IMPACT OF COAL MINING ON LAND USE/LAND COVER IN SINGRAULI INDUSTRIAL BELT, CENTRAL INDIA, USING REMOTE SENSING AND GIS

ABSTRACT

India stands at 4th place in coal reserves and 3rd among the countries that produce maximum output of coal. In India coal mining began in 1774 at Raniganj, West Bengal, which is considered core industry contributing economic development of India. The industrial development requires energy supply for which huge amount of coal is extracted through mining which causes widespread landscape destruction besides deteriorating the environment.

Coal mining has adverse environmental consequences, namely soil erosion, acid mine drainage and increased sediment load as a result of abandoned and un-reclaimed mined land, degradation of agricultural land, changes in natural topography and drainage pattern. Land, air and water are badly affected at different stages of mining processes which results in serious environmental degradation. Mining impact on environment begins in the pre mining stage and continues till post mining phase, which has long term consequences on the environment. Large scale annihilation of forest cover and degradation of agricultural land are some of the prominent implications of coal mining and its associated industries.

Remote sensing and Geographic Information System has been widely used in mapping land use/land cover changes and environmental degradation caused due to mining activities. Remote sensing provides multi temporal data which gives valuable information about the process and pattern of land use/land cover change which may be analyzed and mapped in GIS. The changing land use/land cover pattern of a mining area requires frequent updating of land use/land cover maps to assess the impact of mining. Host of workers have carried out studies related to impact of mining on environment, (Sahu, 1987; Ghosh, 1989; Tiwary and Dhar, 1994; Schmidt and Glaesser, 1998; Ghose and Majee, 2000; Paull et al., 2006; Sarma et al., 2010; Barnes and Clarke, 1964; Pathak and Banerjee, 1992; Sivakumar et al., 1994; James et al., 2000; Chauliya, 2004; Abhishek et al., 2006; Ahlawat and Kumar, 2009;
Belkhiri et al., 2010; Saravankumar and Kumar, 2011). Impact of mining on land use/land cover changes using remote sensing and GIS techniques have been studied by Majumder and Sarkar, 1994; Singh et al., 1997; Prakash and Gupta, 1998; Jayakumar and Arockiasamy, 2003; Joshi et al., 2005; Du et al., 2007; Patil and Katpatal, 2008; Chitade and Katyar, 2010; Panwar et al., 2011 and others.

The present study makes an attempt to assess the impact of coal mining on land use/land cover in Singrauli industrial belt with the help of remote sensing and GIS. The study involves preparation of thematic maps such as base map, drainage map, geological map, geomorphological map, soil map, using time series satellite data, land use/land cover change analysis, water quality analysis/mapping, ground truthing, preparation of DEM and slope. Spatial and non-spatial data have been analyzed using softwares such as Arc-View 3.2, ERDAS IMAGINE 8.6, Geotrans 2.3, Georeferencing software, 3DEM and SAGA 2.0.3. The results obtained from land use/land cover analysis, water quality etc have been interpreted to assess the impact of mining and its associated activities. Thematic maps generated from visual interpretation of IRS data have been digitized using ArcView GIS and polygon topology was built for various thematic maps after editing and cleaning. Water samples have also been collected from the study area and have been analyzed to know their physical and chemical characteristics.

Data sources include Survey of India (SOI) topographic map on 1:50,000 scale, Geocoded False Colour Composite (FCC) of Indian Remote Sensing satellite (IRS-1B) LISS II data with spatial resolution of 36.25 meter of 1993, 2001 and digital data of IRS-P6 LISS III of 2010 having a spatial resolution of 23.5 meter. Meteorological data (temperature and rainfall) of Singrauli district for 1978 - 2010 period was obtained from India Meteorological Department (IMD) Pune, and have subsequently been analyzed, to ascertain variation in temperature and rainfall trends. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data of 30 meter resolution has been used for generating Digital Elevation Model (DEM) and slope map.

The study area lies in Singrauli district of Madhya Pradesh however a small part of it falls in the neighbouring Sonebhadra district of Uttar Pradesh. It is bounded
by 24°00' to 24°15' North latitudes and 82°15' to 82°45' East longitudes and covers geographical area of about 728.40 km². Singrauli is represented by cluster of low lying hills and plateaus on the undulating fertile plains in southwest. The area has a step like scarp faces towards south which represent different stages of peneplanation. The climate is tropical monsoonal with extreme temperatures ranging from 47.2 °C in summer to 2 °C during winter, whereas the average annual rainfall received for the last 33 years is 1119.65 mm. Maximum elevation encountered is 618 m above MSL and minimum is 265 m above MSL. Slope ranges from 0° to 29° classified into four classes, i.e. gentle (0° to 7°), moderate (7° to 15°), steep (15° to 22°) and very steep (22° to 29°).

