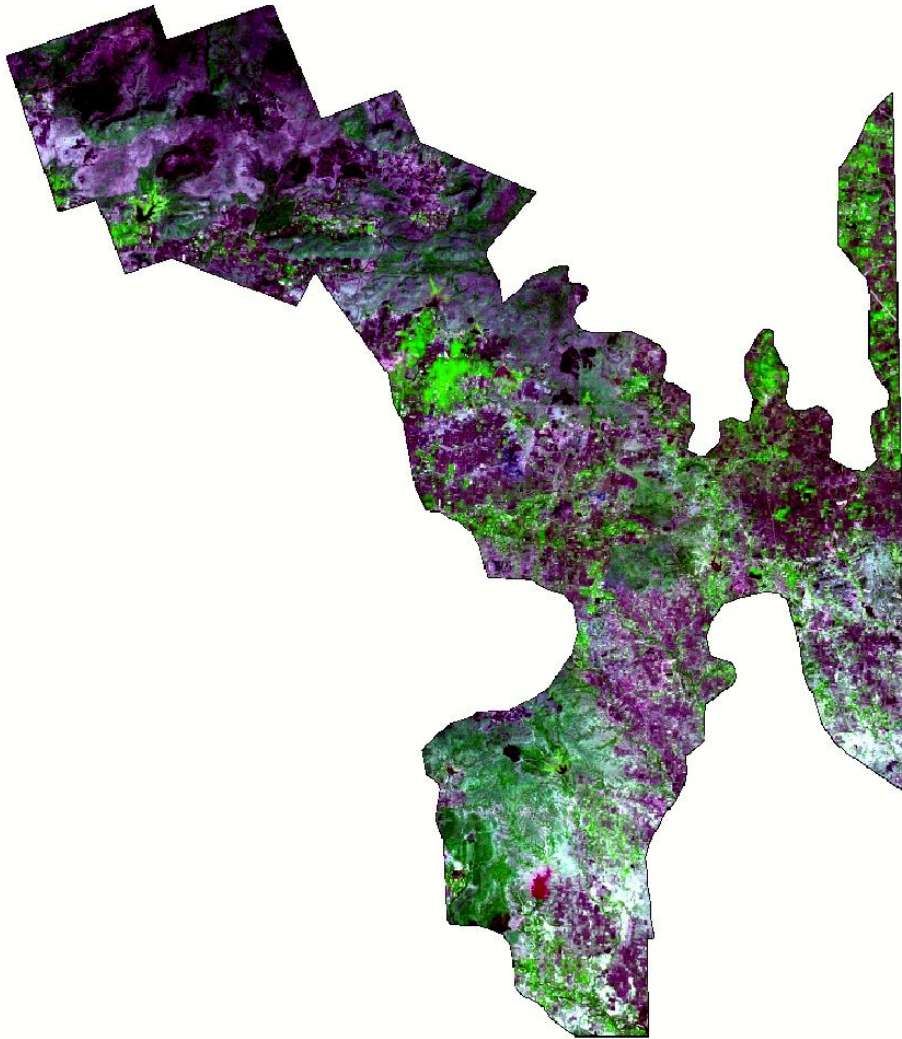


REPORT ON
LAND USE/ VEGETATION COVER MAPPING OF BANDER
COALFIELD OF WCL BASED ON REMOTE SENSING
TECHNIQUE USING SATELLITE DATA OF 2012



March 2013



**REPORT ON
LAND USE/ VEGETATION COVER MAPPING OF BANDER
COALFIELD OF WCL, BASED ON REMOTE SENSING
TECHNIQUE USING SATELLITE DATA OF 2012**

Submitted to

Western Coalfields Limited (WCL)
Nagpur, Maharashtra

March 2013

Central Mine Planning & Design Institute Ltd.
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Contents

	Page No.
Document Control Sheet	i
List of Figures	ii
List of Tables	ii
List of Plates	ii
1.0 Introduction	1 - 4
1.1 Project Reference	
1.2 Objectives	
1.3 Location & Accessibility	
1.4 Drainage	
1.5 Reserved Forests	
2.0 Remote Sensing Concept & Methodology	5 - 13
2.1 Data Source	
2.2 Characteristics of Satellite/Sensor	
2.3 Data Processing	
2.3.1 Geometric Correction, rectification & geo-referencing	
2.3.2 Image enhancement	
2.3.3 Training set selection	
2.3.4 Signature generation & classification	
2.3.5 Creation / Overlay of vector database	
2.3.6 Validation of classified image	
2.3.7 Final thematic map preparation	
3.0 Land Use/ Vegetation Cover Monitoring	14- 27
3.1 Introduction	
3.2 Land use/cover Classification	
3.3 Data Analysis & Change Detection	
3.3.1 Vegetation cover	
3.3.2 Agricultural Land	
3.3.3 Wasteland	
3.3.4 Settlements/Built-up area	
3.3.5 Water bodies	
3.3.5 Changes in Land Use/ Vegetation Cover Classes	
4.0 Conclusion and Recommendations	28-29
4.1 Conclusion	
4.2 Recommendations	

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List of Figures

- 1.1 Location map of Bander Coalfields, nagpur, WCL
- 2.1 Methodology for land use/cover mapping.
- 2.2 Geoid-Ellipsoid –Projection Relationship
- 3.1 Pie-chart depicting land use/Vegetation cover pattern in Bander Coalfield in the year 2012

List of Tables

- 2.1 Characteristics of the satellite/sensor used in the present project work
- 2.2 Classification Accuracy Matrix for Bander Coalfield in the year 2012
- 3.1 Land use/cover classes identified in Bander Coalfield
- 3.2 Land use/cover statistics of Bander Coalfield

List of Plates

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

1. Plate No. HQ/REM/001: Land use/ Vegetation cover map based on IRS – R2 LISS-IV [2012] data.

Chapter 1

Introduction

1.1 Project Reference

CGM (WBP/FPD/ENV), Coal India Ltd. issued a work order to CMPDI vide letter No CIL/WBP/ENV/2011/4706 dated 12th October 2012 for monitoring the status of Land Reclamation in all the Open Cast Projects and Land use/ Vegetation cover Mapping of various Coalfields under the command area of CIL. Accordingly Land Use/Vegetation Cover Mapping of Bander Coalfield of Western Coalfields Ltd. was carried out based on satellite data of the year 2012 to assess the changes taken place on land use/vegetation cover in Bander Coalfield.

