LAND USE
CHANGE

Analysis | India 2020

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LAND USE CHANGE ANALYSIS | INDIA 2020

GIS Mapping and Satellite Image Analysis

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India Map
Adapted from/based on Survey of India digital boundary map
Not to scale

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Disclaimer

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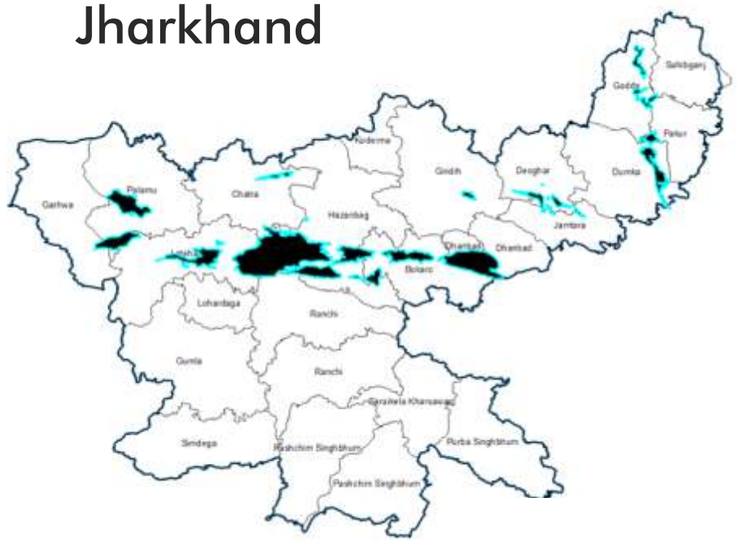
New Delhi, November, 2020

State-wise Details of Coal Fields

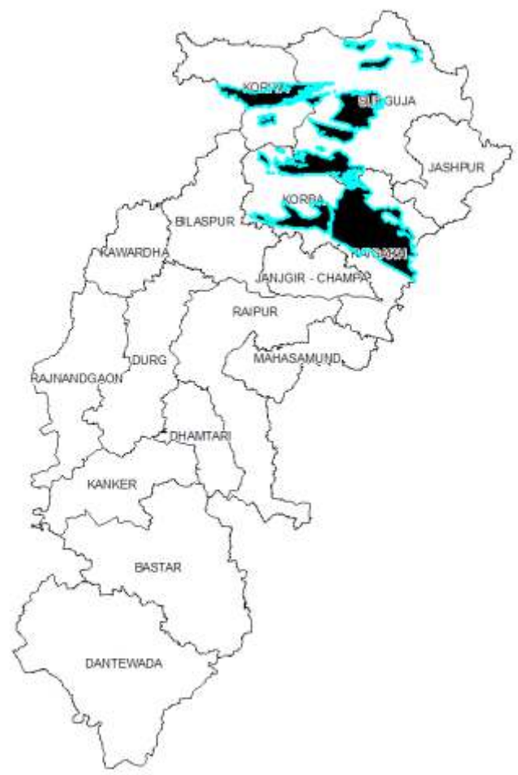
State	Coalfield	Main Source
Jharkhand	Auranga Daltonganj Deogarh East Bokaro Giridih Hutar Chope North Karanpura Hura Chuperbhita Pachwara Mahuagarhi -Brahmani Ramgarh South Karanpura West Bokaro	Coalfields of India, Vol.4, G.S.I., 1987
Chhattisgarh	Auranga Jharia Itkhori Chirimiri Tatapani -Ramkola Panchbhaini Sendurgarh Damhamunda Hasdo -Arand Korba Mand -Raigarh Sonhat Bisrampur Lakhanpur Sonhat	Coalfields of India, Vol.3, G.S.I., 1983
Odisha	Jhilimili Ib river basin Talchir	Coalfields of India, Vol.2, G.S.I., 1982

Jharkhand



Odisha

Chhattisgarh



INTRODUCTION

India is a large economy in global terms and a member of the G20 group of countries. Yet, it is a country that continues to have tremendous energy poverty. Thus, most governments of the country tend to focus on augmenting power generation capacities in the country.

Of late, Renewables have outpaced the conventional sources of power capacity addition, and this has been a heartening feature of India's power sector development. However, conventional sources of energy, especially coal, still continue to dominate the scene due to huge capacities built up over time as well as continuing investments in new coal fired power plants.

While the logic of continuing to invest in coal fired power plants is widely understood and accepted in India, there are some limitations of continuing to rely on coal as the main source of power generation in India that are beginning to be understood.