Singrauli area forms the northern most part of the Son-Mahanadi valley of Gondwana basin. The junctional region lies in the coal field between east-west trending Damodar-Keol-Tatapani graben and north-west trending rift zone of the Son-Mahanadi valley. The stratigraphic and tectonic framework of Singrauli shows characters of both Damodar valley and Son valley of Gondwana basin. The northern limit of Singrauli basin is defined by prominent east-west trending boundary fault which is probably an offshoot of Son-Narmada lineament. The area is tectonically undisturbed and the beds are more or less horizontal with 1°- 3° dip in the north whereas the strike of the bed is east-west. The general structure in the study area is broadly anticline with six series of formations have been recognized on broad lithic characteristics within the Gondwana rocks of Singrauli Coalfield, Viz. Talchir, Barakar, Barren Measures, Raniganj, Panchet and Mahadeva. Only Barakar and Raniganj are coal bearing formations. The area has seven distinctive geomorphological units which include Low lying flats, Structural Plateau, Structural Hills, Residual Hills, Colluvial foot slopes, and Badland. Low lying flats are the dominant geomorphic unit, lithologically composed of Barakar, Talchir and Precambrian in North-west followed by Structural plains, Structural hills, Badland, Colluvial foot slopes and Denudation Hills.

Four major soil types namely Pelluderts, Ustocherpts, Rhodustulls and Haplustslfts are developed. Pelluderts (Deep black soil) is a dominant soil type in the south on the gentle slope (0° - 7°) with elevation range of 300 m to 406 m. Ustocherpts (Shallow Black soil) is the second dominant soil type in the central and northern parts
extending from east to west. Rhodustulls (Red and Yellow soil) is in the northern part on elevation ranging between 442 m to 548 m. Haplustslfts (Red sandy soil) is in the north east and in central part mostly found on gentle to very steep slope with elevation ranges from 422 m to 618 m.

Land use/land cover changes using multi-temporal IRS data of 1993, 2001 and 2010 have been mapped, using visual image interpretation techniques. Land use/land cover categories such as dense forest, open forest, open scrub, cultivated land, uncultivated land, mining pit/operating mine, overburden dumps, wasteland, rocky barren/stony wasteland, settlement/Built-up, ash pond, water body, thermal power plant, dry river channel and plantation have been delineated on IRS data. Area statistics of each land use/land cover category of 1993, 2001 and 2010 generated in Arc View 3.2 has been determined to analyze change in their spatial distribution. By comparing the land use/land cover maps of 1993, 2001 and 2010 change detection maps have been automatically generated in Arc View GIS software to assess the major changes in land use/land cover during 1993 - 2001, 2001 - 2010 and 1993 – 2010 periods. Comparative analysis of 1993 - 2001 and 2001 - 2010 has been carried out to find the spatio-temporal change under each land use/land cover category.