Project Background

Western Coalfields Ltd (WCL) is a Mini Ratna Company under the Maha Ratna Company M/s Coal India Ltd(CIL). WCL is an established company dedicated for coal mining in the western and central part of the country. For maintaining the ecological balance in the aftermath of mining operations in the region, the company has initiated various plantation programmes on areas like backfilled region, OB dump area and wasteland area etc. The advent of high resolution, multispectral satellite data has opened a new avenue in the field of mapping and monitoring of vegetation cover and changes that may have taken place over a period of time. The present study has been taken up to assess the changes in vegetation cover in Bander Coalfield in a span of last three years. While assessing the Land Use/ Vegetation Cover in the Coalfield region, changes in different categories of vegetation cover are also analysed to formulate the remedial measures, if any, required to be taken up to maintain the ecological balance in the region.

1.2 Objectives

The objectives are:

- To prepare land use/vegetation cover map of Bander Coalfield covering an area of 361.09 km² on a scale of 1:50,000 based on satellite data of the year 2012, using digital image processing techniques.
- to assess the impact on vegetation cover and analyse the changes in a span of last three years.

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 20⁰ 29' 06" to 20⁰ 48' 22" and East Longitudes 79⁰ 09' 15" to 79⁰ 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 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-weathered 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 Bhisu village. Uma river in Bander area originate from the Nand reserved forest and flow in the south-east direction.

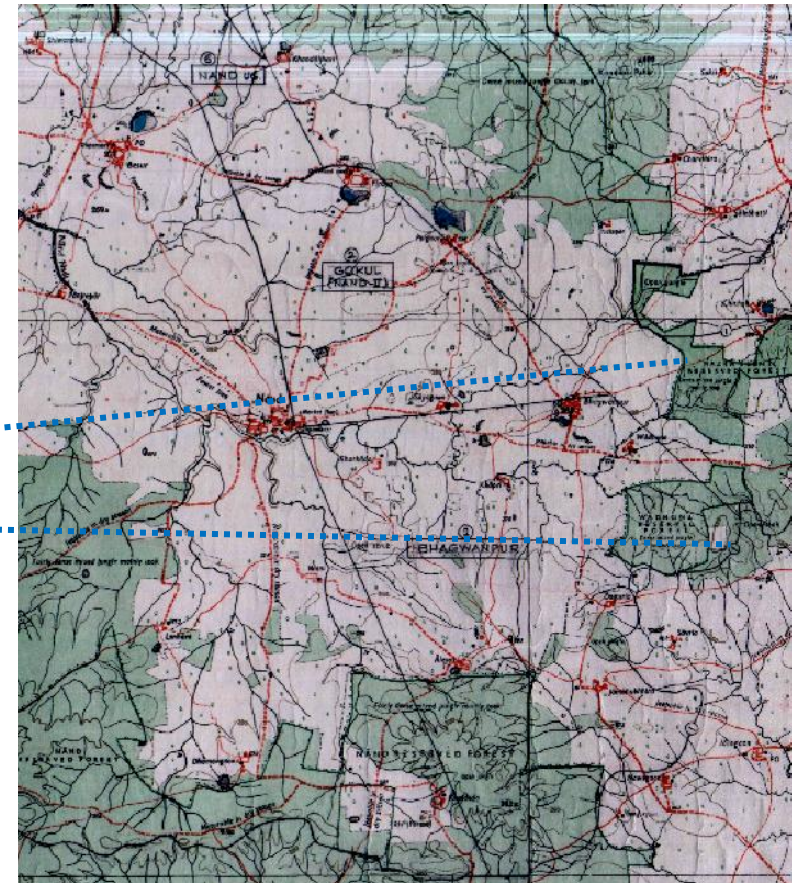


Fig. 1.1 : Location Map of Bander Coalfield, WCL, Nagpur

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.

IRS R2/ LISS IV; Band 2,3,4 Path # 100, Row # 58A; Date of pass 08.03.2012.

The detailed specification of the data is also given in Table 2.2.

- **Secondary Data**

Secondary (ancillary) and ground data constitute important baseline information in remote sensing, as they improve the interpretation accuracy and reliability of remotely sensed data by enabling verification of the interpreted details and by supplementing it with the information that cannot be obtained directly from the remotely sensed data. For **Bander Coalfield**, Survey of India toposheet 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-R2 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	LISS-IV	B2	0.52	-	0.59	Green	10-bit	5.8 m	5 days	India
		B3	0.62	-	0.68	Red		5.8 m		
		B4	0.77	-	0.86	NIR		5.8 m		
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.