These include air quality concerns, as well as impacts of backward linkages of coal with coal mining. Most of India's coal reserves are situated in areas that have the bulk of India's natural forests. These are also the areas that contain a high concentration of population of vulnerable tribal groups of the country.

We sought to understand how the process of coal mining has an impact on forests on the one hand, and agricultural land on the other, since tribal populations in the mining areas of India tend to rely on both these resources for their livelihoods as well cultural practices.

The impact of coal mining on forests is also important to understand from the perspective of India's National Determined Contributions to the UNFCCC and the Paris Agreement. Reportedly, the one aspect of India's contribution that pertains to forestry, viz. "To create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030" is the only target, unlike others pertaining to renewables as well as emission intensities of the economy, that is not being met so far.

Thus, a continuing reliance on coal as the dominant source of energy generation in India may lead to contradictions with other aspects of India's obligations to the UNFCCC and the Paris Agreement. Further, India also has obligations relating to biodiversity conservation as well as arresting land degradation under the Convention on Biological Diversity and the Convention to Combat Desertification, that could become difficult to meet if the power sector continues to rely on coal for power generation leading to continuing and expanding need for coal mining, especially in forested tracts that are also inhabited by vulnerable tribal populations.

The purpose of the analysis is to highlight the extent of land use due to coal mining operations, and to drive home the point that with increasing coal mining operations, meeting one of India's goal of creating additional carbon sinks of 2.5 billion to 3 billion tonnes of CO_2 equivalent through creating additional forest cover could be a daunting task.

Further, the objective of the analysis is also to show case that with energy transition, which is a shift from fossil fuel energy pathway to a renewable energy dominant pathway being imminent, many of the coal mining operations could end up becoming stranded assets.

This analysis also aims at Energy and Clean Air Sector Policy Makers at the National and State Levels, Energy sector investors and bankers, Power Producers, Think Tanks and Environment NGOs, State Climate Change Departments, State Energy Department, Electricity Distribution Utilities, Environmentalists, city planners amongst others.

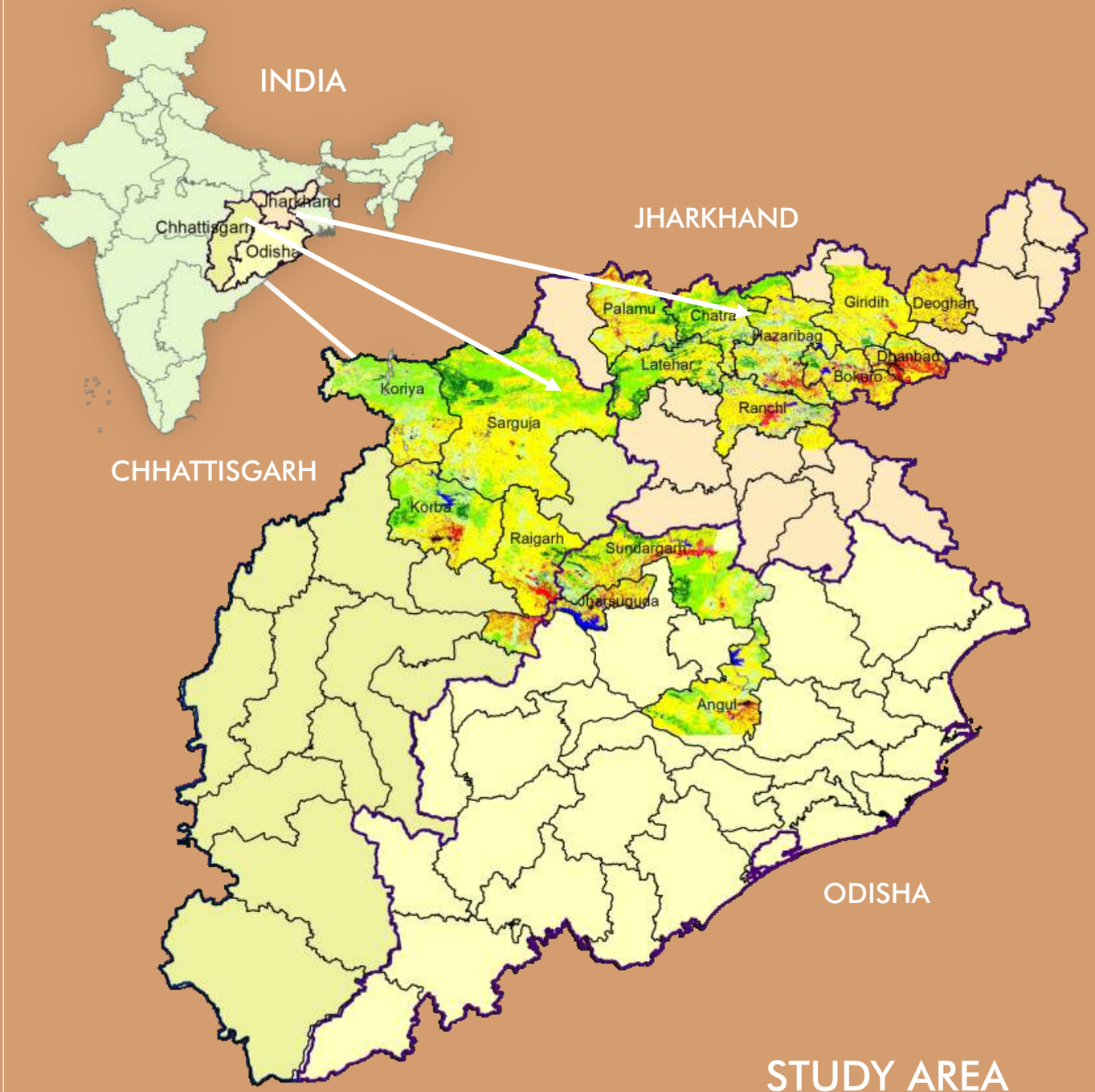
MAPPING OF LAND USE/LAND COVER CHANGES IN

