Singrauli Coal Mine - LULC Analysis

Project - 7

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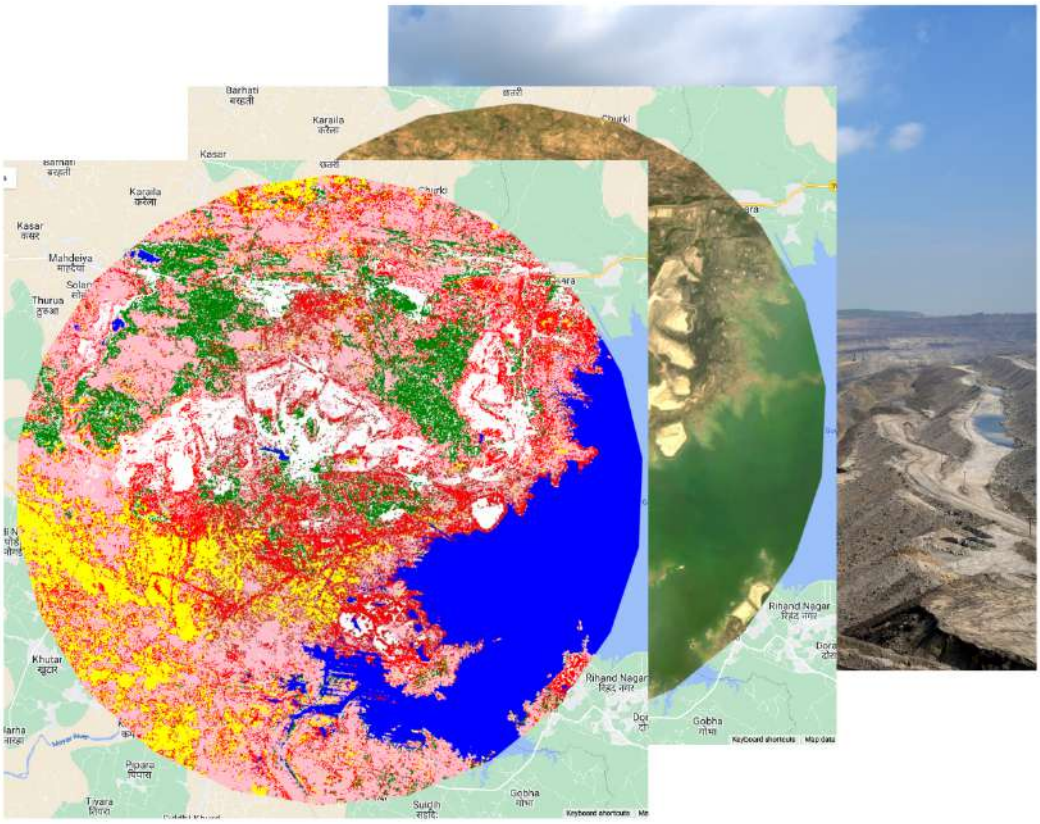
March 11, 2024

Contents

Abstract

This study investigates the temporal evolution of land cover and settlement patterns surrounding the Singrauli coal mine in India from 2000 to the present. Focusing on a 15km radius centered on the coal mine, the research employs satellite imagery analysis techniques to quantify changes in land cover types and settlement dynamics. Methodologically, the project involves data acquisition, preprocessing, land cover classification, and spatial analysis. Preliminary results reveal significant shifts in land cover composition and settlement expansion over the study period. These findings contribute to understanding the broader environmental and socio-economic implications of coal mining activities in the region.



1 Problem Definition

The Singrauli coal mine in India is a significant source of coal extraction, contributing to regional economic development. However, the expansion of coal mining activities often leads to changes in land cover and settlement patterns in the surrounding areas, with potential environmental and socio-economic implications. The problem addressed in this project is to analyze and quantify the land cover changes and settlement dynamics within a 15km radius around the Singrauli coal mine from the year 2000 to the present. By understanding the extent and nature of these changes over time, the project aims to provide insights into the environmental impacts of coal mining activities and support informed decision-making for sustainable land management in the region.

2 Assumptions

1. The satellite imagery data used for analysis is accurate, reliable, and consistent over the study period.
2. Land cover classification algorithms accurately differentiate between different land cover types.
3. Settlement data sources provide comprehensive and up-to-date information on urban areas and infrastructure development.
4. The 15km radius around the coal mine adequately captures the spatial extent of potential impacts from coal mining activities.
5. Settlement areas are defined as regions primarily occupied by residential, industrial, or commercial buildings.

3 Data Processing

1. **Finding coal mine to study:** Googled the list of all coal mines in India, selected singrauli in Madhya Pradesh (since I am from Madhya Pradesh).

2. **Finding Dataset:** Used LandSat 7 (2000-2014) and LandSat 8 (2015-2023).

3. **Finding ROI on Map:** First got the coordinates (Latitude and Longitude) of the mine using google maps. Then drew a 15km radius circle around the area as Region of Interest.