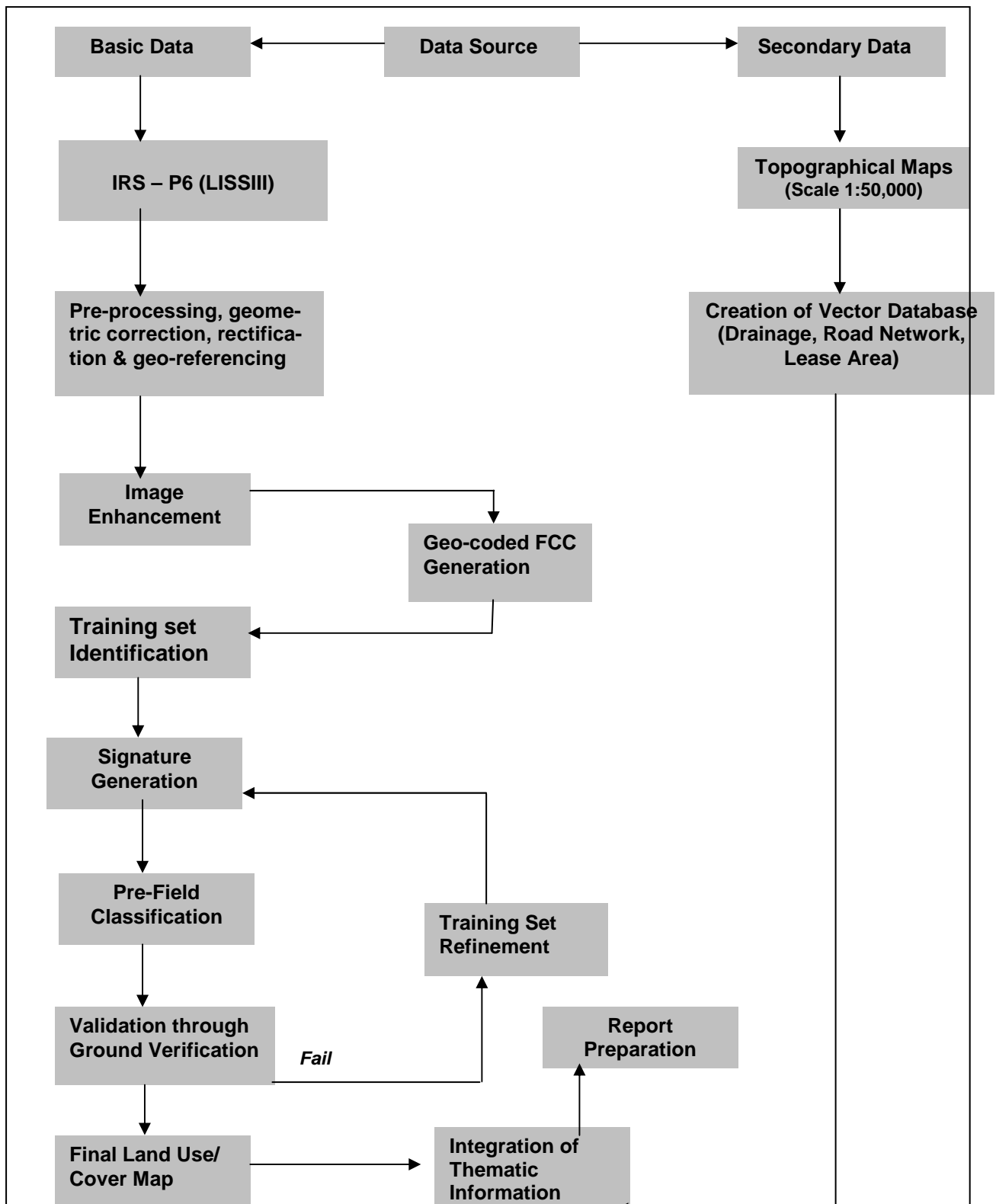


Fig. 2.1 Methodology for Land use/Vegetation Cover Analysis

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.

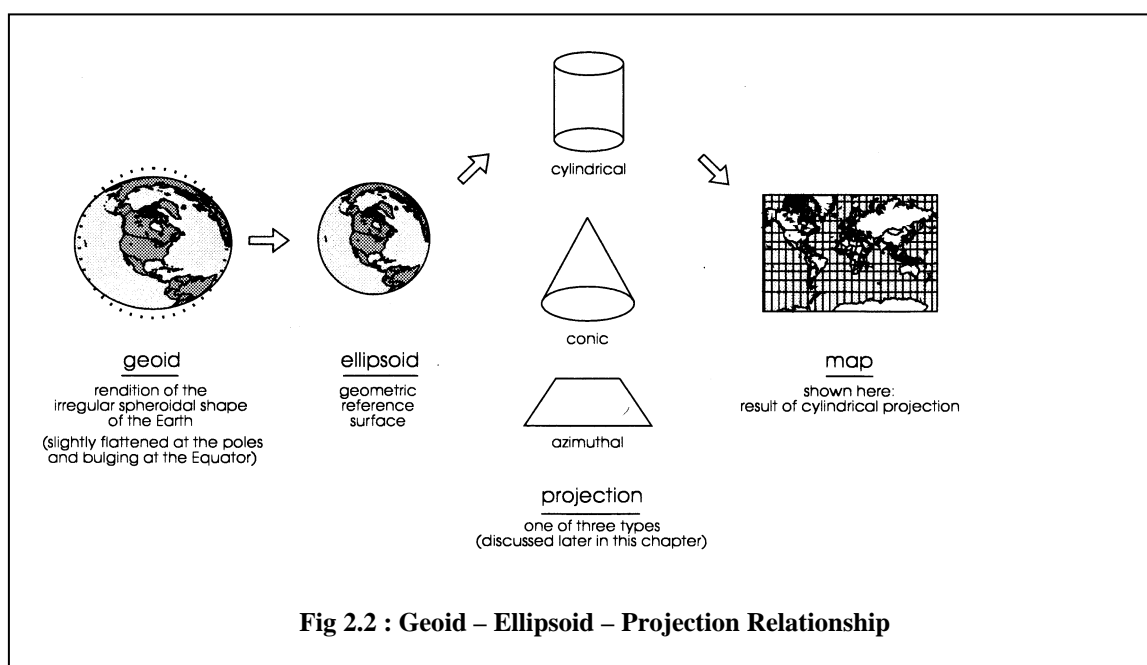
In spite of ‘System / Bulk correction’ carried out at supplier end; some residual errors in respect of attitude attributes still remains even after correction. Therefore, fine tuning is required for correcting the image geometrically using ground control points (GCP).

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) topographic 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*.



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.9.0 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 IMAGINE s/w.

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 IMAGINE s/w. The classified image for the year 2012 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 9.0.

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 100% - 90%. In case of open forest, dense forest, the classification accuracy varies from 90.0% to 95.0%. Classification for scrubs was 91.7%. It was mostly due to poor *signature separability index*. The overall classification accuracy in case **Bander Coalfield** was 93.1%.

