LAND USE/LAND COVER CHANGE DUE TO MINING ACTIVITIES IN SINGRAULI INDUSTRIAL BELT, MADHYA PRADESH USING REMOTE SENSING AND GIS

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ABSTRACT

Singrauli coal field situated in central India is managed by the Northern Coal fields Ltd, (NCL), and contributes 13% of India's coal production through mechanized opencast mining. With the availability of power grade coal reserves and nearby water reservoirs it offers an excellent location for super thermal power plants (STPS), Aluminum plants, and cement industries. In an area like Singrauli coal field, where large scale opencast mining is going on continuously, land use/land cover studies are of vital importance. The present study utilizes multi-spectral multi-temporal data of Indian Remote Sensing Satellite (IRS) geocoded False Colour Composite (FCC) of 8th May 2001 and 4th May 2010 for land use/land cover mapping. Survey of India toposheet 63L/12 on scale 1: 50,000 were used to derive the base map which was overlaid on the FCC for land use/land cover mapping through visual interpretation method. Interpretation of satellite data led to the identification and delineation of 14 land use/land cover categories such as dense forest, open forest, open scrub, cultivated land, un cultivated land, mining pit, overburden dumps, wasteland and settlement. Ground truth verification was conducted in key areas. The comparative analysis of land use/land cover derived from 2001 and 2010 data shows that loss off dense forest area are due to the expansion of coal mining activity. Open scrub area has increased from 29.82 km² in 2001 to 42.45 km² in 2010 due to the plantation activities undertaken by the NCL, Overburden dumps area have increased from 30.4 km² in 2001 to 39.44 km² in 2010 as a result of expansion of coal mining areas, settlement area has also increased from 39.72 km² in 2001 to 44.82 km² in 2010, whereas area of cultivated land has decreased from 104.54 km² in 2001 to 92.61 km² in 2010. The drivers for land use/land cover change are mainly coal mining activities and industrial expansion, which have changed this belt into one of the prominent industrial zone in northern India. It has also been observed that the overburden dumps have been reclaimed under operation operation "Green Gold" launched by Northern Coalfield Ltd, through plantation activities.

Key Words : Land use/ Land cover, Change detection, Mining activities, Industrialization, Remote Sensing and GIS

INTRODUCTION

Land is the most important physical resources and material basis for people's life. Land use/land cover is an important indicator for global environmental change, which indicates the influence of human activities on physical environment. Land use/land cover change is a dynamic, widespread and accelerating process, mainly driven by natural phenomenon and anthropogenic activities, which in turn drive changes that would impact natural ecosystem. In the surrounding of surface mining area land use/land cover changes are taking place rapidly, which causes serious environmental degradation to the landscape. Human induced activities are largely responsible for land use/land cover changes which indicate land quality, environmental...
change and interaction between human and natural driving forces. Land use/land cover in mining area is obviously affected by the development of mining industry which results in serious ecological degradation. Coal extraction from the earth's surface through mining operation tends to make a prominent impact on the landscape, environment and biological community.

Remote sensing technology has been widely used since the past few decades to monitor land use/land cover changes in time and space. The change detection method can be used to monitor land use/land cover change and to build spatio-temporal patterns of change, in order to derive better understanding of the cause and consequence of the change by using multi-date images.

The present study makes an attempt to quantify land use/land cover changes in Singrauli industrial belt using multi-temporal remote sensing data, supported by topographical maps, Census of India, revenue records and ground truth data as other inputs. The main objective of present study is to understand the dynamics of land use/land cover change in time and space, in the backdrop of coal mining activities.

