Spatio - temporal landcover dynamics and environmental impact in coal mine area of Korba district (Chhattisgarh)

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Abstract
Detection of digital change is the approach that helps to assess the changes associated with land use and land cover resources. Detection of landuse/landcover change in the form of maps and statistical data is very useful for land spatial planning, management and utilisation. In order to research land use / land cover shifts, Remote Sensing and Geographic Information System (GIS) were used. The goal of this study is to detect changes in land use between 1929 and 2009 using satellite images of 1990, 1999 and 2009 TM map data and 2009 Google Earth Imagery and topographic map surveys of India. The study developed a five-year (1929,1970,1999,2005,2009) land use/land cover map of the Korba district of Chhattisgarh to detect changes in the residential area, mining area, water bodies, farm lands, and forest areas in particular. The objective of study is to prepare land use/land cover map for different time periods, analyse the land use changes and evaluate the socio – economic implications of predicted change. Landuse changes have been detected by image processing method in ArcGIS9.3. Monitoring of landuse/landcover changes help to study impact of increase in industrialization on environment and to plan development activities and frame development policies. During this period of 80 years the forest area decreased nearly by half of that in 1929 from 4622.82 km² in 1929 to 2241.66 km² in 2009. The agriculture area increased during the period 1929 -1970 showing that deforested land was converted into agriculture land during this period. from 1970 onwards mines and barren area increased from nil to 527.72 km² in 2009. Residential area showed a drastic increase during the period 1970 -1999 due to migration of people from nearby areas to coal fields in search of livelihood.

1. Introduction
Land is perhaps the most valuable natural resource of the entire ecosystem in terms of soil, water and associated flora and fauna. With a rising population and human activity, the demand on limited land and soil resources for food, energy and many other needs is increasing. Detailed information on the spatial distribution of the land use/land cover categories and the pattern of their transformation is a prerequisite for the planning, use and management of the country’s land resources. Land cover inventories are
becoming increasingly relevant in various resource sectors, such as agricultural planning, settlement and cadastral surveys, environmental studies and agro-climate zone based operational planning. As the population increases, particularly in urban areas, by attracting job opportunities, and the city grows outward from its limit, encroachment begins on the available land surrounding it. Agricultural land is beginning to be transformed into built-up areas as a result of a rising number of people, and forested areas are beginning to be converted into agricultural land, built-up land, etc.

Coal mining is a significant habitat transformation practise that has a number of adverse environmental consequences, such as soil erosion, acid-mine drainage and increased sediment load as a result of abandoned and unrecovered mined land (Parks et al., 1987). Mining operations tend to have a significant impact on the atmosphere, ecosystem and biological activities that include the extraction of minerals from the earth’s crust (Down & Stocks, 1997 and Bell 2001). There is a major environmental risk from unscientific extraction of minerals, resulting in decreased forest cover, higher-scale soil degradation, air, water and land pollution, and loss of biodiversity (UNESCO, 1985). The waste rock dump problems are ruining the environment around mining areas (Goretti, 1998).

Therefore, recognizing land use trends in mine-areas is important in order to assess the impact of mining operations on the environment and to frame development policies for the region. The land use/land cover pattern of an area is an outcome of natural and socioeconomic parameters and their use by man in spatial and temporal. Land is becoming a scarce resource due to immense agricultural and demographic stress. Therefore, knowledge of land use / land cover and possibilities for their efficient use are important for the selection, planning and implementation of land use schemes to satisfy the increasing requirements for basic human needs and welfare activities. This data also helps track the dynamics of land use arising from changing population demands.

Satellite remote sensing has gained considerable attention for inventorying and monitoring of natural resources and is increasingly being applied to land use/land cover monitoring in the region. The remote sensing approach to rapid assessment and periodic monitoring of the environmental impacts of construction activities such as mining is also becoming much more important today. With the Geographical Information System, the method has a distinct advantage over conventional methods/approaches for mapping and monitoring the evolution of degraded areas (GIS). The technique has proven its utility in assessing environmental degradation with respect to earth, water, air and vegetation.

