.86**	**152.36**	**42.19**	**1.21**	**0.33**

Dense forest – Forest having crown density of above 40% comes in this class. Dense forest over the area has increased slightly, basically due to less biotic interference by local people. A total increase in dense forest is estimated to be 0.67 Sq km, i.e. 0.18% of the coalfield area.

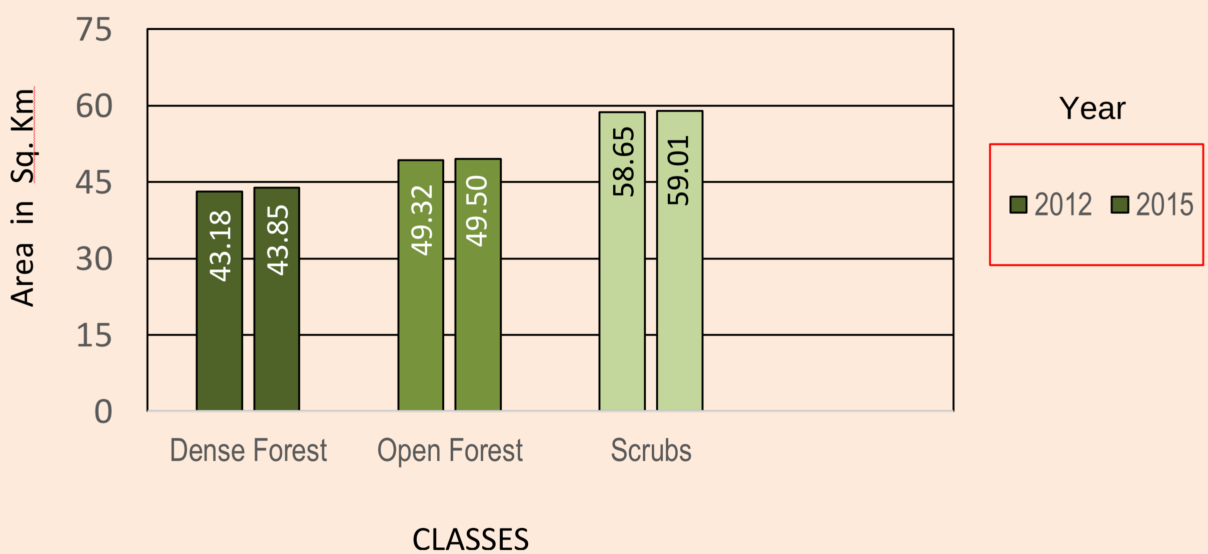
Open Forest – Forest having crown density between 10% to 40% comes under this class. Open forest cover over the area has also increased in the coalfield area. Some of the reduction is also due to deforestation and natural degradation. The total increase observed in open forest is .18 Sq Km, i.e. 0.05% of the coalfield area..

Scrubs – Scrubs are vegetation with crown density less than 10%. Scrubs in the coalfield has increased. This is due to adequate rainfall . There has been increase of 0.36 Sq km, ie 0.10 % of land with scrubs in the Coalfield area.

It is significant to note that the vegetation cover in Bander Coalfield has increased by 1.21 Sq km which is about 0.33% of the Coalfield area. This increase is mainly due to presence of plenty of streams , Nala ,water reservoir and good rainfall which helps to irrigate the vegetation.

The variation in the vegetation classes which took place during year 2012 and 2015 within the area are shown in bar diagram in Figure – 3.1.