STUDY AREA

The study area falls within the geo-coordinates 24° 00' to 24° 15' N latitudes and 82° 30' to 82° 45' E longitudes, and lies partly in Singrauli district of Madhya Pradesh and partly in Sonebhadra district of Uttar Pradesh (Fig. 1). The area is well connected by motorable road with Varanasi (220 km), Mirzapur (215 km), Rewa (206 km) and Sidhi (130 km). The nearest railway station is Singrauli on Chopan-Katni line passes parallel to northern periphery of the coal field and Renukut which is 45 km from Singrauli. The coalfield has been divided into eleven mining blocks viz. Kakri, Bina, Marak, Khadia, Dudichua, Jayant, Nigahi, Amlohi, Moher, Gorb and Jhingurdah. The total area of the coal field is 2201 km² however at present only 300 km² area is exploited for coal. Because of the availability of power grade coal reserves and water reservoir (Govind Ballabh Pant Sagar) nearby, it offers an excellent site for super thermal power plants (STPS), Aluminium plants, and cement industries. Singrauli coalfield has coal reserves of 1789.41 million tonnes with a steep rise in coal production from 30.70 million tonnes in 1993 to 67.67 million tonnes in 2010. The area is well suited for thermal power generation and is expected to produce 25% of thermal power need of India. The climate of the area is tropical monsoonal dry during the period November to June while during rainy season the atmosphere is very humid. The climate data analysis for the period 1978 to 2010 has revealed that average rainfall received during the last 33 years is 1119.65 mm, the maximum and the minimum rainfall received is 1457.30 mm and 685 mm in 1978 & 2009, respectively.

The geological sequence of the area is represented by six series of formations that have been recognized on broad lithic characteristics within the Gondwana rocks of Singrauli coal field. They are Talchir, Barakar, Barren Measure, Raniganj, Panchet and Mahadeva. Barakar and Raniganj are the only coal bearing formations of the area. The area is represented by structural hills in the northern part with elevation ranging between 270m - 620m above mean sea level (MSL) whereas slope varies from 0° to 29° which are formed by resistant Precambrian rocks. The structural plateaus are made up of coal-bearing Gondwana rocks. Low lying flats characterized by gentle-undulating topography in the central part of the area where most of the agricultural activities have been noticed. The four main rivers Kachan, Mayar, Matwani and Baliya nala transverse through the Singrauli area are mostly seasonal. The north flowing streams join the Bijul tributary of Son river and south flowing streams mostly join the Kachan and Mayar tributary of Rihand reservoir.

The development of the Singrauli area began during the year 1950s with the construction of a dam on the Rihand river. The Reservoir of the dam was mainly for irrigation purpose but three super thermal power stations of NTPC, two of Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited and one of Hindalco Industries Limited are also using water to generate 8575 MW of thermal power. The coal production of NCL is capable of generating over 11000 MW of thermal power. NCL alone can fulfil the one-sixth of the power requirement of the nation.
MATERIAL AND METHODS

Data Used
In order to analyse the land use/land cover change in the study area, Indian Remote Sensing Satellite (IRS) LISS II geo coded False Color Composite (FCC) data of 8th May 2001 and IRS P6 LISS III data of 4th May 2010 were used. Data from the same season gives uniform spectral and radiometric characteristics and minimize the seasonal variation, in spectral reflectance of land cover types. The survey of India topographic sheets No 63L/12 scale 1:50,000 of 1976 was used to derive the base map. The climate data of district Singrauli from 1978 to 2003 has been obtained from the India Meteorological Department (IMD) Pune. Secondary data obtained from published and unpublished sources such as internet (www.ncl.nic.in, www.ntpc.com, www.singrauli.nic.in), district statistical handbook, NCL and state government department have been also used. Techniques used to monitor the land use/land cover change include visual interpretation and
change detection analysis. Visual image interpretation is the major tool for getting information about land use/land cover from satellite data. Various photographic and geotechnical elements such as tone, texture, shape, size, association, drainage, landform, soil and vegetation etc are used to identify and delineate the different land use/land cover classes. Land use/land cover change information can be obtained by either image-to-image comparison or map-to-map comparison. The image-to-image comparison involves subtracting two images which does not give detailed information how the changes in particular land use/land cover are taking place. But in map-to-map comparison, images are to be classified and then maps are generated to compare which give complete detail of land use/land cover changes. In the present study, map-to-map comparison was used for land use/land cover change detection. The images of both the years (2001 and 2010) were registered with topographical map to minimize geometric errors. Base map of the area having details such as settlement, road, railway line network, rivers and water bodies etc was prepared using SOI toposheet. The same was superimposed on geocoded False Colour Composite (FCC) for visual interpretation which led to the identification and delineation of 14 classes of land use/land cover namely dense forest, open forest, open scrub, cultivated land, uncultivated land, mining pit, overburden dumps, wasteland, rocky area, settlement, ash pond, water body, thermal power plant and dry river channel. These categories were identified on the basis of visual interpretation of satellite imagery and subsequently ground truth verification was done in key area. The maps were then digitized and the data base of land use map has been created using Arcview 3.2 software for land use change analysis. The steps followed for analysis are (a) Digitization of land use map, (b) Creation of polygon topology assigning unique identity (id) for each polygon and (c) Editing. Area statistics of land use categories have been calculated in Arcview 3.2 in sq. km as well as in percentage. The change in the extent of different land use categories during the period from 2001 - 2010 was analysed and computed.