4. **Selection of Bands:** Tried out all various possible combinations of bands but finally settled on True Color Composite for classification (Bands 3, 2 and 1 for LandSat 7 and bands 4, 3 and 2 for LandSat 8).

5. **Classification:** Marked the classification examples points for water body, vegetation (forest and other vegetation), build up area, coal mine area, and crops. Ran the classification algorithm and assigned colors, Took the screenshot of the final outcome (classified map):

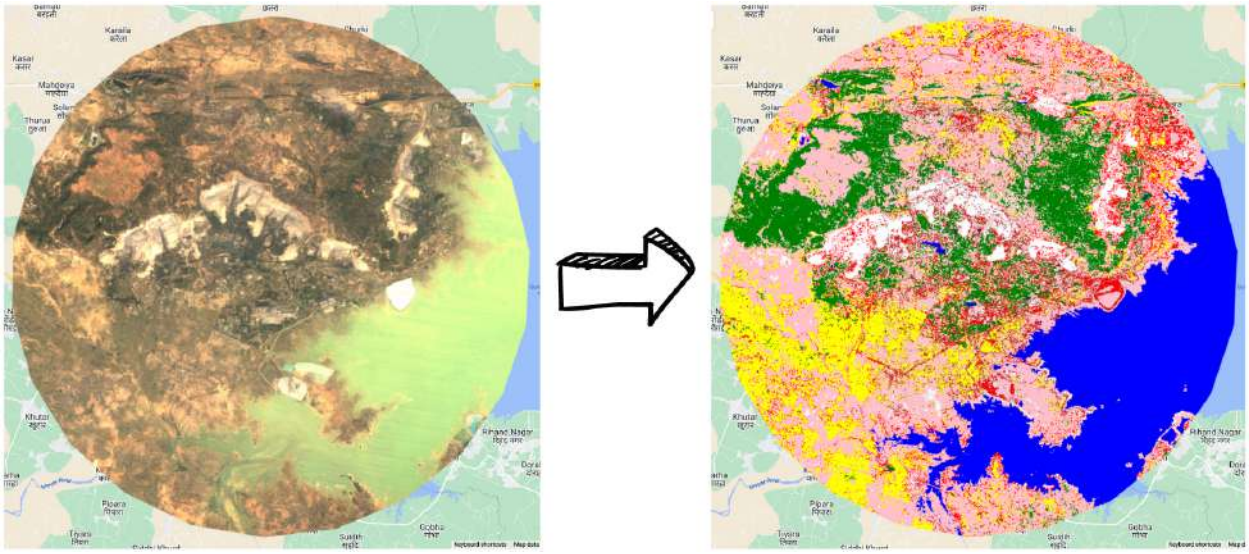
Color	Name	Class	HexValue
White	coal_mine	1	#FFFFFF
Blue	water_body	2	#0000FF
Red	build_up	3	#FF0000
Green	vegetation	4	#00FF00
Yellow	crop_land	5	#FFFF00
Pink	barren_land	6	#F04CFF

Table 1: Color Classification Key

6. **Analysis and Inference:** After completing the classification process and verifying the accuracy of the classified maps using Sentinel Land Use/Land Cover (LULC) data, I collected additional datasets including population statistics, forest cover information, and data on the size of the coal mine from diverse sources. Subsequently, I synthesized these datasets to draw meaningful conclusions and insights regarding the land cover dynamics around the Singrauli Coal Field.