Figure-3.1
Changes in Vegetation Cover in Bander Coalfield during Year 2012 &2015



3.3.2 **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)

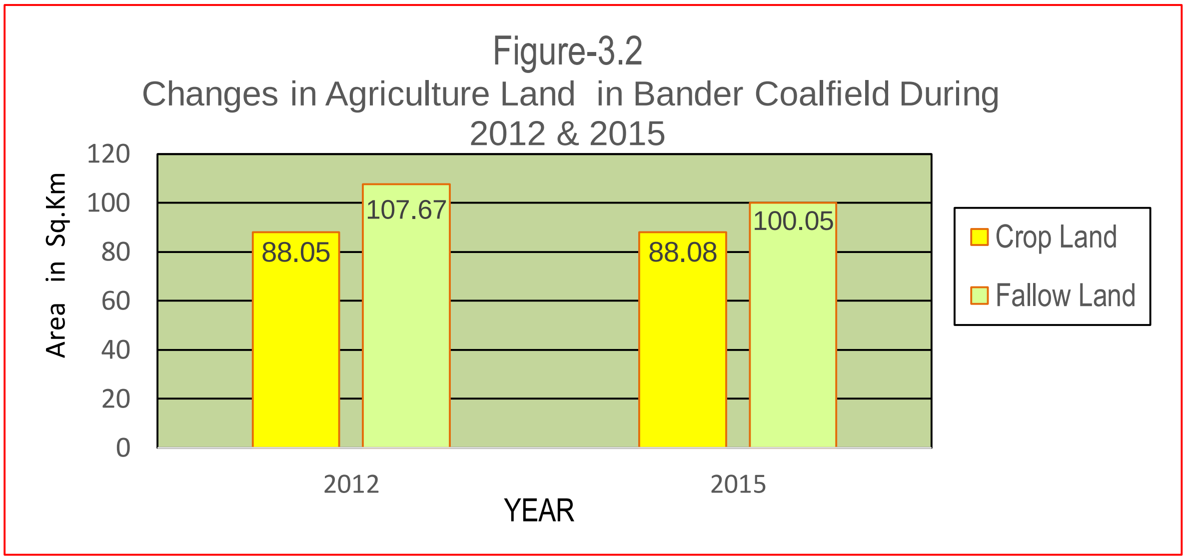
Total agricultural land which was 195.72 Sq km in year 2012 has marginally decreased to 188.13 Sq km in the year 2015. The decrease of 7.59 km (2.10%) in agricultural land is due to presence of Nala ,Streams ,Reservoir and conversion of some fallow land into Waste Land including Sand body and conversion of fallow land into crop Land. . The details are shown below in Table 3.4**.**

TABLE – 3.4

Changes in Agricultural Land in Bander Coalfield during the year 2012 & 2015

	Year 2012		Year 2015		Change Analysis	
Agricultural Land	**Area (sq km)**	**% of total**	**Area (sq km)**	**% of total**	**Area (sq km)**	**% of total**
Crop Land	88.05	24.38	88.08	24.39	0.03	0.01
Fallow Land	107.67	29.82	100.05	27.71	-7.62	-2.11
Sub Total	**195.72**	**54.20**	**188.13**	**52.10**	**-7.59**	**-2.10**

The variation in the Agricultural Land which took place during year 2012 and 2015 within the coalfield area are shown in bar diagram in Figure – 3.2.



3.3.3 Waste Land

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. There has been a slight increase of 0.99 sq km, ie 0.28% of the area as some of the fallow land have become Waste land.

The land use pattern within the area for waste lands is shown below in Table – 3.5.