RESULTS AND DISCUSSION

The land use/land cover categories delineated in the study area are dense forest, open forest, open scrub, cultivated land, uncultivated land, mining pit, overburden dumps, wasteland, rocky area, settlement, ash pond, water body, thermal power plant and dry river. Land use/land cover details of the area as obtained from IRS LISS II data of 2001 (Fig. 2) and IRS P6 LISS III data of 2010 (Fig. 3). Table 1. shows the changes in land use/land cover statistics (in Km² and percentage) that have taken place during the period between 2001-2010. The results of the land use/land cover analysis are also graphically represented in bar diagram (Fig.4). The analysis of land use/land cover change that has been taken place under different land use categories from 2001 to 2010 due to the rapid expansion of mining are given below:

Dense forest
Dense forest can be interpreted from the FCC satellite image by its dark red tone, coarse - medium texture, contiguous pattern and regular to irregular shape. The dense forest covers an area of 103.84 km² (14.26 %) of the total area during 2001 and 79.95 km² (10.98 %) during 2010. Dense forest shows a decrease of 23.89 km² (3.28 %) in the area from 2001 to 2010 during 9 years. Most of the coal mining activities are taking place in dense forests area because most of the coal resources are located beneath the dense forest region. So the decrease in the dense forest is due to the removal of trees which is the first step of the expansion of coal mining activities, removal of forest for the development of infrastructure for heavy industrialization and increase in the population is another cause because peoples use wood for their livelihood so excessive felling of trees for fuel and fodder.

Open forest
Open forest is easily identified on FCC by its light red - greenish colour, smooth - medium texture, contiguous to non contiguous pattern with irregular outline. Open forest covers an area of 152.72 km² (20.97%) of the total area in 2001 which has increased to 169.14 km² (23.22 %) of
the total area in 2010. Open forest shows increase of 16.42 km² (2.25%) in the area from 2001 to 2010. Open forest area increase is due to the decrease in the density of dense forest and reclamation of overburden dumps under operation "Green Gold" launched by Northern Coalfield Ltd. Besides NTPC has also carried out plantation program around colonies under social forest scheme. **Open scrub**

Open scrub on the FCC can be identified by its pink - light yellow tone, coarse to medium texture scattered pattern and irregular outline boundary. Open scrub also shows an increase of 12.63 km² from 29.82 km² (4.09%) area in 2001 to 42.45 km² (5.83%) in 2010. Open scrubs are mostly on the plain area and along the south western side of the study area.

**Cultivated land**

Cultivated land in the study area is under Kharif crops in this season which are wheat, Jawhar,
Masoor, Channa. Cultivated land is recognized on the FCC by its red - light greenish tone, smooth - medium texture having non contiguous pattern with regular - sub regular outline shape. Cultivated land which was 104.54 km² (14.35 %) area during 2001 has been decreased to 92.61 km² (12.72 %) in 2010. The loss of 11.93 km² (1.64%) in the cultivated land has been observed during 2001 to 2010. The development of infrastructure, residential complexes of mining industries and thermal power plants may results in loss of agriculture land. Development of agriculture is mainly affected by lack of irrigation. The decrease in area under cultivated land is attributed to decline in rainfall which adversely affects the rainfed agriculture as has been corroborated by rainfall data analysis. The irrigation from the bore wells is not successful because in the Singrauli tehsil average ground water level is 125 feet and the mining pits are more than 100
mts deep which results in the depletion of ground water in the surrounding area which results in the decrease in agriculture area.

Uncultivated land
The uncultivated land on the FCC has been identified by its light brown to light yellow tone, medium to smooth texture having non-contiguous pattern with irregular outline. The area under uncultivated land category covers 142.36 km² (19.55 %) area during 2001 and 147.29 km² (20.22 %) area during 2010. The uncultivated land shows an increase of 4.93 km² (0.68 %) from 2001 to 2010. The increase might be due to the loss of cultivated land which has changed to uncultivated land as a result of the rapid increase in mining activities, decrease in water level in surrounding areas and decrease in rainfall which leads to the failure of agriculture in the area.