2.3.7 Final thematic map preparation

Final land use/Vegetation cover map (Plate - 1) was printed using HP Designjet 4500 Colour Plotter. The map is 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 Settlement	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	90.0	90	91.7	100	
Overall Accuracy (%)				93.1								

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 Banader 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 2009 to analyse the existing land use/ vegetation cover, which will serve as the base data for future purposes. Currently the findings of analysis of the data of year 2012 is now compared for temporal changes with the results of the analysis of 2009, for the changes 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 2012. 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
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 2012 was processed using ERDAS Imagine v.9.0 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 therein for the year 2009 and 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 2009 & 2012

Area in Sq km

Land Use Classes	Year 2009		Year 2012		Change		Reasons
	Area	% of total	Area	% of total	Area	% of total	
VEGETATION COVER							
Dense forest	45.78	12.68	43.18	11.96	-2.60	-0.72	Due to biotic interference
Open Forest	50.52	13.99	49.32	13.66	-1.20	-0.33	-do-
Total Forest	96.3	26.67	92.50	25.62	-3.80	-1.05	
Scrubs	62.02	17.17	58.65	16.24	-3.37	-0.93	
Sub Total	158.32	43.84	151.15	41.86	-7.17	-1.92	
AGRICULTURAL LAND							
Crop Land	87.43	24.21	88.05	24.38	0.62	0.17	
Fallow Land	99.35	27.51	107.67	29.82	8.32	2.31	
Sub Total	186.78	51.72	195.72	54.20	8.94	2.48	Due to conversion of scrubs, wasteland and water bodies in agriculture land
WASTELAND							
Wasteland	10.79	2.99	9.85	2.73	-0.94	-0.26	
Sub Total	10.79	2.99	9.85	2.73	-0.94	-0.26	
SETTLEMENTS							
Urban	0.36	0.10	0.69	0.19	0.33	0.09	
Rural	0.33	0.09	1.12	0.31	0.79	0.22	
Sub Total	0.69	0.19	1.81	0.50	1.02	0.31	Due to urbanisation
WATER BODIES	4.55	1.26	2.56	0.71	-1.99	-0.55	
TOTAL	361.09	100.00	361.09	100.00	0.00	0.00	

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 2009 & 2012

Land Use Classes	Year 2009		Year 2012		Change	
	Area	% of total	Area	% of total	Area	% of total
VEGETATION COVER						
Dense forest	45.78	12.68	43.18	11.96	-2.60	-0.72
Open Forest	50.52	13.99	49.32	13.66	-1.20	-0.33
Total Forest	96.3	26.67	92.50	25.62	-3.80	-1.05
Scrubs	62.02	17.17	58.65	16.24	-3.37	-0.93
Total Vegetation Cover	158.32	43.84	151.15	41.86	-7.17	-1.92

Dense forest – Forest having crown density of above 40% comes in this class. Dense forest over the area has decreased slightly, basically due to natural degradation. A total decrease in dense forest is estimated to be 2.60 sq km, i.e. 0.72% of the coalfield area.

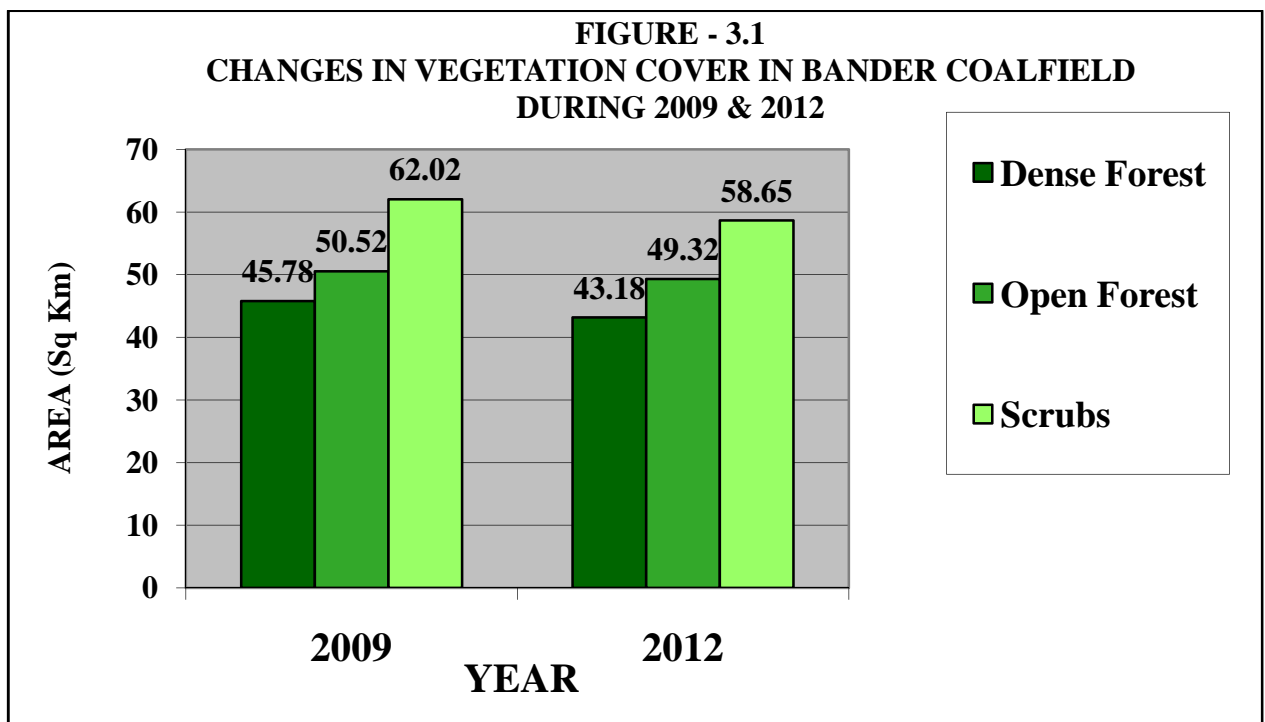
Open Forest – Forest having crown density between 10% to 40% comes under this class. Open forest cover over the area has also reduced in the coalfield area. Some of the reduction is also due to deforestation and natural degradation. The total decrease observed in open forest is 1.20sq km, i.e. 0.33% of the coalfield area..

Scrubs – Scrubs are vegetation with crown density less than 10%. Scrubs in the coalfield has also decreased. This is because of being converted into agricultural land and

settlements. There has been decrease of 3.37 sq km, ie 0.93% of land with scrubs in the coalfield area.

It is significant to note that the vegetation cover in Bander Coalfield has decreased by 7.17 sq km which is about 1.92% % of the coalfield area. This decrease is mainly due to natural depletion of vegetation cover and land being converted into agriculture and settlements areas. Also depletion of forest is seen at many places.

The variation in the vegetation classes which took place during year 2009 and 2012 within the area are shown in bar diagram in Figure – 3.1.