CHHATTISGARH, JHARKHAND AND ODISHA

Mining, especially open cast mining brings significant changes in Land Use Land Cover (LULC) specifically due to its impact on forests and agriculture. According to the Geological Survey of India It is estimated that the potential coal reserves of India are scattered in the patches covering around 42953 Sq km area. 32% of these coal reserves fall within Chhattisgarh, Jharkhand and Odisha. However, these states are also known for their dense forest cover, rich biodiversity and distinct tribal culture. Thus, Monitoring and assessment of land use/land cover changes are important for policy making to properly address sustainable development as well as avoiding the conflict between development and nature on one hand and development and tribal culture and wellbeing or progress on the other.

This study took account of the spatio-temporal land use/landcover changes in these three states around the coal mines and surrounding areas (in the periphery of 20 km) during the period from 2004 to 2019. Land use/ land cover maps for the year 2004 and 2019 were generated through the visual interpretation of Indian Remote Sensing Satellite (IRS) Linear Imaging Self-Scanning Sensor (LISS-III) satellite images. It is observed that the rate and intensity of LULC change has increased considerably during the past couple of decades to the detriment of both forests as well as agricultural lands.

The majority of changes are identified as expansion of coal mining areas over agricultural land and forests. According to the study findings the overall coal mining area expanded from 223.41 sq. km in year 2004 to 363.41 sq. km in year 2019 indicating 61% area increase in coal mining induced land use changes. In the area under observation, coal mining expanded mostly at the expense of cropland (49.9%) and dense forest (39.7%).