2. Study Site And Methodology

Korba is situated in the eastern part of Chhattisgarh as shown in figure 1. It is covering an area of about 7145.44 sq.km. Bounded by latitude 22˚30’00” N to 22˚15’00”N and longitude 82˚32’30”E to 82˚42’30”E. It is on the left bank of the Hasdeo River which is a major tributary of Mahanadi River. Ahiran is another river in the area that joins Hasdeo River. It is about 238 kilometers by road from capital city Raipur. Coal is the major natural resource available in this region. Major power generating units of the state have come up in Korba owing to huge reserves of coal. Korba is popularly known as power hub of India.

![Figure 1. Location of study area (Korba district)](image-url)
3. Methodology
The detailed methodology adopted in this thesis to achieve the above objective is described in this chapter. Flowchart of the broad steps followed in this work for deriving statistics of land use pattern of the area is shown in Figure 2.

![Flowchart of the broad steps followed in this work for deriving statistics of land use pattern of the area](image)

Figure 2. Flowchart of the broad steps followed in this work for deriving statistics of land use pattern of the area

4. Result And Discussion

4.1 Change in Different Land Features

4.1.1 Mines and Barren Land. The area occupied by coal 1929 and 1970 was zero as the extraction would not have started or it might be underground mining which cannot be accounted in the topographic sheet. In twenty nine year from 1970 to 1999 the area of coal and barren land increases from zero to 6.22 which clearly shows that in this phase rapid coal exploration and industrialization has taken place. Due to which the coal and barren land count has increased. A large part of barren land in 2005 land use map can be seen nearby river Hasdeo which shows a large amount of ash and waste dump on the water banks.

| Year | Coal and barren land area occupied (km²) | Percentage of total area occupied | Percentage change in area with duration |
|------|-----------------------------------------|-----------------------------------|----------------------------------------|
| 1929 | 0                                       | 0                                 | 0 (1929-1970)                          |
| 1970 | 0                                       | 0                                 | 0 (1929-1970)                          |
| 1999 | 411.48                                  | 6.22                              | 100 (1970-1999)                        |
| 2005 | 452.36                                  | 6.84                              | 9.96 (1999-2005)                       |
| 2009 | 527.72                                  | 7.98                              | 16.67 (2005-2009)                      |
4.1.2 Forest. The forest area of Korba region degraded from 69.92% in 1929 to 33.90 % in 2009 in the 80 years duration forest cover reduced to half the value. From the table above the result came out that during the period between 1929 to 1970 a decrease of 21.59% of total area was observed this was due to large amount of forest was being converted unto agriculture land. The period 1970 to 1999 seen the rise coal exploration in Korba region which led to the conversion of forest area into coal mine area, residential area and agriculture area. From 1999 onwards the degradation of forest has been due to the demand of land for residential and many areas were converted into coal mines. Due to decrease in forest area the flora and fauna of Korba region degraded. Many animals, birds become during this periods.

Table 2. Year wise forest occupied area

| Year | Forest area occupied (km²) | Percentage of total area occupied | Percentage change in area with duration |
|------|---------------------------|----------------------------------|----------------------------------------|
| 1929 | 4622.82                   | 69.92                            |                                        |
| 1970 | 3195.26                   | 48.33                            | -44.67 (1929-1970)                     |
| 1999 | 2547.94                   | 38.53                            | -20.27 (1970-1999)                     |
| 2005 | 2441.90                   | 36.93                            | -4.15 (1999-2005)                      |
| 2009 | 2241.66                   | 33.90                            | -8.2 (2005-2009)                       |

4.1.3 Agriculture. The period from 1929 to 1970 seen nearly double rise in the area of agriculture land during this phase large amount of forest land was converted into agriculture to fulfill the need of rising population. In this phase agriculture flourish in the country to make India a self-dependent in food and similarly the pattern can be seen in Korba region. The 29 years duration between 1970 to 1999 saw only 2.66% increase in the agriculture area. this was due to the rapid industrialization in the region in this phase which shifted the workforce from agriculture to industry. After 1999 there is a gradual increase in agriculture land in the region.