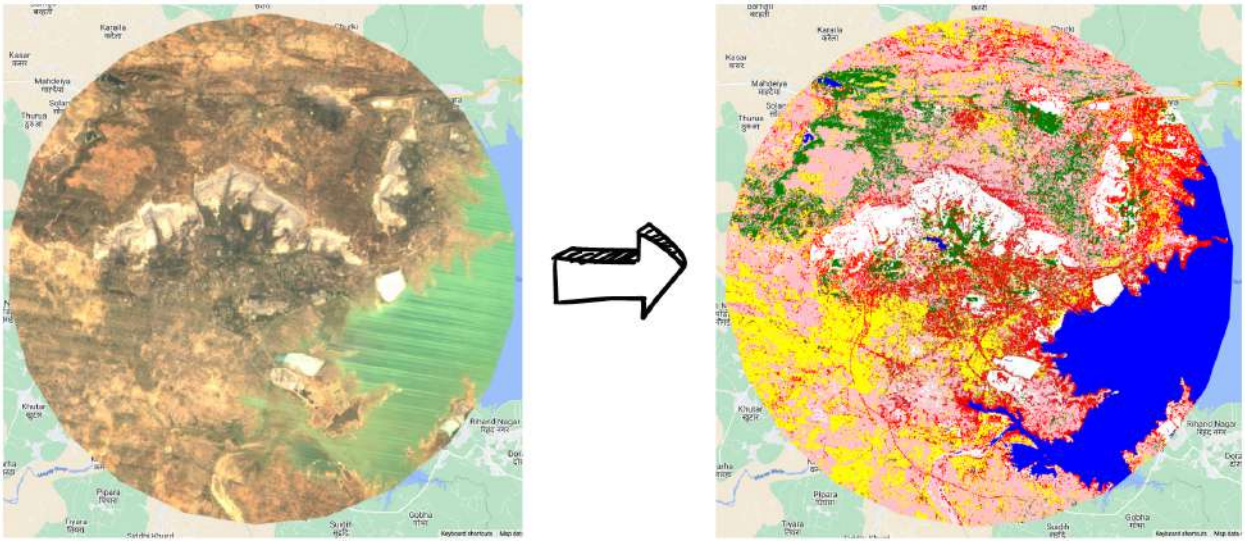
4 Map Outputs

2000 - 2004



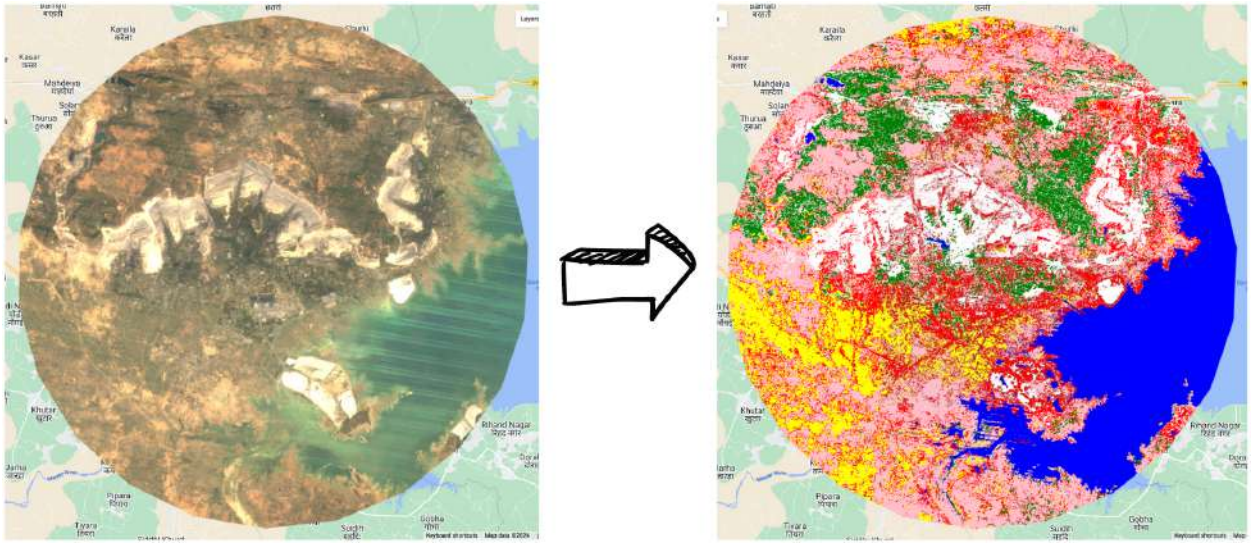
Link: `https://code.earthengine.google.com/47a0cd4743a49b77a44e2ba176d96c79`

2005 - 2009



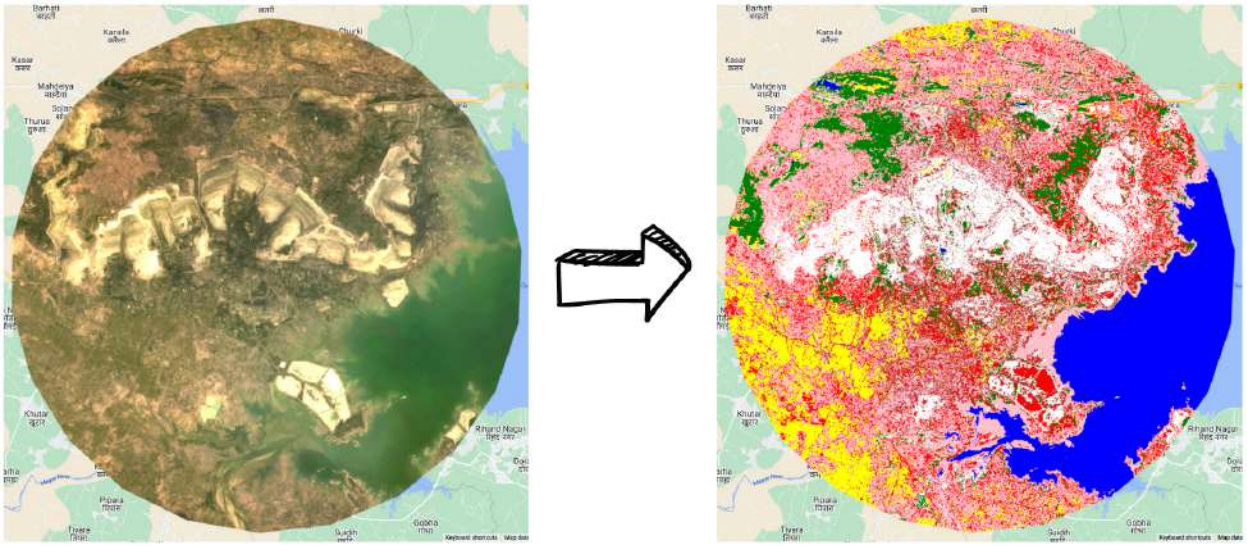
Link: `https://code.earthengine.google.com/6c4aab71664d4b3794b52a997faff426`