Methodology

- **Selection of Districts**

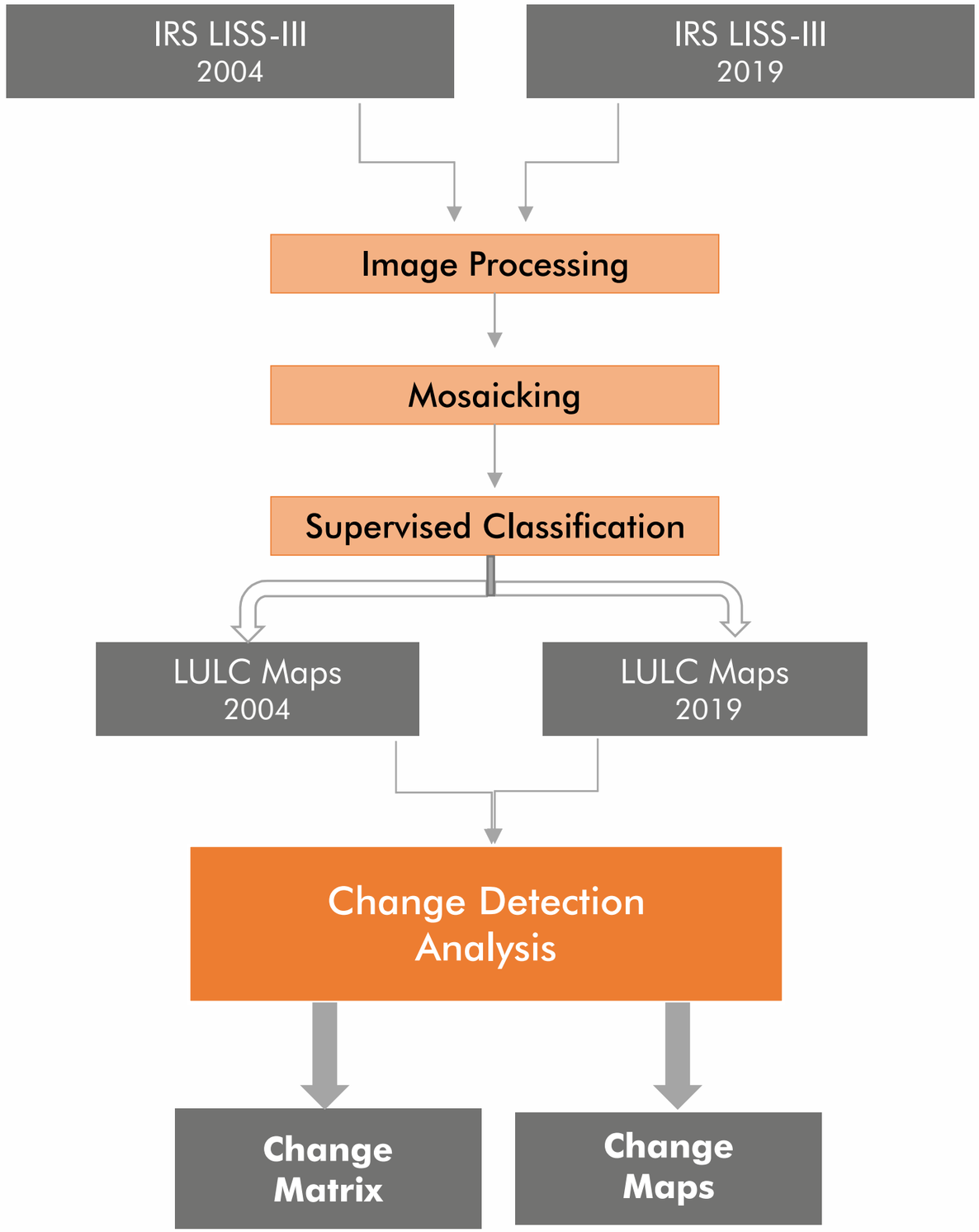
  Mining areas (covering operating as well as non-operating mines) of prominent coal reserves dominated districts i.e. Palamu, Latehar, Chatra, Bokaro, Hazaribagh, Dhanbad, Giridih, Deogarh and Ranchi of Jharkhand, Korba, Koriya Raigarh and Sarguja districts of Chhattisgarh and Angul, Jharsuguda and Sundargarh districts of Odisha were identified on LISS-III Satellite image with the help of state mineral maps, Geological Survey of India reports.

- **Selection of Satellite Data**

  To cover open cast mining and cover different land categories IRS LISS-III satellite data/images (cloud free period) were procured from National Remote Sensing Centre (NRSC) for the years 2004 and Year 2019 respectively.

- **Analytical Approach**

  The prime objective of this study was to assess the change that occurred during the interval of the last 15 years. In this regard LULC maps, change detection analysis, and landscape metrics have been computed for the two time periods (Year 2004 and Year 2019). Categories of land use were categorized as Built-up, coal mines, Agriculture, plantation and forest. The forest category is further classified into very dense forest (VDF), Moderately dense forest (MDF), Open forest (OF) and Non-Forest (NF) categories according to the Forest Survey of India (FSI) classification scheme.