Table 3. Year wise agriculture occupied area

| Year | Agricultural area occupied (km²) | Percentage of total area occupied | Percentage change in area with duration |
|------|----------------------------------|----------------------------------|----------------------------------------|
| 1929 | 1758.34                          | 26.60                            |                                        |
| 1970 | 3177.76                          | 48.06                            | 80.72 (1929-1970)                      |
| 1999 | 3353.40                          | 50.72                            | 5.53 (1970-1999)                       |
| 2005 | 3358.04                          | 50.79                            | 0.138 (1999-2005)                      |
| 2009 | 3447.53                          | 52.14                            | 2.65 (2005-2009)                       |

4.1.4 Residential. During the 80 years duration the residential area had seen double increase in the area occupied by residential area. In the period between 1929 to 1970 the residential area increases by 11% of total area accounting for rise in population in this phase. After 1970 the rate of increase in settlement was accelerated due to industrialization and the migration of people from nearby area. Moreover during these phase the landuse map depicts the concentration of residential area nearby coal mine area which shows the increase in residential area was due to the increase in coal mining activity. In 2009 the 3% of the area was occupied by residential area which shows that only a small part of land area was occupied by people in the regions.

Table 4. Year wise residential occupied area

| Year | Residential area occupied (km²) | Percentage of total area occupied | Percentage change in area with duration |
|------|---------------------------------|----------------------------------|----------------------------------------|
| 1929 | 70.15                           | 1.06                             | 10.37 (1929-1970)                      |
| 1970 | 77.87                           | 1.17                             | 71.79 (1970-1999)                      |
| 1999 | 133.28                          | 2.01                             | 27.36 (1999-2005)                      |
| 2005 | 169.53                          | 2.56                             | 16.79 (2005-2009)                      |
| 2009 | 197.51                          | 2.99                             |                                        |
4.1.5 Water Bodies. A water body in the region mainly comprises of the river Hasdeo, Ahiran, their distributaries, lakes, wells. Very little change in the area occupied by water bodies is seen in 80 years. There was increase in the in the area water bodies during 1999-2005 phase and 2005-2009 this might be due formation of lakes on the area from which coal has been extracted. Moreover the change in area of water bodies was not observable to large extent.

Table 5. Year wise water bodies occupied area

| Year | Water bodies area occupied(km²) | Percentage of total area occupied | Percentage change in area with duration |
|------|--------------------------------|----------------------------------|----------------------------------------|
| 1929 | 159.97                         | 2.42                             |                                        |
| 1970 | 160.39                         | 2.42                             | 0 (1929-1970)                          |
| 1999 | 155.18                         | 2.35                             | -2.89 (1970-1999)                      |
| 2005 | 189.45                         | 2.86                             | 21.70 (1999-2005)                      |
| 2009 | 196.86                         | 2.98                             | 4.2 (2005-2009)                        |

5. Comparison of land features in different years

During the period from 1929 to 2009 mining and barren land increased by 527.72 square kilometer, a percentage increase of 7.98 forest area saw a decrease during the same period from 4622.82 to 2241.66 square kilometer. The change in area of forest was the maximum when compared with all the classes. Water body increased from 159.97 to 196.86 square kilometer during the period 1929-2009. There was an increase in agriculture area from 1758.34 to 3447.53 square kilometer during the period of 1929-2009 with maximum during the period of 1929 to 1970 which may be attributed to an increase in population. The residential area in the region increased from 70.15 to 197.51 during the period of 1929 to 1970. During this period residential area pattern change from being dispersed in 1929 to concentrate near coal mine area in 2009.