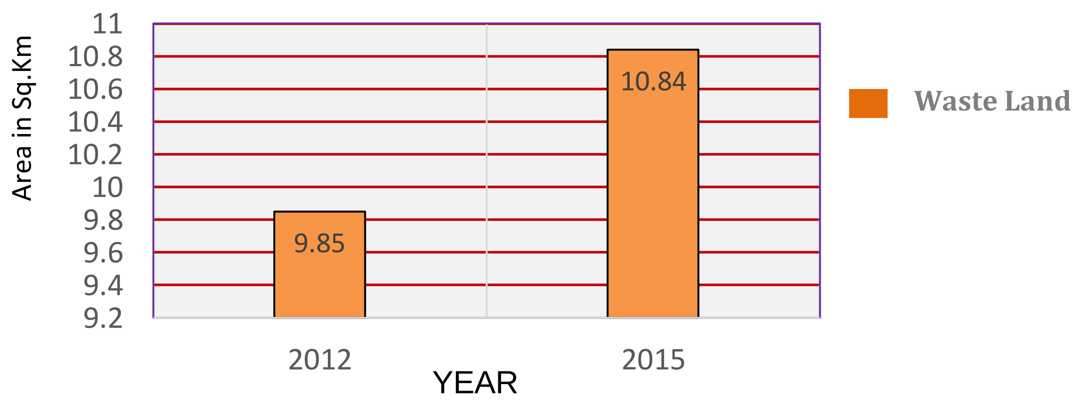
TABLE – 3.5

Changes in Wastelands in Bander Coalfield during the year 2012 & 2015

	Year 2012		**Year 2015**		**Change Analysis**	
Waste land	**Area (Sq km)**	**% of total**	**Area (Sq km)**	**% of total**	**Area (Sq km)**	**% of total**
Wasteland with/without	9.85	2.73	10.35	2.87	0.50	0.14
Sand Body	0	0	0.49	0.14	0.49	0.14
Total Waste Land	9.85	2.73	10.84	3.01	0.99	0.28

The variation in the Waste Land which took place during year 2012 and 2015 within the coalfield area are shown in bar diagram in Figure – 3.3

Figure 3.3
Changes in Waste Land in Bander Coalfield during 2012& 2015



3.3.4 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 and urban classes. The details of the land use under this category are shown in Table 3.6 as follows:

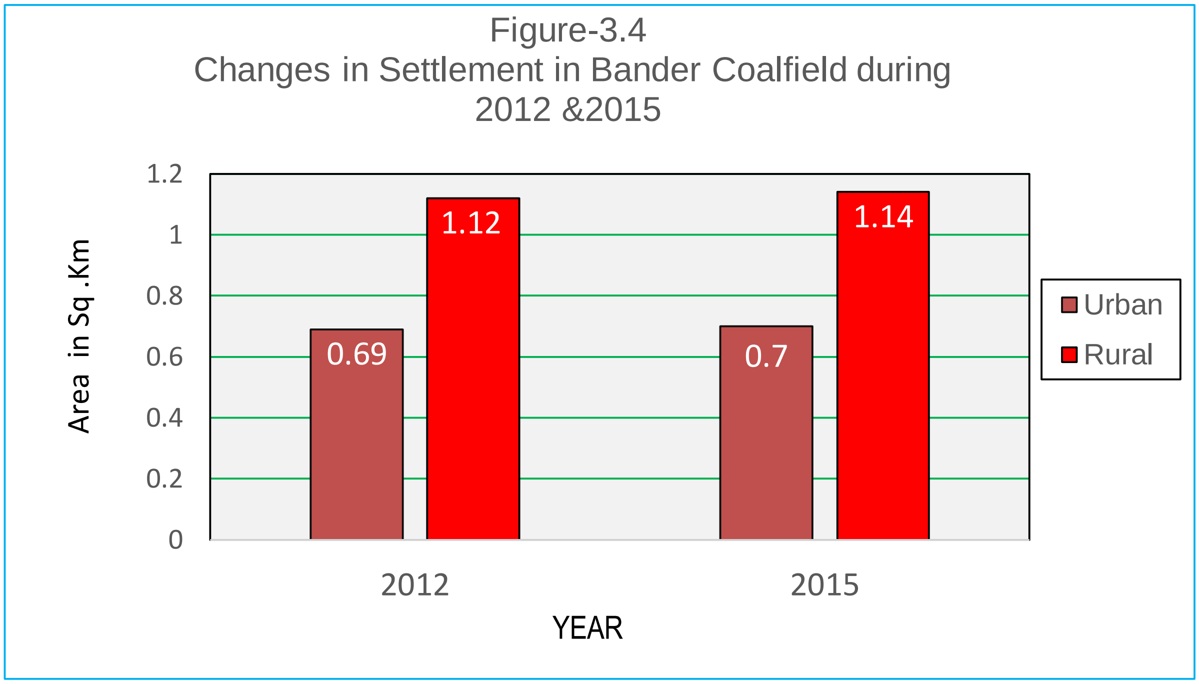
TABLE- 3.6

Changes in Settlements in Bander Coalfields during the year 2012 & 2015

	Year 2012		Year 2015		Change Analysis	
Settlements	Area (sq km)	% of total	Area (sq km)	% of total	Area (sq km)	% of total
Urban	0.69	0.19	0.70	0.19	0.01	0.00
Rural	1.12	0.31	1.14	0.32	0.02	0.01
Sub Total	**1.81**	**0.50**	**1.84**	**0.51**	**0.03**	**0.01**

It is observed that the settlements within the coalfield have grown by 0.03 sq km, which is about 0.01% of the coalfield area. It is observed that the rural settlements have grown marginally by 0.02 sq km which is 0.01% of the coalfield area. The Urban settlement within the coalfield area has grown by about 0.01 sq km. This increase is due to the increasing trend of urbanisation.

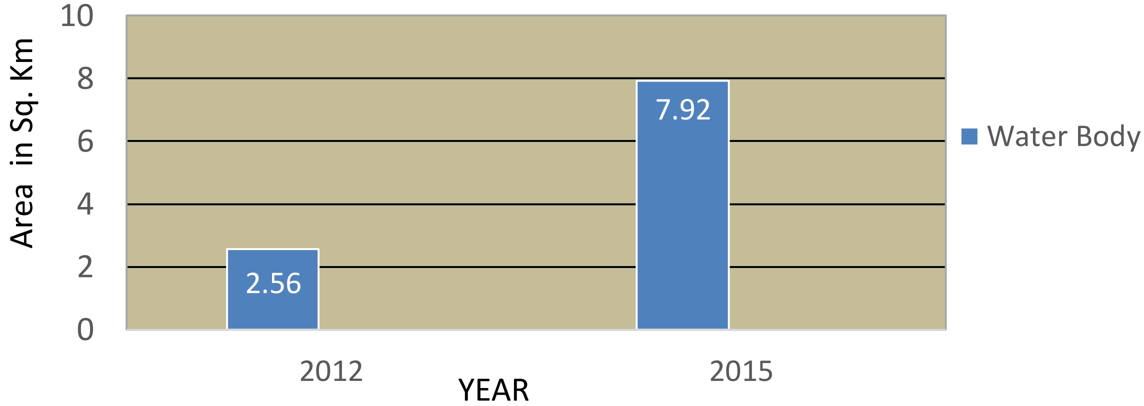
The variation in the Built-up Land/Settlements which took place during year 2012 and 2015 within the coalfield area are shown in bar diagram in Figure – 3.4



3.3.2 Water bodies

It is the area of impounded water includes natural lakes, rivers/streams and man made canal, reservoirs, tanks etc**.** The water bodies in the study area have increased from 2.56 sq km in year 2012 (0.71%) to 7.92 sq km (2.19%) in 2015. This is due to the availability of adequate surface water bodies, Canal and streams in many places. The variation in area under various water bodies within the coalfield area is shown in figure 3.5

Figure-3.5
Changes in water bodies in Bander Coalfield during year 2012& 2015



3.3.3 Changes in Land Use/Vegetation Cover Classes

The overall variation in various Land Use /Cover classes in Moher sub-basin of Bander Coalfield during the year 2012 and 2015 is shown in the Bar Chart below:

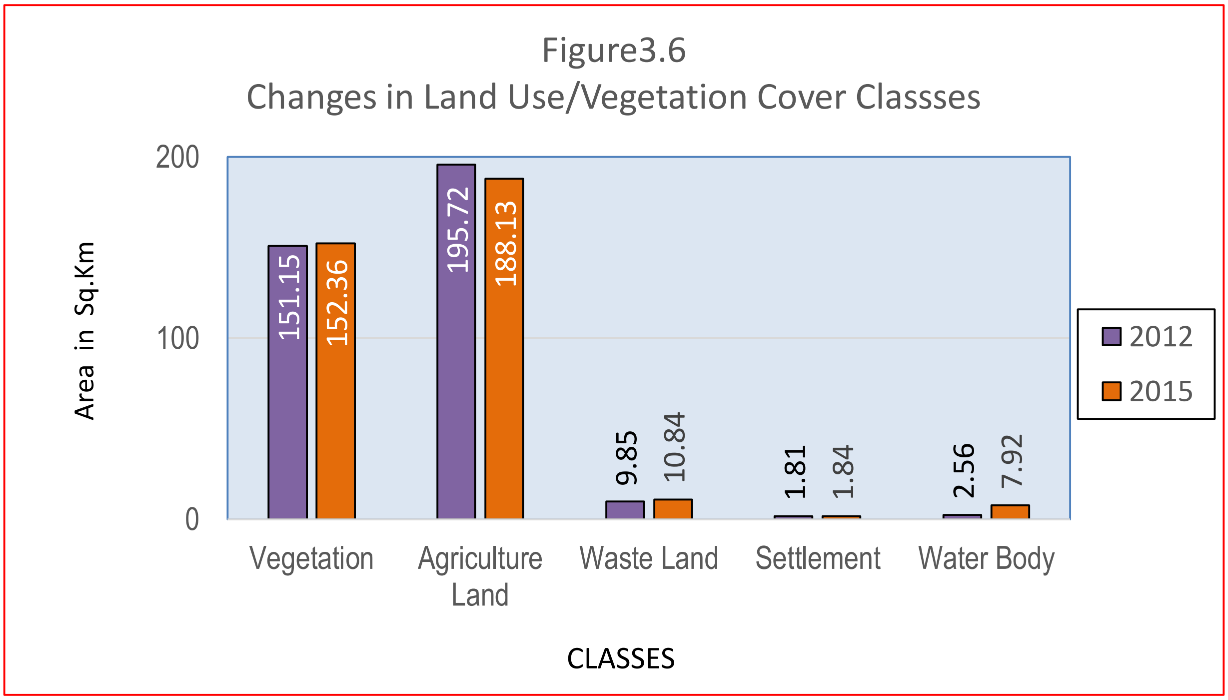
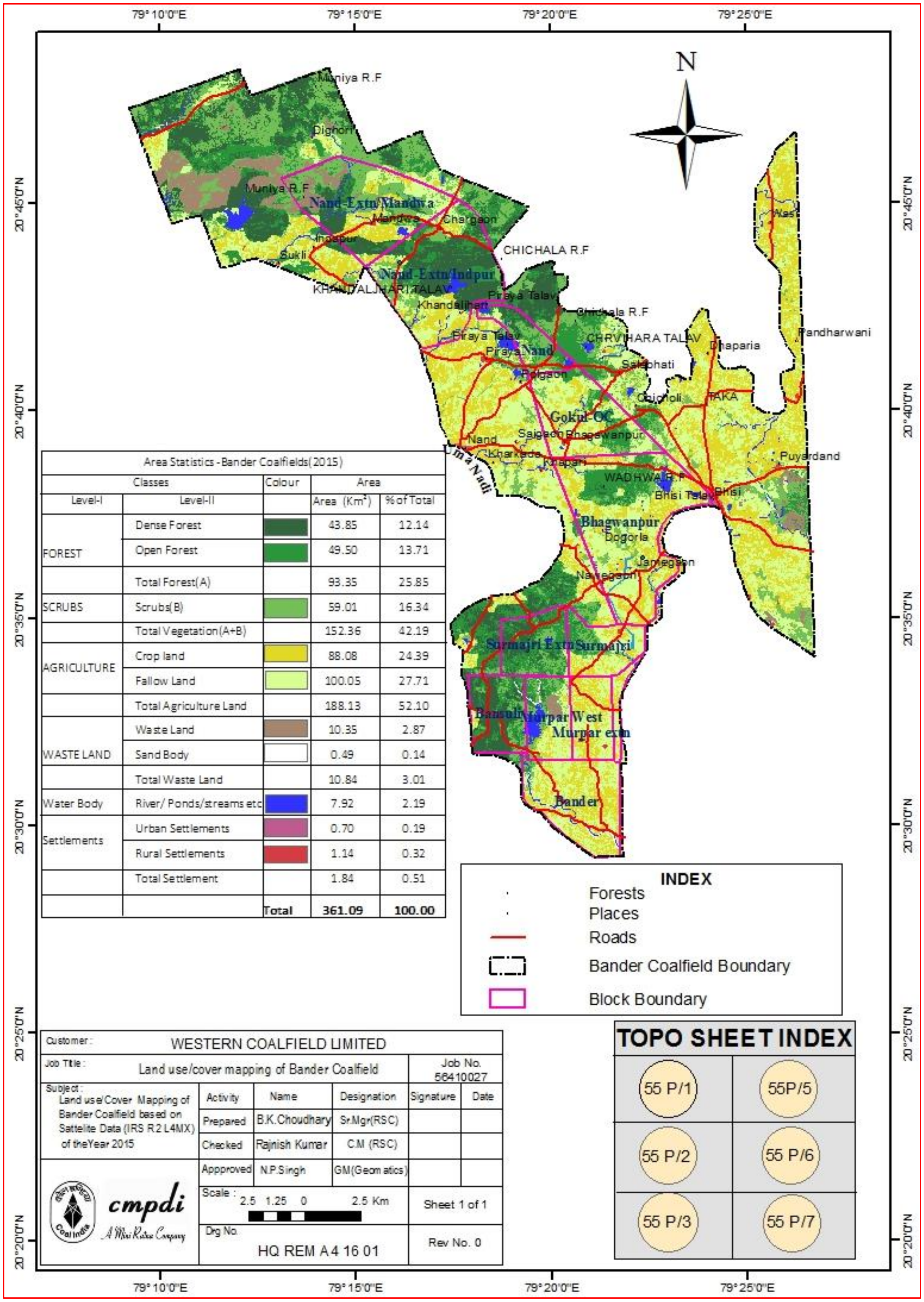