Mining pit and Overburden dumps
Coal mining is a very prominent activity in the area for having good reserves of coal. Mining pits are interpreted on FCC by its black tone, medium to smooth texture having linear to curvilinear pattern and irregular shape whereas overburden dumps have white to light blue tone coarse to medium texture having contiguous pattern and irregular outer shape. Generally mining area also lacks all types of vegetation. The mining occupied an area of 8.38 km² (1.15 %) during 2001 and 11.19 km² (1.54 %) during 2010. The increase of 2.81 km² (0.39 %) in the mining pit area has been observed from 2001 to 2010. Overburden dumps also show increase of 9.04 km² (1.24 %) area during 2001 to 2010 period. The overburden dumps occupies an area of 30.4 km² (4.17 %) during 2001 which has increased to 39.44 km² (5.41 %) area during 2010. The increase in the area of overburden dumps is because of huge removal of material from mining blocks which were dumped along the periphery of the plains and forms artificial landscapes. It was estimated that the overburden dump removal increases from 136.00 M cum in 2001 to 177.98 M cum in 2010

Wasteland
Wasteland on the FCC was identified by its white tone, smooth texture scattered pattern and irregular outline. The wasteland cover an area of 26.61 km² (3.65 %) during 2001 and 31.52 km²
There has been an increases in wasteland area by 4.91 km$^2$ (0.67 %) from 2001 to 2010. The increase might be due to the increase in population, increasing mining activities, anthropogenic activities, and increase in temperature and decrease in rainfall may cause lack of irrigation facilities in the area.

**Settlement**

The settlement area is situated mostly in the central and south western region in the plain area. It is identified on FCC by its Cyan - light grey tone, coarse texture, scattered pattern and irregular outline. Settlement occupies an area of 39.72 km$^2$ (5.45 %) during 2001 and 44.82 km$^2$ (6.15%) in 2010. The settlement shows an increase of 5.1 km$^2$ (0.70 %) during 2001 to 2010. The increase in settlement area is due to the development of industrial sector (NCL and NTPC) which requires residential colonies, industrial buildings, schools, community halls etc and increasing demand for labour work has attracted people from other states to settle in this industrial belt resulting in expansion of villages, towns and cities.

**Ash pond**

On the FCC image ash pond is clearly recognized by its Sky blue colour Medium to coarse texture, contiguous pattern and regular outline. Thermal power plants generate fly ash is disposed through pipelines to the ash pond along the boundary of the GBP Sagar reservoir. The area of the ash pond was 4.86 km$^2$ (0.67 %) during 2001 and 8.44 km$^2$ (1.16 %) in 2010. The increase of 3.58 km$^2$ (0.49 %) has been observed.

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**Table 1 : Details of land use/land cover changes in the study area during 2001-2010.**

<table>
<thead>
<tr>
<th>Land use categories</th>
<th>Land use/Land cover IRS IB LISS II - 2001</th>
<th>Land use/Land cover IRS P6 LISS III - 2010</th>
<th>Net change in Sq km$^2$</th>
<th>Net change in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area in Km$^2$</td>
<td>Area in %</td>
<td>Area in Km$^2$</td>
<td>Area in %</td>
</tr>
<tr>
<td>Dense forest</td>
<td>103.84</td>
<td>14.26</td>
<td>79.95</td>
<td>10.98</td>
</tr>
<tr>
<td>Open forest</td>
<td>152.72</td>
<td>20.97</td>
<td>169.14</td>
<td>23.22</td>
</tr>
<tr>
<td>Open scrub</td>
<td>29.82</td>
<td>4.09</td>
<td>42.45</td>
<td>5.83</td>
</tr>
<tr>
<td>Cultivated land</td>
<td>104.54</td>
<td>14.35</td>
<td>92.61</td>
<td>12.72</td>
</tr>
<tr>
<td>Uncultivated land</td>
<td>142.36</td>
<td>19.55</td>
<td>147.29</td>
<td>20.22</td>
</tr>
<tr>
<td>Mining pit</td>
<td>8.38</td>
<td>1.15</td>
<td>11.19</td>
<td>1.54</td>
</tr>
<tr>
<td>Overburden dumps</td>
<td>30.4</td>
<td>4.17</td>
<td>39.44</td>
<td>5.41</td>
</tr>
<tr>
<td>Wasteland</td>
<td>26.61</td>
<td>3.65</td>
<td>31.52</td>
<td>4.33</td>
</tr>
<tr>
<td>Rocky area</td>
<td>7.44</td>
<td>1.02</td>
<td>7.44</td>
<td>1.02</td>
</tr>
<tr>
<td>Settlement</td>
<td>39.72</td>
<td>5.45</td>
<td>44.82</td>
<td>6.15</td>
</tr>
<tr>
<td>Ash pond</td>
<td>4.86</td>
<td>0.67</td>
<td>8.44</td>
<td>1.16</td>
</tr>
<tr>
<td>Water body</td>
<td>59.25</td>
<td>8.13</td>
<td>37.5</td>
<td>5.15</td>
</tr>
<tr>
<td>Thermal power plant</td>
<td>12.05</td>
<td>1.65</td>
<td>12.05</td>
<td>1.65</td>
</tr>
<tr>
<td>Dry river</td>
<td>6.36</td>
<td>0.87</td>
<td>4.51</td>
<td>0.62</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>728.35</td>
<td>100.00</td>
<td>728.35</td>
<td>100.00</td>
</tr>
</tbody>
</table>