The land use map for the year 1929, 1970, 1999, 2005 and 2009 has been shown in the below

5.1. Landuse map of the year 1929

The 1929 map shows that most of the study area is covered by forest. In 1975 area occupied by forest was 4622.82 square kilometer, 69.22 percent of the total area. Agriculture occupied 1758.34 square kilometer, which is about 26.60 percent of the total study area. Area occupied water body was 159.97 square kilometer, 2.42 percent of the total study area. Residential area was 70.15 square
kilometer which was 1.06 percent of the total area. In 1929, there was no coal mine and barren area and maximum land was occupied by forest and minimum by coal mines and barren land. The graph above shows the comparison between different classes of land use and it clearly depicts a high percentage forest land followed by agriculture area and water bodies and residential area very little of total area.

5.2. Landuse map of the year 1970

![Landuse map of the year 1970](image)

Figure 4. Landuse map of the year 1970

In 1970, land use land cover pattern has changed drastically with respect to 1929. Area under forest witnessed a huge percentage decrease of 20.89 percent of total area that accounted for 1427.56 square kilometre of forest area being deforested. Area occupied by mining and barren land remained zero. The area occupied by water body from remained nearly same with 159.97 in 1929 to 160.39 in 1970. Agriculture land increased from 1758.34 in 1929 to 3177.76 in 1970, a increase of 22 percent of total area. Residential area increased from 70.15 in 1929 to 77.87 in 1970. In 1970, dense forest and agriculture land occupied the largest classes with total of 97 percent of the total area. After barren land, residential occupied minimum area with just 1.06 of total area. It is estimated that almost all the decrease in forest area is due to the fact that forest land have been utilized for agriculture and related activities and also due to human pressure on forest for firewood as well as grazing of cattle in the forested area.

5.3. Landuse map of the year 1999
Figure 5. Landuse map of the year 1999

In 1999, area under mines and barren land increase to 133.28 square kilometre which is 6.22 percent of the total area. There was a decrease in dense forest area from 3195.26 square kilometre in 1970 to 2547.94 square Kilometre in 1999, a 6.8 percent decrease of total area. This decrease can be attributed to the increase in mining area and residential area. Water body decreased from 160.39 square kilometre in 1970 to 155.18 square kilometre in 1999. Agriculture land increased from 3177.76 square kilometre in 1970 to 3353.04 in 1999. Residential area saw an increase in area from 77.87 square kilometre in 1970 to 197.51 square kilometre in 1999 since migration of population took place due to increase in mining activities. During this period colonies were built in the coal mines area to provide shelter to the employee due to which the residential area which spread all around in previous years got concentrated in coal mine area.

5.4. Landuse map of the year 2005

Figure 5. Landuse map of the year 2005

In 1999, area under mines and barren land increase to 133.28 square kilometre which is 6.22 percent of the total area. There was a decrease in dense forest area from 3195.26 square kilometre in 1970 to 2547.94 square Kilometre in 1999, a 6.8 percent decrease of total area. This decrease can be attributed to the increase in mining area and residential area. Water body decreased from 160.39 square kilometre in 1970 to 155.18 square kilometre in 1999. Agriculture land increased from 3177.76 square kilometre in 1970 to 3353.04 in 1999. Residential area saw an increase in area from 77.87 square kilometre in 1970 to 197.51 square kilometre in 1999 since migration of population took place due to increase in mining activities. During this period colonies were built in the coal mines area to provide shelter to the employee due to which the residential area which spread all around in previous years got concentrated in coal mine area.