Figures represent area in sq km

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)

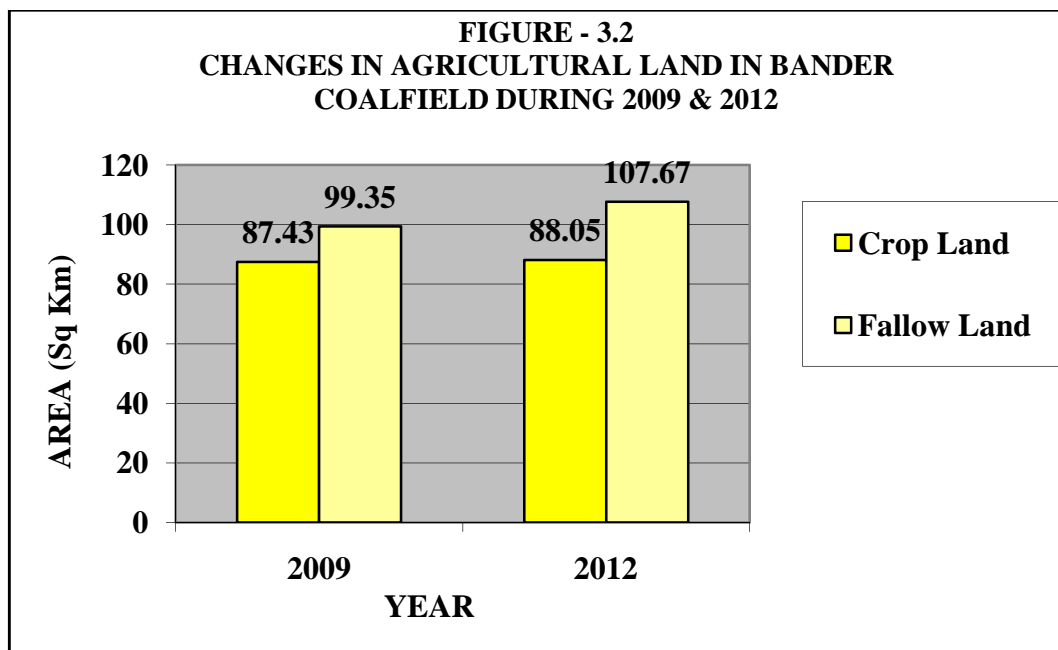
Total agricultural land which was 186.78 sq km in year 2009 has marginally increased to 195.72 sq km in the year 2012. The increase of 8.94 km (2.48%) in agricultural land is due to conversion of some scrubs, area around waterbodies and waste land into agriculture. The details are shown below in Table 3.4.

TABLE – 3.4

Changes in Agricultural Land in Bander Coalfield during the year 2009 & 2012

Agricultural Land	Year 2009		Year 2012		Change Analysis	
	Area (sq km)	% of total	Area (sq km)	% of total	Area (sq km)	% of total
Crop Land	87.43	24.21	88.05	24.38	0.62	0.17
Fallow Land	99.35	27.51	107.67	29.82	8.32	2.31
Sub Total	186.78	51.72	195.72	54.20	8.94	2.48

The variation in the Agricultural Land which took place during year 2009 and 2012 within the coalfield area are shown in bar diagram in Figure – 3.2.



3.3.3 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.

There has been a slight reduction of 0.94 sq km, ie 0.26% of the area. Some of the waste lands have become fallow land.

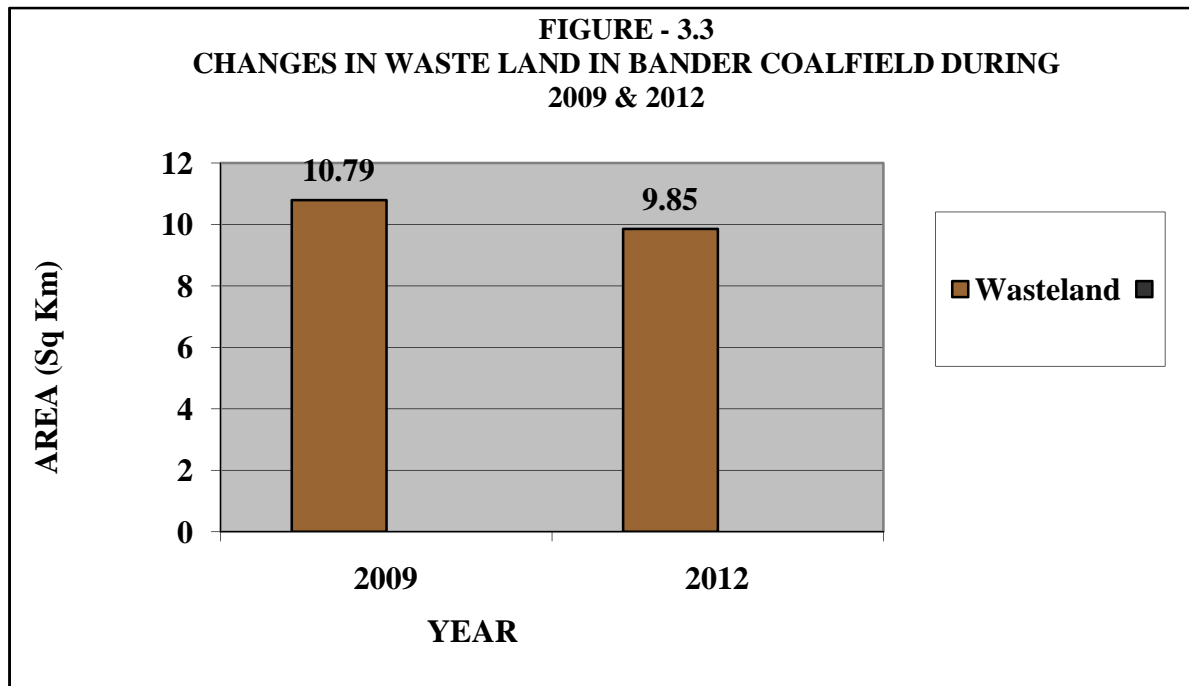
The land use pattern within the area for waste lands is shown below in Table – 3.5.