(4.33%) area in 2010. There has been an increases in wasteland area by 4.91 km$^2$ (0.67 %) from 2001 to 2010. The increase might be due to the increase in population, increasing mining activities, anthropogenic activities, and increase in temperature and decrease in rainfall may cause lack of irrigation facilities in the area.
during 2001 to 2010. The increasing area of ash pond mostly encroaches the cultivated land, and is due to the increase in power generation from super thermal power plants.

**Water body**
Water body on the FCC imagery is identified by its light blue to black tone, smooth texture and irregular shape. The water body occupied an area of 59.25 km² (8.13 %) in 2001 and 37.5 km² (5.15%) in 2010. The water body shows a decrease of 21.75 km² (2.99 %) during 2001 to 2010. The decrease in the area is due to the decrease in rainfall by 313 mm from 1978 - 2010, siltation caused by the material runoff from dump sites, atmospheric dust pollution. The utilisation of water for thermal power plants and mining activity is also the important cause for depletion of water body because the usage is more than the storage to the reservoir. The washed out material runoff from dump sites is also responsible for blocking the natural drainage.

**Dry river**
It is easily recognized by its white tone, medium to smooth texture with irregular outline on the FCC image. The dry river occupied an area of 6.36 km² (0.87 %) in 2001 and 4.51 km² (0.62%) in 2010. The dry river shows a decrease of 1.85 km² (0.25 %) during 2001 to 2010. The decrease in the area of dry river is because of its transformation into cultivated land (vegetables garden), open forests and uncultivated land because of the availability of nearby water reservoir GBP Sagar.

**Rocky area**
The rocky area is mostly on the northern side of the study area. It is identified on FCC image by its green to brownish tone, coarse texture with irregular outline. The area occupied during 2001-2010 remains almost unchanged. The area occupied by rocky area is about 7.44 km² (1.02%).

**Thermal power plant**
Thermal power plant is located on the south eastern side of the area near to the G.B.P Sagar water reservoir were from water is pumped for different uses in the thermal power plants and open cast coal mines. It is identified on the FCC image by its regular outer Boundary shape, bluish tone and coarse texture. The area occupied during 2001-2010 remains almost unchanged. The area of thermal power plant is about 14.00 km² (1.65 %) of the total area.

**CONCLUSION**
The present study has revealed that considerable land use/land cover changes have taken place in and around Singrauli coal field during 2001 to 2010. Before the start of coal mining and other industrial activities the region was covered with tropical deciduous forests. Coal mining operation on large scale has significantly changed the pre-mining environment scenario. The mining shows increase of 11.84 km² during nine years which is due to the rapid increase in the coal production, dense forest areas are decreasing but the plantations at overburden dumps under reclamation schemes have also been going on. In addition to mining activity, the industrialization especially thermal power plants in the surrounding have also adversely affected the land use/land cover, air and water quality of the study area due to the discharge of waste products in the form of ash, smoke and chemical effluents. It may be concluded that the land use/land cover change in the Singrauli coal field has taken place due to the rapid expansion of mining and industrial activity during the period 2001 to 2010. This has resulted in the drastic changes in the land cover dynamics of the fragile ecosystem.

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