Major land use/land cover changes which have been observed include reduction in dense forest by 48.9 km² (6.71 %) from 1993 to 2010, out of which 24.6 km² (3.37 %) from 1993 to 2001 and 24.3 km² (3.34 %) during 2001 - 2010. Dense forest has reduced due to clearance of protected forest for expansion of coal mining activities, and has been converted into open forest, overburden dumps and mining pits from 1993 to 2010. Cultivated land has shrunk by 21.2 km² (2.91 %) from 1993 to 2010, out of which 8.60 km² (1.18 %) from 1993 to 2001, and 12.59 km² (1.73 %) during 2001 – 2010, due to decline in rainfall, land becoming infertile and farmers relocation. Water table data also support this finding as sufficient water is not available for crops. The area under water body has reduced by 21.6 km² (2.97 %) from 1993 to 2010, out of which 6.8 km² (0.94 %) from 1993 to 2001, and 14.80 km² (2.03 %) during 2001 - 2010. This change is possibly due to decline in annual rainfall, increase in withdrawal of water from G. B. Pant reservoir for cooling the generators of thermal power plant and increased demand for water in coal washery, sprinkling to stop dust generation on haul roads, dumpsites and also in open cast mines.
Land use/land cover categories which show increase in area from 1993 to 2010 are open forest, open scrub, uncultivated land, mining pit/operating mine, overburden dumps, wasteland, settlement/builtup, ash pond, dry river and plantation. Open forest has increased by 4.09 km² (0.56 %) from 1993 to 2010, but during 1993 – 2001 it has reduced by 1.1 km² (0.16 %) whereas from 2001 – 2010 it has increased by 5.23 km² (0.72 %), probably due to the degradation of dense forest into open forest near mining area and growth of natural vegetation at the periphery of the G. B. Pant Sagar reservoir due to drying up of water. Open scrub has increased by 17.7 km² (2.43 %) during 1993 – 2010, out of which 5.20 km² (0.72 %) from 1993 to 2001 and 12.48 km² (1.71 %) from 2001 to 2010, which is attributed to degradation of dense forest, and conversion of uncultivated land into open scrub. Cultivated land abandoned by farmers due to resettlement to other places under rehabilitation program has also been converted into open scrub. Open scrub has also increased near mining block where plantation is in progress under afforestation programme launched by Northern Coal field Ltd and National Thermal Power Corporation. Uncultivated land has increased by 4.9 km² (0.67 %) from 1993 to 2010, out of which 1.6 km² (0.21 %) from 1993 to 2001 and 3.30 km² (0.46 %) from 2001 to 2010. The increase in uncultivated land is due to decline in rainfall which has converted agriculture land to uncultivated land, besides decline of water table leading to drying up of wells resulting in loss of cultivated land. Mine pit/operating mines have expanded by 3.62 km² (0.50 %) during 1993 - 2010 period, out of which 0.90 km² (0.12 %) from 1993 to 2001 and 2.74 km² (0.38 %) from 2001 to 2010. Since coal mining, development and operation has been expanded hence, overburden dumps have also shown increase in their extent, showing an increase of 20.61 km² (2.83 %) from 1993 to 2010 period, out of which 11.81 km² (1.62 %) from 1993 to 2001 and 8.80 km² (1.21 %) from 2001 to 2010. Overburden dumps have expanded due to removal of huge quantity of material from mine pits for extraction of coal which is dumped into dense forest and on agriculture land resulting in degradation of forest and agriculture land. Wasteland has increased by 6.25 km² (0.86 %) during 1993 – 2010 period, out of which 3.7 km² (0.51 %) from 1993 to 2001 and 2.55 km² (0.35 %) from 2001 to 2010, due to land degradation, soil erosion and polluted water coming out from industries and overburden dumps also deteriorate fertility of cultivated land leading to wasteland development. Settlement/built-up area
shows overall increase of 12.77 km² (1.75 %) from 1993 to 2010, out of which 4.60 km² (0.63 %) from 1993 to 2001, and 8.17 km² (1.12 %) from 2001 to 2010. Increase in settlement/built-up area is due to the development of industrial sector which requires residential colonies, industrial buildings, schools, community halls etc besides demand for labour work has also attracted people from other states/cities to settle in this industrial belt resulting in expansion of villages, towns and cities. Ash pond shows an increase of 6.2 km² (0.85 %) during 1993 - 2010 period out of which 2.60 km² (0.36 %) from 1993 to 2001 and 3.54 km² (0.49 %) from 2001 to 2010. Ash generated due to enhanced power production is disposed off to ash ponds which have increased in number from two in 1993 to three in 2001 and finally to five in 2010. Dry river has increased by 4.70 km² (0.64 %) from 1993 to 2001 and reduced by 1.76 km² (0.24 %) from 2001 to 2010, but shows an overall increase of 2.9 km² (0.40 %) from 1993 to 2010. This increase is attributed to the decline in rainfall and increase in consumption of water by industrial and mining sector from the reservoir which contributes drying up of water body/rivers. It was found that dry aiver channel has been used for cultivation of vegetables along the periphery of the G. B. Pant sagar reservoir, Kachani river and Mayar river by local people. Area under Plantation has increased by 12.6 km² (1.74 %) during 1993 - 2010, out of which 5.90 km² (0.81 %) from 1993 to 2001 and 8.69 km² (1.19 %) from 2001 to 2010. Plantation is mostly seen in NTPC and NCL residential complexes and on overburden dumps around mining blocks of Jayant, Nigahi, and Amlori open cast mines, carried out under “Operation Green Gold” scheme by NCL, and under social forestry scheme by NTPC. The area occupied by rocky barren/stony wasteland and thermal power plant remains unchanged from 1993 to 2010.