TABLE – 3.5

Changes in Wastelands in Bander Coalfield during the year 2009 & 2012

	Year 2009		Year 2012		Change Analysis	
	Area (sq km)	% of total	Area (sq km)	% of total	Area (sq km)	% of total
Waste land						
Wasteland with/ without scrub	10.79	2.99	9.85	2.73	-0.94	-0.26

The variation in the Waste Land which took place during year 2009 and 2012 within the coalfield area are shown in bar diagram in Figure – 3.3



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:

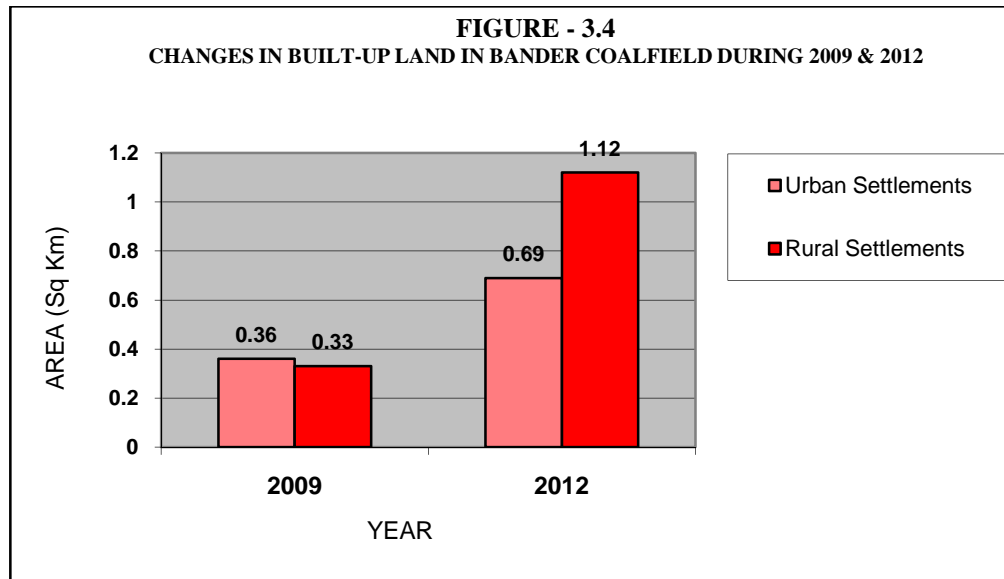
TABLE- 3.6

Changes in Settlements in Bander Coalfields during the year 2009 & 2012

Settlements	Year 2009		Year 2012		Change Analysis	
	Area (sq km)	% of total	Area (sq km)	% of total	Area (sq km)	% of total
Urban	0.36	0.10	0.69	0.19	0.33	0.09
Rural	0.33	0.09	1.12	0.31	0.79	0.22
Sub Total	0.69	0.19	1.81	0.50	1.02	0.31

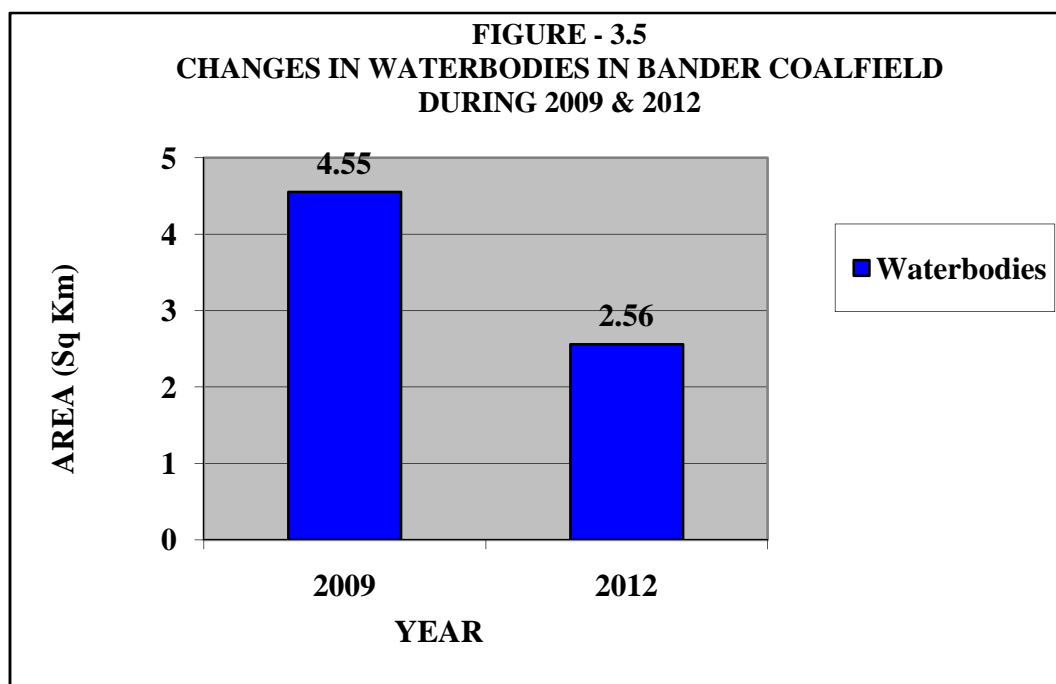
It is observed that the settlements within the coalfield have grown by 1.02 sq km, which is about 0.31% of the coalfield area. It is observed that the rural settlements have grown marginally by 0.79 sq km which is 0.22% of the coalfield area. The Urban settlement within the coalfield area has grown by about 0.33 sq km, i.e. 0.09%. This increase is due to the increasing trend of urbanisation.