Fig 3.6 Overall Changes in Land Use/Cover Classes in Bander Coalfield in the Year 2012 & 2015

It can be seen from the chart above that there is a Marginal increase in vegetation cover in the coalfield area mainly because of less biotic interference by local people. . Agricultural land has decreased which may be due conversion of some fallow land into waste land. Wasteland has also increased due to presence of Sand Body in River/ Streams ,Nala etc. Settlements have also increased which is due to increase in population and other related human activities.



Area Statistics - Bander Coalfields (2015)

Classes		Colour	Area	
Level-I	Level-II		Area (Km^2)	% of Total
FOREST	Dense Forest		43.85	12.14
	Open Forest		49.50	13.71
	Total Forest(A)		93.35	25.85
SCRUBS	Scrubs(B)		59.01	16.34
	Total Vegetation(A+B)		152.36	42.19
AGRICULTURE	Crop land		88.08	24.39
	Fallow Land		100.05	27.71
	Total Agriculture Land		188.13	52.10
WASTE LAND	Waste Land		10.35	2.87
	Sand Body		0.49	0.14
	Total Waste Land		10.84	3.01
Water Body	River/ Ponds/streams etc		7.92	2.19
Settlements	Urban Settlements		0.70	0.19
	Rural Settlements		1.14	0.32
	Total Settlement		1.84	0.51
		Total	361.09	100.00