2010 - 2014



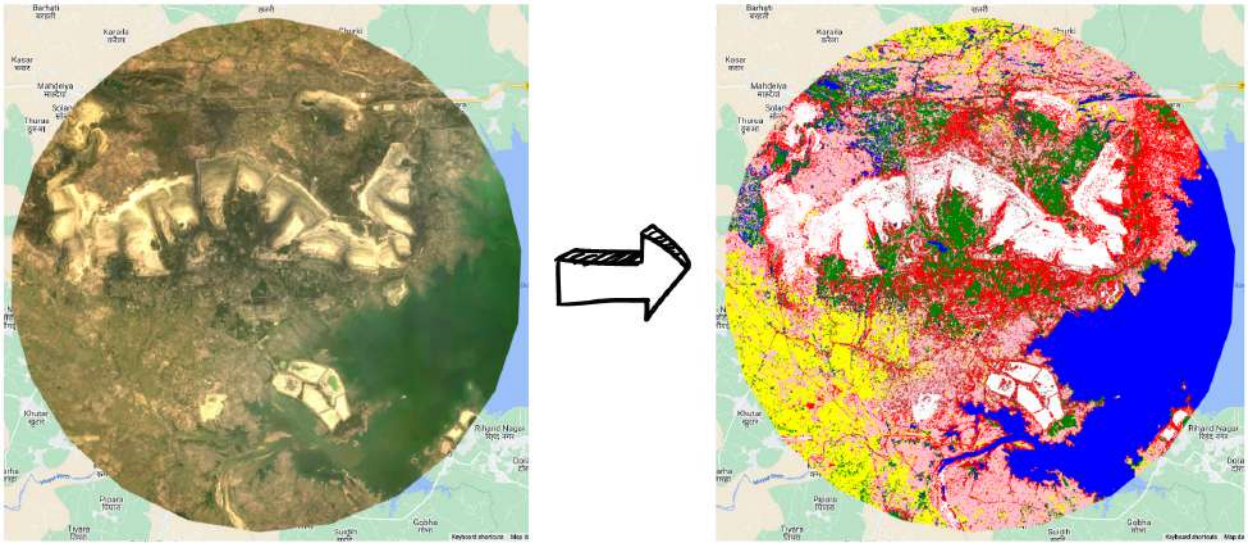
Link: `https://code.earthengine.google.com/7be076066c1f9c3d7f5217033a03c31c`

2015 - 2019



Link: `https://code.earthengine.google.com/aadced280b9cfbe86cbf769652224324`

2020 - 2023



Link: `https://code.earthengine.google.com/260ffdf94f437dc976e7103af58bed7b`

5 Code

5.1 LandSat 7

Listing 1: JavaScript code for LandSat 7

```
var center = ee.Geometry.Point(82.6753, 24.1172);
var ROI = center.buffer(15000); // 15km radius

// Add the polygon to the map
Map.centerObject(ROI, 8); // Center the map on the polygon
Map.addLayer(ROI, {}, '15km_Radius_Polygon');

// Defining the dataset
var L7 = ee.ImageCollection("LANDSAT/LE07/C02/T1_L2");

// Filtering the dataset
var image = L7.filterBounds(ROI)
              .filterDate('2000-01-01', '2004-12-31')
              .filterMetadata('CLOUD_COVER', 'less_than', 1)
              .median()
              .clip(ROI);

// Defining bands and visualisation parameters
var bands = ["SR_B3", "SR_B2", "SR_B1"];
var visParams = {
  bands: bands,
  gamma: 1,
  max: 13912,
  min: 7233,
  opacity: 1
};

Map.addLayer(image.visualize(visParams));
```

```
// Merging all the samples in one variable
var sample = coal_mine.merge(water_body)
                      .merge(build_up)
                      .merge(vegetation)
                      .merge(crop_land)
                      .merge(barren_land);

// Note there is no Band 6 in LandSat 7 Database
var bands = ['SR_B1', 'SR_B2', 'SR_B3', 'SR_B4', 'SR_B5', 'SR_B7'];

// Classification based on property Class
var classProperty = 'Class';

// Training Set
var training = image.select(bands).sampleRegions({
  collection: sample,
  properties: [classProperty],
  scale: 30
});

// Training the Classifier
var classifier = ee.Classifier.smileCart().train({
  features: training,
  classProperty: classProperty,
  inputProperties: bands
});

// Running the classifier for all bands on the image
var classified = image.select(bands).classify(classifier);

// Displaying classified image, each color corresponds to respective class
Map.addLayer(classified,
             {min:1, max:6,
             palette:['white', 'blue', 'red', 'green', 'yellow', 'pink']});
```