The variation in the Built-up Land/Settlements which took place during year 2009 and 2012 within the coalfield area are shown in bar diagram in Figure – 3.4



3.3.5 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 decreased from 4.55 sq km in year 2009 (1.26%) to 2.56 sq km (0.71%) in 2012. This is due to the reason of natural drying up of surface water bodies in many places and the increase in settlements. The variation in area under various water bodies within the coalfield area is shown in figure 3.5



3.3.6 Changes in Land Use/Vegetation Cover Classes

The overall variation in various Land Use /Cover classes in Bander Coalfield during the year 2009 and 2012 is shown in the Bar Chart below:

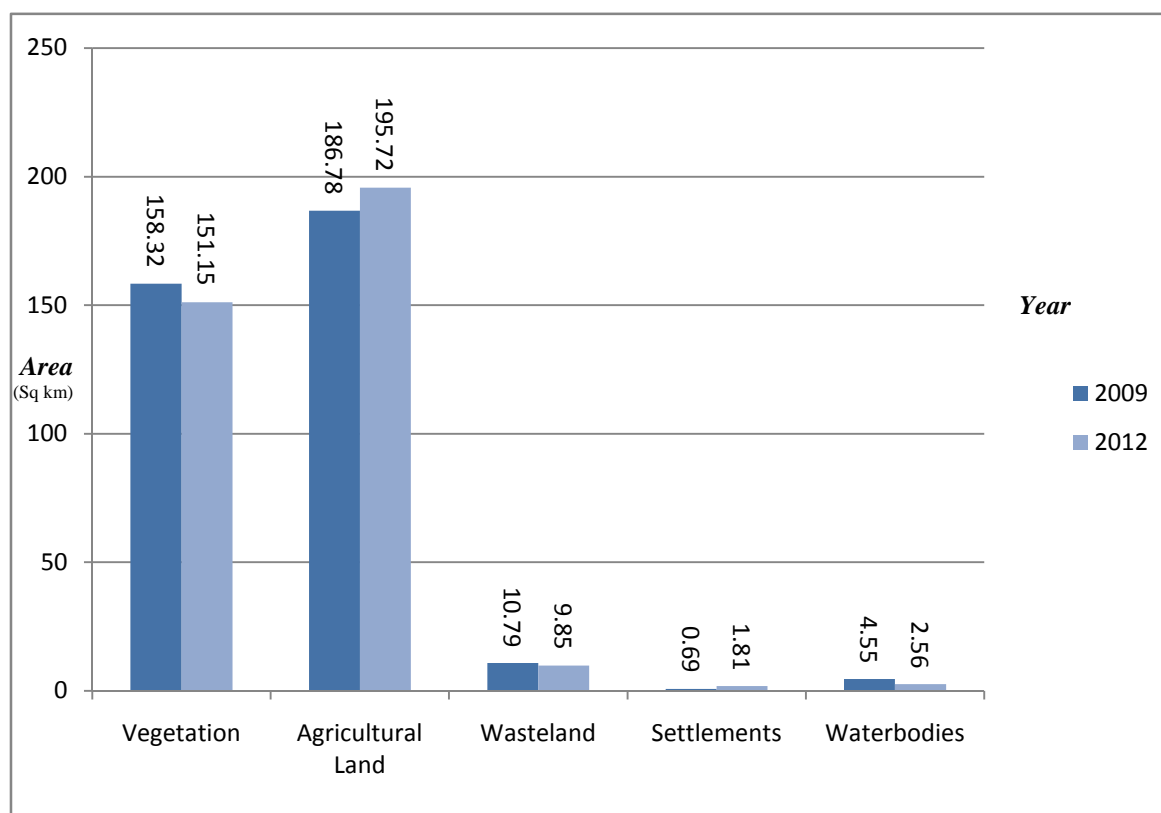


Fig 3.6 Overall Changes in Land Use/Cover Classes in Bander Coalfield in the Year 2009 & 2012

It can be seen from the chart above that there is a decrease in vegetation cover in the coal-field area mainly because of deforestation and scrub areas becoming suitable for the purpose of agriculture. Agricultural land has increased which may be due enhanced human activities near the forest areas and other related activities. Wasteland has also reduced due to increase in human activities. Settlements have also increased, which is due to increase in population and other related human activities.