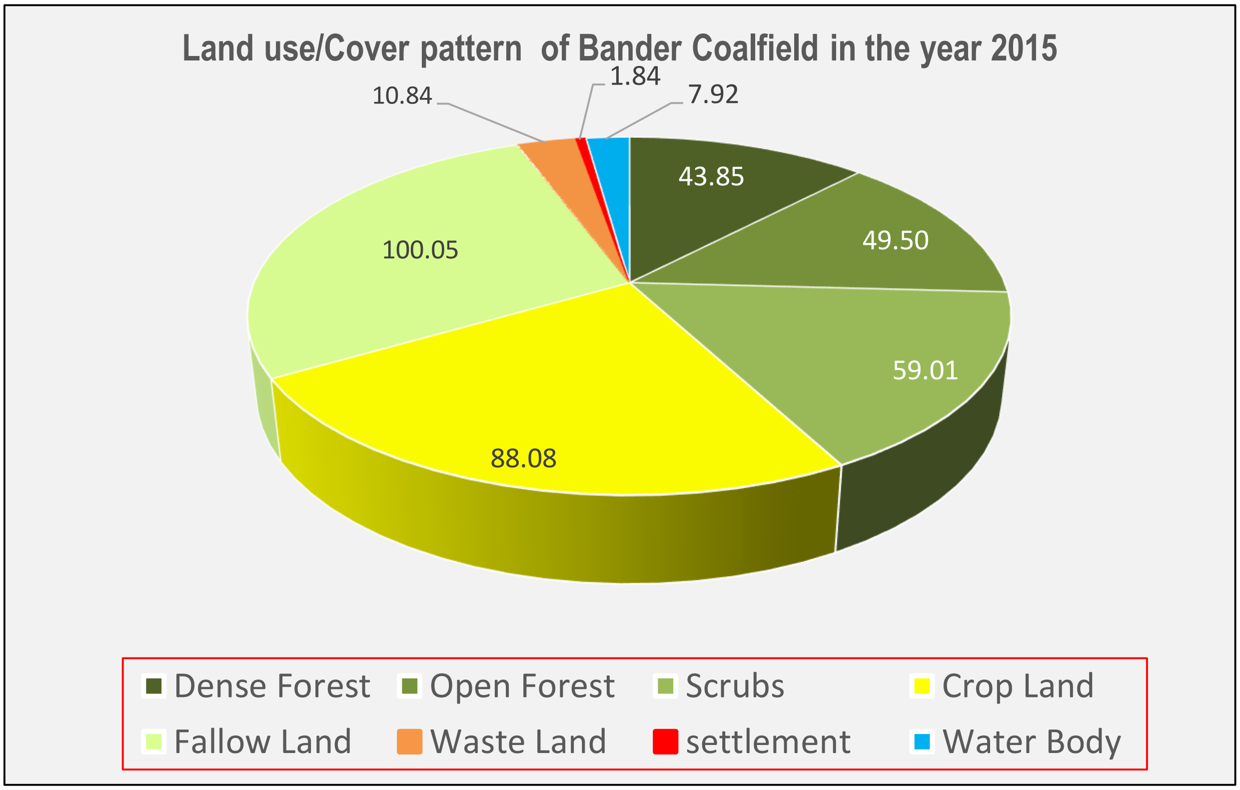
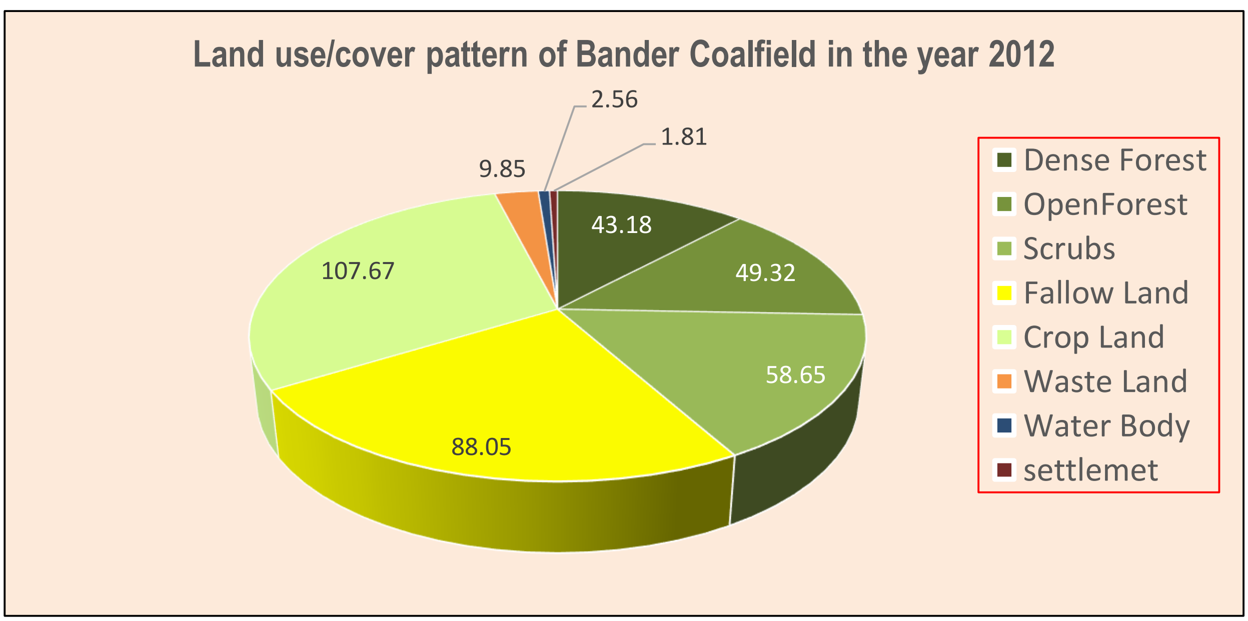