5.2 LandSat 8

Listing 2: JavaScript code for LandSat 8

```
var center = ee.Geometry.Point(82.6753, 24.1172);
var ROI = center.buffer(15000); // 15km radius

// Add the polygon to the map
Map.centerObject(ROI, 8); // Center the map on the polygon
Map.addLayer(ROI, {}, '15km_Radius_Polygon');

// Defining the dataset
var L8 = ee.ImageCollection("LANDSAT/LC08/C02/T1_L2");

// Filtering the dataset
var image = L8.filterBounds(ROI)
              .filterDate('2015-01-01', '2019-12-31')
              .filterMetadata('CLOUD_COVER', 'less_than', 1)
              .median()
              .clip(ROI);

// Defining bands and visualisation parameters
// Note here the bands 4, 3 and 2 gives True color composite
var bands = ["SR_B4", "SR_B3", "SR_B2"];
var visParams = {
  bands: bands,
  gamma: 1,
  max: 13912,
  min: 7233,
  opacity: 1
};

Map.addLayer(image.visualize(visParams));

// Merging all the samples in one variable
```

```
var sample = coal_mine.merge(water_body)
                      .merge(build_up)
                      .merge(vegetation)
                      .merge(crop_land)
                      .merge(barren_land);

// Note LandSat 8 contains all the bands
var bands = ['SR_B1', 'SR_B2', 'SR_B3', 'SR_B4', 'SR_B5', 'SR_B6', 'SR_B7'];

// Classification based on property Class
var classProperty = 'Class';

// Training Set
var training = image.select(bands).sampleRegions({
  collection: sample,
  properties: [classProperty],
  scale: 30
});

// Training the Classifier
var classifier = ee.Classifier.smileCart().train({
  features: training,
  classProperty: classProperty,
  inputProperties: bands
});

// Running the classifier for all bands on the image
var classified = image.select(bands).classify(classifier);

// Displaying classified image, each color corresponds to respective class
Map.addLayer(classified,
            {min:1, max:6,
            palette:['white', 'blue', 'red', 'green', 'yellow', 'pink']});
```