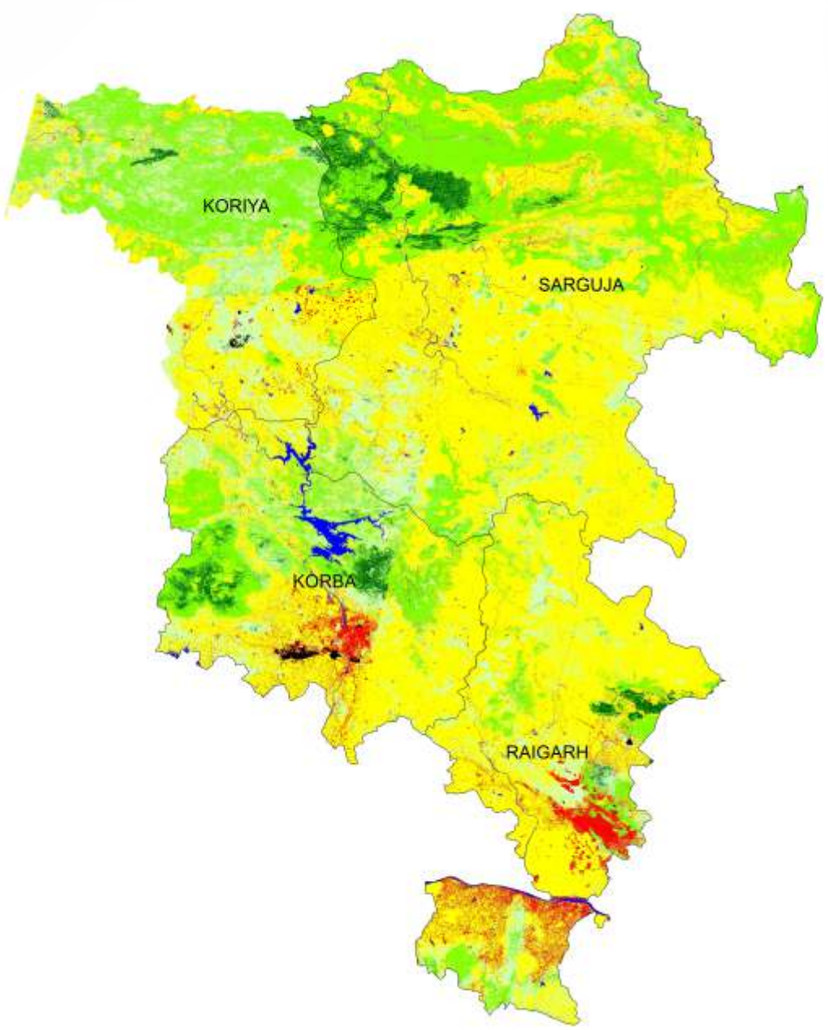
CHHATTISGARH

Assessment of Land-use/ Land cover Changes at District Scale

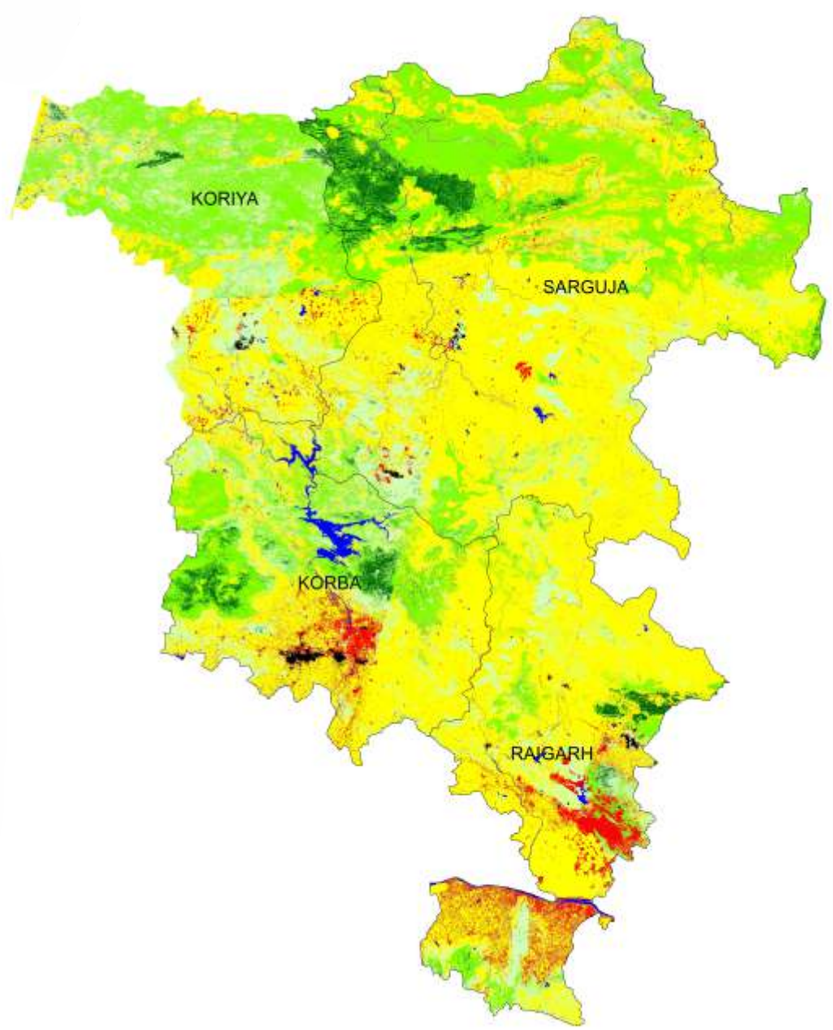
KORIYA, SARGUJA, KORBA, RAIGARH

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	163.77	166.05	2.28	1.39 %
Wasteland	133.60	140.43	6.83	5.11 %
Coal Mine	73.91	114.33	40.42	54.68 %
Built Up	1040.92	1207.52	166.60	16.01 %
Water Bodies	406.23	415.16	8.92	2.20 %
VDF	978.34	1092.70	114.37	11.69 %