5.4. Landuse map of the year 2005

In 1999, area under mines and barren land increase to 133.28 square kilometre which is 6.22 percent of the total area. There was a decrease in dense forest area from 3195.26 square kilometre in 1970 to 2547.94 square Kilometre in 1999, a 6.8 percent decrease of total area. This decrease can be attributed to the increase in mining area and residential area. Water body decreased from 160.39 square kilometre in 1970 to 155.18 square kilometre in 1999. Agriculture land increased from 3177.76 square kilometre in 1970 to 3353.04 in 1999. Residential area saw an increase in area from 77.87 square kilometre in 1970 to 197.51 square kilometre in 1999 since migration of population took place due to increase in mining activities. During this period colonies were built in the coal mines area to provide shelter to the employee due to which the residential area which spread all around in previous years got concentrated in coal mine area.
In 2005, land use land cover pattern has changed with respect to 1999 as coal mines and other industries began to spread. Area under forest witnessed a percentage decrease of 1.40 of total area that accounted for 106.04 square kilometre of forest area being deforested. Area occupied by mining and barren land increased from 411.48 square kilometre in 1999 to 452.36 in 2005. The area occupied by water body increased from 155.18 in 1999 to 189.45 in 2005. Agriculture land increased from 3353.40 in 1999 to 3358.04 in 2005, a minute increase of 0.07 percent of total area. Residential area increased from 133.28 in 1999 to 169.53 in 2005. In 2005, forest and agriculture land occupied the largest classes with total of 87.72 percent of the total area which reduced from 86.25 percent of total area in 1999. Residential occupied the minimum area with just 2 percent of total area. It is estimated that almost all the decrease in forest area is due to the fact that forest land have been utilized for mining activities and in the construction of colonies to occupy the people near coal mines.

5.5. Landuse map of the year 2009
In 2009, area under quarry increase to 527.72 square kilometre which is 7.98 percent of the total area. There was a decrease in dense forest area from 2441.90 square kilometre in 2005 to 2241.66 square Kilometre in 2009, a 3.03 percent decrease of total area. This decrease can be attributed to the increase in mining area and residential area. Water body increased From 189.45 square kilometre in 2005 to 196.86 square kilometre in 2009. Agriculture land decreased from 3358.04 square kilometre in 2005 to 3447.53 in 2009. This decrease was due to mining activity due to which much agriculture land was converted into mines. Residential area saw an increase in in area from 169.53 square kilometre in 2005 to 197.51 square kilometre in 2009 since migration of population took place due to increase in mining activities.
Figure 7. Landuse map of the year 2009

Table 6. NDVI values for different land use

| S.N. | CLASS     | NDVI          |
|------|-----------|---------------|
| 1    | Forest    | 0.45 to 1.00  |
| 2    | Mines     | -0.40 to 0.00 |
| 3    | Settlements | 0.00 to 0.09  |
| 4    | Water body | -1.00 to -0.09|
| 5    | Non-forest | 0.11 to 0.44  |

6.1. NDVI map of the year 1990

(82°32’30”E, 22°30’N)  (82°45’E, 22°15’N)
Figure 8. NDVI map of the year 1990

Table 7. Legends and their corresponding NDVI Value for map 1990

| LEGENDS | NDVI       | LEGENDS | NDVI       |
|---------|------------|---------|------------|
| 1       | -1 to -0.77| 2       | -0.077 to -0.48 |
| 3       | -0.48 to -0.28 | 4       | -0.28 to -0.13   |
| 5       | -0.13 to -0.014 | 6       | -0.014 to 0.125 |
| 7       | 0.125 to 0.31 | 8       | 0.31 to 0.52      |
| 9       | 0.52 to 0.75 | 10      | 0.75 to 1           |

Table 8. Class and their corresponding Legends for map 1990

| S.N. | CLASS         | LEGEND |
|------|---------------|--------|
| 1    | Forest        | 9-10   |
| 2    | Agriculture   | 7-8    |
| 3    | Settlements   | 5-6    |
| 4    | Mines         | 3-4-5  |
| 5    | Water body    | 1-2    |

The NDVI values referring to legends 9 and 10 describe a forest area that, due to high reflectance, provides the highest NDVI values among all groups. The NDVI values that represent the coverage of agriculture correspond to legends 7 and 8. Seeing the NDVI map, it is clear that a large percentage of land in the area covers forest cover and agricultural land. Residential cover is shown by the NDVI values corresponding to legend 6, and it is evident that it exists in traces and occupies the least value of all groups. The NDVI values corresponding to Legend 3, 4 and 5 represent the region of the mine. The NDVI values corresponding to legends 1 and 2 reflect minimum NDVI values for water bodies.
6.2. NDVI map of the year 1999