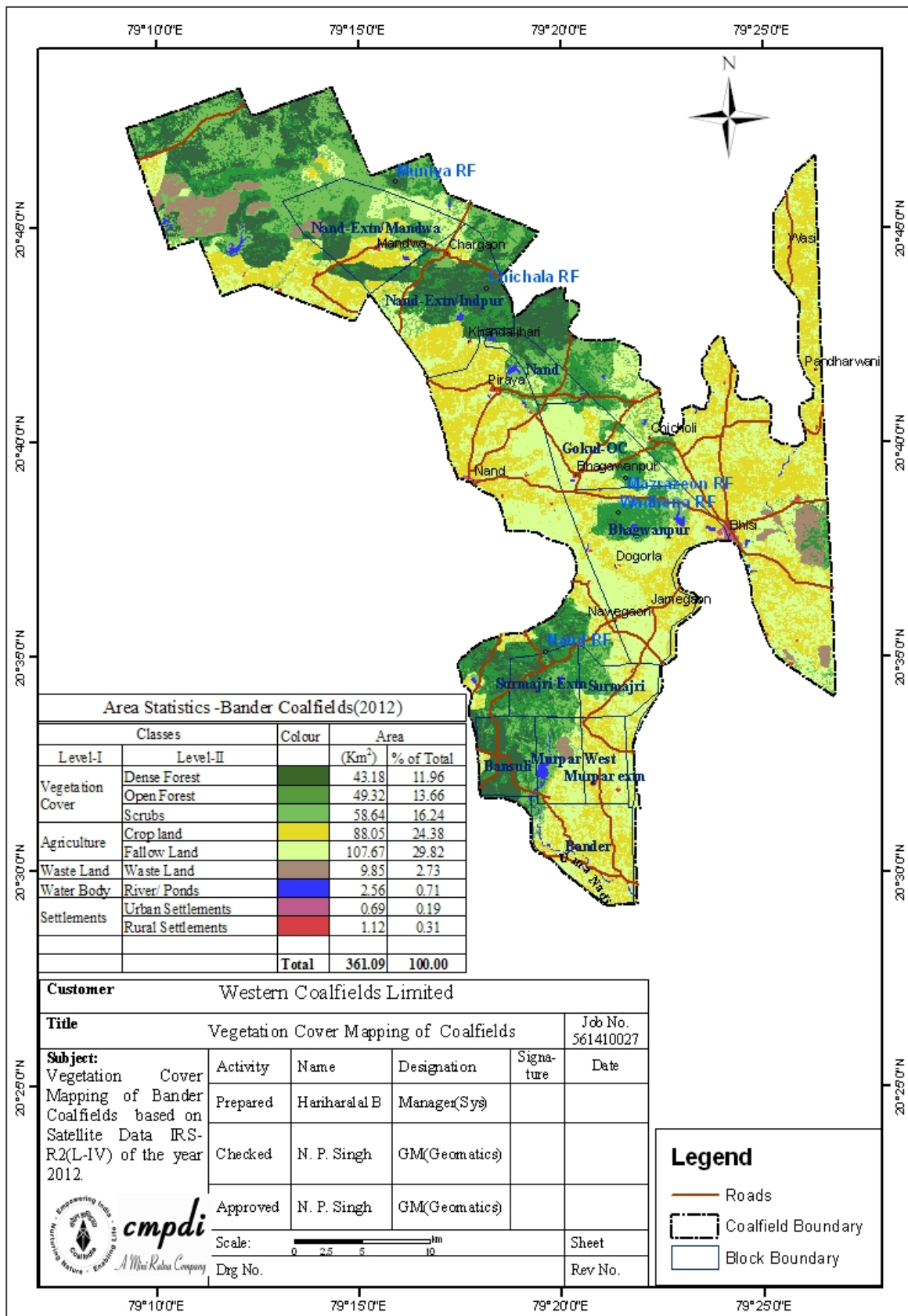


Plate -1 VegetationCover Classes in Bander Coalfield in the Year 2012

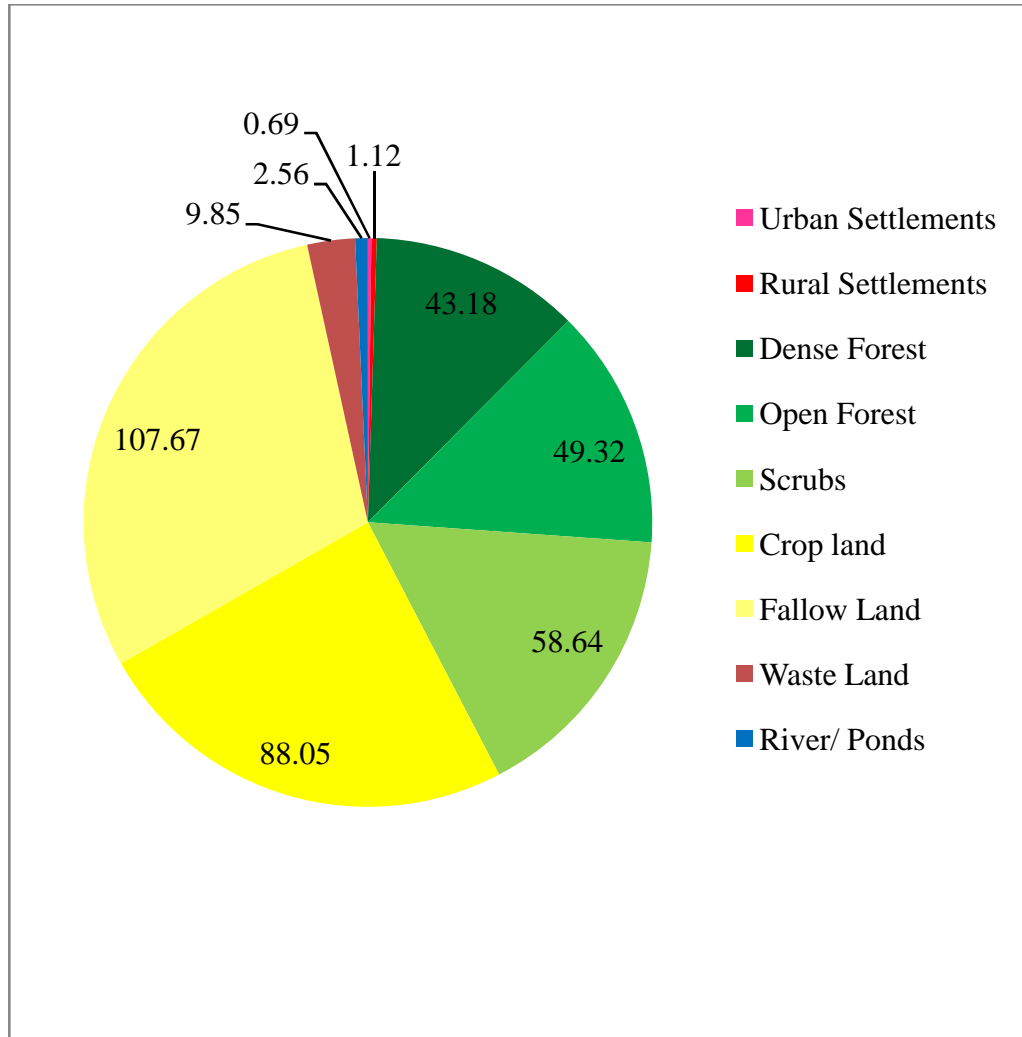


Fig. 3.7 Land use / cover pattern in Bander Coalfield region

Chapter 4

Conclusion & Recommendations

4.1 Conclusion

In the present study, land use/vegetation cover map of Bander Coalfield is prepared based on IRS-R2/ LISS IV data of March 2012 in order to generate the database on vegetation cover and land use pattern to detect the changes in respect to the year 2009 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 decreased by 7.17 sq km which is 1.92% of the coalfield area in a span of last three years. The major factors for decrease in vegetation cover has been found to be the depletion of natural forests and increase of settlements and related activities. 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 decreased by 0.93 % in the area because of the settlements and agricultural needs. This shows that the area is under advancement of human activities. Study reveals that decrease in dense forest (-0.72%) and open forests (-0.33%) is mostly due natural depletion and human interferences.

Besides vegetation cover, other land use classes were also analysed and it was observed that in a span of three years, agricultural area has increased from 186.78 sq km to 195.72 sq km. This increase of 8.94 sq km (2.48%) in agricultural area is due to increase in human settlements and related activities for livelihood.

Further study reveals the area of wasteland has also decreased very marginally from 10.79 sq km to 9.85 sq km during the last 3 years. This reduction of 0.94 sq km is mainly due to conversion of wasteland into settlements and building the infrastructure in urban areas. Area of settlement has increased from 0.69 sq km to 1.81 sq km. This increase of 1.02 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. To combat the effect of rapid deforestation, WCL should start the afforestation programme to balance the ecological changes.
- B. Efforts should be made to protect the vegetation cover from further depletion.
- C. Fresh settlements should not be allowed in the region.
- D. 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 the ground water table.



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