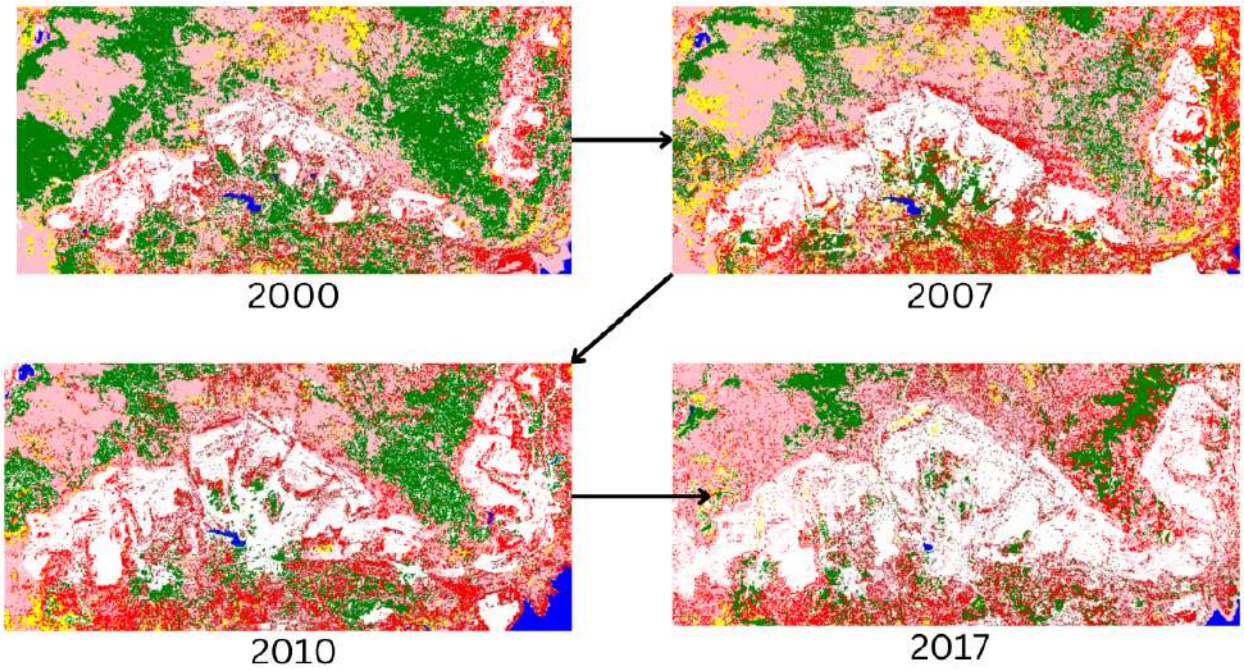
6 Difficulties Faced

- **Limited Dataset Availability:** Initially attempted to use Landsat 9 data, but it was only available from October 2021, while analysis required data from as early as 2000.
- **Insufficient Radius for Region of Interest (ROI):** Initially selected a 10 km radius around the center point of the coal mine for analysis, but found it insufficient due to the large size of the mine. Increased the radius to 15 km to encompass the necessary area.
- **Band Selection:** Experimented with various band combinations for classification, indicating a trial-and-error process to determine the most suitable bands for analysis.
- **Classification Challenges:** Faced difficulties in accurately classifying different land cover types, such as distinguishing between small houses and barren land using true-color composite images.
- **Color Differentiation for Classification:** Initially used brown for coal mine classification, but it was indistinguishable from red, requiring a change to white for better visibility.
- **Data Quality Issues:** Noticed line dropouts in the Landsat 7 data from 2005 onwards, potentially impacting the accuracy and reliability of the analysis.
- **Data Limitations:** Since Landsat 8 data was only available from 2013 onwards, had to rely solely on Landsat 7 data for analysis until 2013, which could have limited the comprehensiveness of the study.
- **Verification Challenges:** Required verification of classified maps based on Sentinel Land Use/Land Cover (LULC) data, indicating potential challenges in ensuring the accuracy and reliability of the classification results.
- **Data Gathering:** I posed problem in collecting relevant and reliable data for all the time frames for which classification is done.

7 Analysis and Inference

7.1 Increase in area of mines

We can see from the Classified maps that the coal mine area is increasing at a steady pace from 2001 to 2009 and then there is a sudden increase in coal mine area from 2010 to 2017 (Mine area is represented by white color).

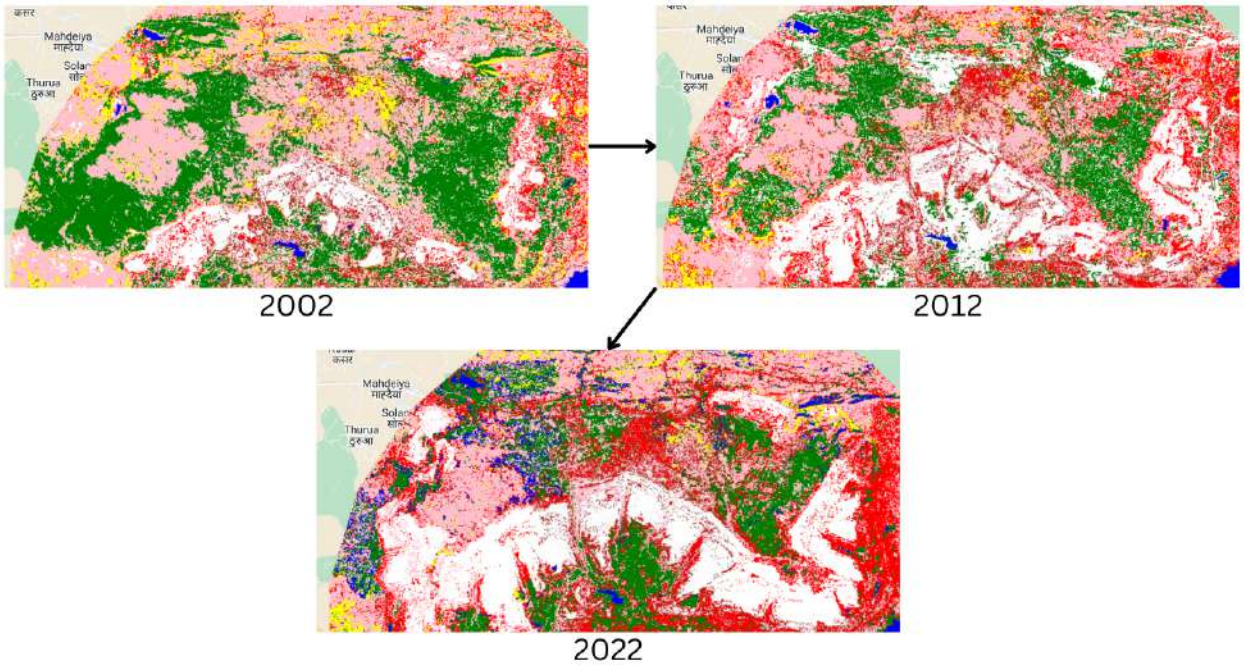


This can be supported by the following data [1]:

	Area (Ha/Year) increase of mines
Between (1976-2002)	135.2
Between (2002-2010)	364.8
Between (2010-2015)	574.3

7.2 Decrease in the forest cover

We can see from the Classified maps that the forest area above the coal mines is decreasing as the coal mine is expanding, also as the build-up area grows the forest cover is decreasing (Forest area is represented by green color).