Figure-3.7 Land use / Cover pattern in Bander Coalfield , WCL



Figue-3.8 Land use/Cover pattern in Bander Coalfield ,WCL

Chapter 4

Conclusion & Recommendations

4.1 Conclusion

In the present study, land use/vegetation cover map of Bander Coalfield is prepared based on IRS-Resourcesat 2 L4FX data of March 2015 in order to generate the database on vegetation cover and land use pattern to detect the changes in respect to the year 2012 for effective natural resource management and its planning. The Land use/vegetation cover analysis will help to analyse and monitor the possible impact of mining and other industrial activities in the area.

Study reveals that vegetation cover has increased by 1.21Sq. Km which is 0.33% of the coalfield area in a span of last three years. The major factors for increase in vegetation cover has been found to be increase in water resources and less biotic interference by local people in this region. Scrubs have been kept as separate entity from the forests in line with the practice adopted by Forest Survey of India (FSI). The Scrubs have also increased by 0.36 Sq.Km (0.10%) in the area because of adequate rainfall. Study reveals that increase in dense forest (0.18%) and open forests (0.05%) is mostly due to less biotic interference by local people in this region.

Besides vegetation cover, other land use classes were also analysed and it was observed that in a span of three years, agricultural area has decreased from 195.72 Sq.Km to 188.13 sq km. This decrease of 07.59 Sq.Km (-2.10%) in agricultural area is due to conversion of the some area in waste Land and presence of water reservoir streams etc.

Further study reveals the area of wasteland has also increased very marginally from 9.85 Sq km to 10.84 Sq.Km during the last 3 years. This increase of 0.99 Sq. Km is mainly due to conversion of fallow land into sand body. Area of settlement has increased from 1.81sq km to 1.84Sq.Km. This increase of 0 .03 Sq.Km in settlement area has taken place mainly due to growth of rural population and migration to urban settlements in the region.

The detailed change analysis is given in Table-3.2.

4.2 Recommendations

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

a. Regular plantation should be carried out in order to compensate the deforestation which occurs due to encroachment and other human activity.

b. Fresh settlements should not be allowed in the region.

c. Surface water bodies should be protected and preserved. Efforts are required for rain water harvesting in both urban & rural areas, which may in turn contribute to enhance layer of water in underground.