The present study also aims to assess water quality for drinking and irrigation purposes by analyzing water samples from the study area. Ten samples from surface water and seventeen samples from ground water collected from the field were analysed in the laboratory. The result suggests that pH is slightly more than 7 which indicate alkaline nature of water. TDS in 15 samples is below 1000 mg/l which are in fresh water category whereas, 12 samples exceed standard value and fall in brackish water category, suggests that 55% are suitable for use and rest 44 % is unsuitable. The conductivity in two samples show higher value and fall in medium conductivity
class I but rest of the samples show slightly higher value than the permissible limit but can be used for drinking. The carbonate and hydroxyl ions are absent in the samples because phenolphthalein alkalinity in the area is zero. Total alkalinity value ranges from 65mg/l to 585 mg/l, only eight samples show alkalinity within desirable limit whereas 19 samples indicate higher alkalinity. Total alkaliniies higher than the desirable limit indicate pollution of water because of waste water runoff from the coal mine, industrial and residential areas. Total hardness ranges from 28mg/l – 148mg/l which indicate soft to moderately soft water in the area.

The major cations Ca and Mg are within the desirable limits. Sodium exceeds the desirable limit and indicates high concentration in all samples which suggests its unsuitability for irrigation or domestic use. Water classified on the basis of sodium percentage shows 81% sample are under doubtful, 14.81% under permissible limit and only 3.7% shows unsuitable for use. Potassium values are within desirable limit in 26 samples except sample No 8 (Baliya nulla) which shows higher concentration due to direct discharge from coal mines into Baliya nulla. Chloride concentration is above the desirable limit due to the wastewater coming from industries, municipal waste and combustion of coal. Sulphate values are within the limit in 25 samples but in rest 2 samples it is higher than the prescribed limit.

The minor ions like copper and zinc are within desirable limits whereas nickel concentration exceeds the desirable limit in 8 samples due to discharge of effluents from mine waste deposits, industries, residential areas which makes water unsuitable for drinking purpose. Iron content is under desirable limit in 19 samples but in 8 samples iron concentration is over the prescribed limit, suggesting by and large water is suitable for domestic use. Magnesium and Zinc content is under desirable limit which shows water is free from contamination of these elements. Cobalt shows higher values than desirable limit which results in poor quality of water. Chromium value exceeds in 9 samples which suggests that water is not fit for drinking and in 18 samples it is within the limit.

The quality of water for irrigation purpose has also been attempted using U.S salinity laboratory classification criteria by SAR and Conductance values. The results demonstrate that water quality is suitable for irrigation purpose at most of the places.
but near mining area and Mahajan chowk (wasteland) water quality is not suitable for irrigation. Residual sodium carbonate (RSC) has been also determined for quality of water, which reveals that 14 samples (51.8%) fall in unsuitable class, 5 samples (18.5%) falls in doubtful class and 8 samples (29.6%) fall under good class which also suggests that at most of the places water is not suitable for irrigation purpose.

The water composition can be identified by using hydro geochemical facies in piper trilinear diagram, 85% of the sample falls in area 7, whereas 11% in the area 9 which indicate two types of water composition. The field 7 is the dominant type indicates Na-Cl or Na-HCO3-Cl type non-carbonate alkali exceeds fifty percent and the chemical properties are dominated by alkalies and strong acid whereas field 11 shows no one cation-anion pair exceeds fifty percent.

The study has presented the latest status on the environmental degradation of the area which has been monitored using time series remotely sensed data. It has brought out major land use/land cover changes taken place as a result of rapid industrialization due to coal mining and its associated activities. Water quality in the area has also been severely affected due to mining activities which has led to many adverse impacts. Efforts should be made by NCL, NTPC and other industries operating in the area to make an ecological balance by taking extensive plantation drive in the region. Moreover, NCL and NTPC should take effective measures as a corporate social responsibility (CSR). Safe methods of waste disposal should be followed by industries so as to minimise water pollution prevailing in the area. Industries should adhere to the norms and regulations of various laws on the Environmental pollution and Protection.