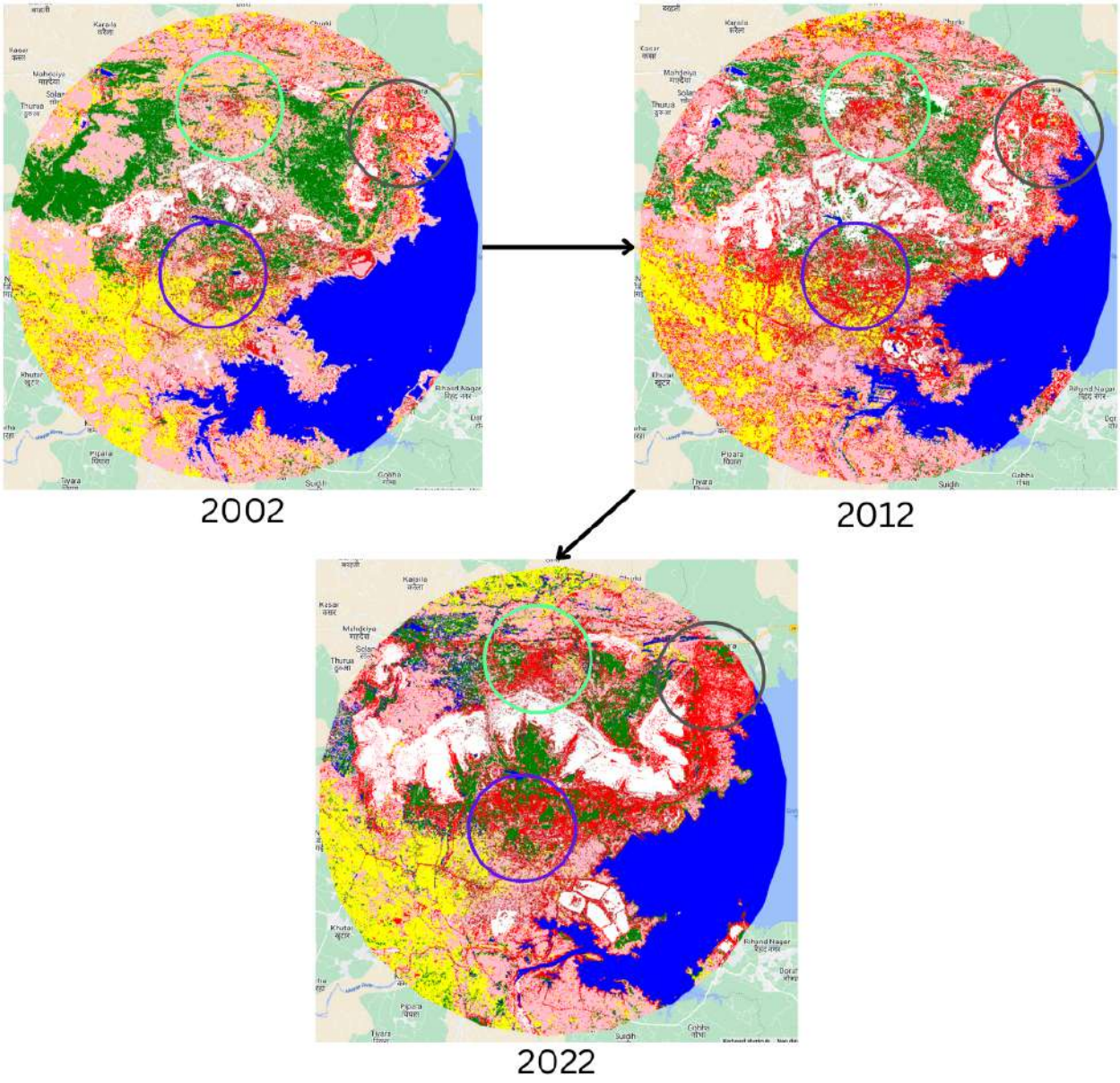


This can be supported by the following data [1]:

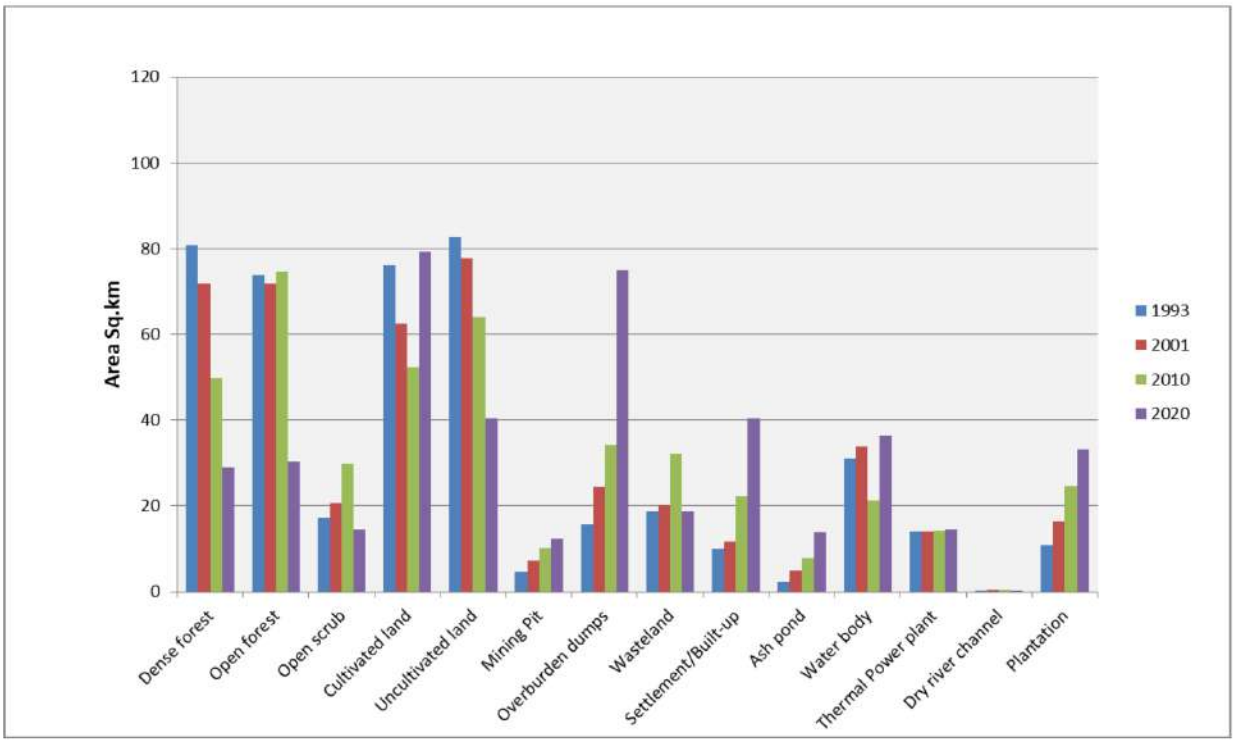
	Area (Ha/Year) increase of mines	Area (Ha/Year) decrease of dense forest due to mines	Area (Ha/Year) decrease of open forest due to mines
Between (1976-2002)	135.2	-47.48	-35.8
Between (2002-2010)	364.8	-58.28	-46.22
Between (2010-2015)	574.3	-105.28	-104.08

7.3 Growth of villages (Build-up/Settlement area)

We can see from the Classified maps that the build-up/settlement area increases with time as the mine expands, this indicates economic prosperity in the region. As the mine expands more people get jobs and they settle in the surrounding region itself (Build-up/Settlement area is represented by red color).



This can be supported by the following data [2]:



From the above bar diagram we can also calculate the change in settlement/build-up area from year 2000 to 2023, (assuming there is not much difference in the settlement/build-up area between 2001 and 2000 and 2020 and 2023). So according to the bar graph the settlement/build-up area in the year 2020 and 2001 was $40.43km^2$ and $11.72km^2$ respectively, hence there has been an increase of $28.71km^2 \equiv 244.96\%$ settlement/build-up area.

7.4 Waterbodies

We can see from the Classified maps that the area covered by water bodies have more or less remained the same over the years (Water bodies are represented by blue color).
This can be supported by the above bar graph [2]

8 Appendix

8.1 Google Earth Engine

Google Earth Engine (GEE) is a cloud-based platform developed by Google for planetary-scale environmental data analysis. It provides access to a vast amount of satellite imagery and geospatial datasets, along with powerful computational tools for analysis. **Features of Google Earth Engine**

- **Data Catalog:** GEE hosts an extensive data catalog containing petabytes of satellite imagery, climate data, land cover datasets, and more.
- **Code Editor:** GEE's Code Editor allows users to write and execute JavaScript or Python code directly in the browser, facilitating the analysis of geospatial data.
- **Image Processing:** GEE provides a wide range of image processing capabilities, including filtering, compositing, and analysis.

Code Editor: `https://code.earthengine.google.com`
Data Catalog: `https://developers.google.com/earth-engine/datasets/catalog/`
LandSat 7 Dataset (USGS Landsat 7 Level 2, Collection 2, Tier 1): `https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LE07_C02_T1_L2`
LandSat 8 Dataset (USGS Landsat 8 Level 2, Collection 2, Tier 1): `https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LC08_C02_T1_L2`

8.2 Canva

The images and illustrations included in this report were generated using Canva. These visuals were created to enhance the presentation of data, provide visual aids, and improve the overall readability and engagement of the report. They were carefully designed to align with the report's objectives and effectively communicate key information to the audience.
To access Canva and start creating your own designs, visit: `https://www.canva.com`

References

[1] Firoz Ahmad and Laxmi Goparaju. "Spatio-temporal dynamics of mines in Singrauli, India: An analysis using geospatial technology". In: *Journal of Geomatics* 11.1 (2017), pp. 53–59.

[2] Rizwan Ahmad Akram Javed and Imran Khan. "Impact of Coal Mining on landuse/-landcover in Singrauli coalfield, Central India: A study using Remote Sensing GIS". In: *Global Scientific Journals* 9.11 (2021), pp. 2253–2275.