Figure 9. NDVI map of the year 1999

Table 9. Legends and their corresponding NDVI Value for map 1999

| LEGENDS | NDVI     | LEGEND  | NDVI     |
|---------|----------|---------|----------|
| 1       | -1 to -0.8126 | 2       | -0.8126 to -0.52 |
| 3       | -0.52 to -0.33  | 4       | -0.33 to -0.17  |
| 5       | -0.17 to -0.06  | 6       | -0.06 to 0.07   |
| 7       | 0.07 to 0.19    | 8       | 0.19 to 0.38    |
| 9       | 0.38 to 0.75    | 10      | 0.75 to 1       |

Table 10. Class and their corresponding Legends for map 1999

| S.N. | CLASS      | LEGEND  |
|------|------------|---------|
| 1    | Forest     | 9-10    |
| 2    | Agriculture| 7-8     |
| 3    | Settlements| 6       |
| 4    | Mines      | 3-4-5   |
| 5    | Water body | 1-2     |

The NDVI values corresponds to legends 9 and 10 describe a forest area that, due to high reflectance, provides the highest NDVI values among all groups. The NDVI values that represent the coverage of agriculture correspond to legends 7 and 8. Seeing the NDVI map, it is clear that large percentages of land in the area are covered by forest cover and agriculture land. Residential cover is shown by the NDVI values corresponding to legend 6, and it is evident that it exists in traces and holds the least value of all groups. The NDVI values corresponding to Legend 3, 4 and 5 represent the region of the mine. Water bodies with minimum NDVI values reflect NDVI values corresponding to legends 1 and 2.
6.3. NDVI map of the year 2009

Figure 10. NDVI map of the year 2009

Table 11. Legends and their corresponding NDVI Value for map 2009

| LEGENDS | NDVI       | LEGEND | NDVI       |
|---------|------------|--------|------------|
| 1       | -1 to -0.67| 2      | -0.67 to -0.26 |
| 3       | -0.26 to -0.04| 4  | -0.04 to 0.015 |
| 5       | 0.015 to 0.055| 6  | 0.055 to 0.086 |
| 7       | 0.086 to 0.126| 8  | 0.126 to 0.234 |
| 9       | 0.234 to 0.624| 10 | 0.624 to 1   |

Table 12. Class and their corresponding Legends for map 2009

| S.N. | CLASS       | LEGEND |
|------|-------------|--------|
| 1    | Forest      | 9-10   |
| 2    | Mines       | 7-8    |
| 3    | Settlements | 5-6    |
| 4    | Water body  | 3-4    |
| 5    | Agriculture | 1-2    |

The NDVI values relating to legends 9 and 10 describe a forest area that, due to high reflectance, provides the highest NDVI values among all groups. The NDVI values that represent the coverage of agriculture correspond to legends 7 and 8. Seeing the ndvi map, it is clear that large percentages of land in the area are covered by forest cover and agriculture land. Residential cover is shown by the NDVI values corresponding to Legend 3 and 4 and it is obvious that it occurs in traces and takes up the least value of all groups. The NDVI values corresponding to Legend 5 and 6 it is obvious that it occurs in traces and takes up the least value of all groups. The NDVI values corresponding to legends 5 and 6 it is obvious that it occurs in traces and takes up the least value of all groups. The NDVI values corresponding to Legend 3 and 4 reflect the region of the mine. Water bodies with minimum NDVI values reflect NDVI values corresponding to legends 1 and 2.
7. Conclusion
It is evident from the above discussion that the mining activities in the Korba district of Chhattisgarh are adverse to the forest cover. It is advisable that such activities should be strictly monitored in order to avoid further damage, and that, in order to minimize vegetation damage, scientific mining should be carefully carried out. Effective recovery steps must be taken in the mine-affected areas using certain plants that can expand (Sarma, 2005). The current transition study will be useful in recognizing the shift in different land use/land cover patterns in mine-affected areas, as well as in identifying the areas of vegetation at risk due to mining activities. When formulating the district management plan, the study findings can be useful.

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