MDF	8707.23	8230.67	-476.56	-5.47 %
Agriculture	18936.6	18907.8	-28.80	-0.15 %
OF	5429.85	5595.86	166.01	3.06 %

2004

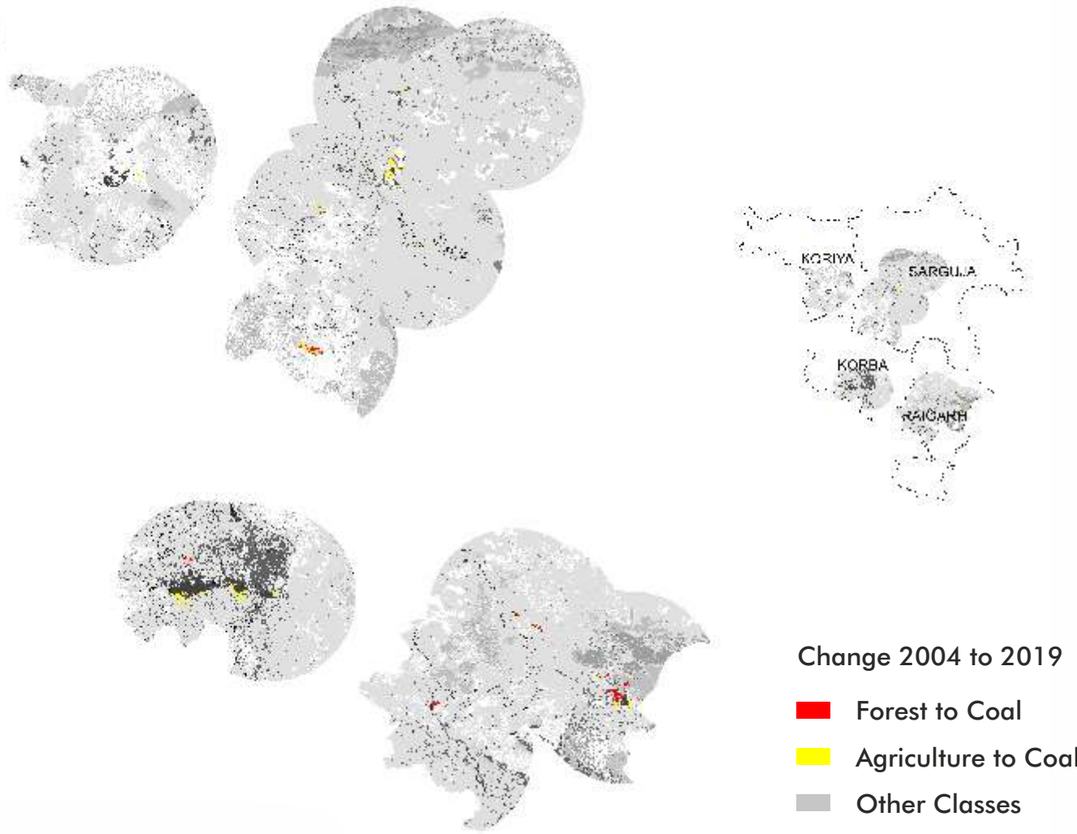


2019



- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

Change within the Periphery (20 km) of Coal Mines



Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	29.30	0.02	0.62	0.40	0.02	0.00	0.00	2.18	0.05	**32.59**
	Waste Land	0.00	59.51	0.73	2.58	0.00	0.00	0.00	0.26	0.31	**63.40**
	Coal Mine	0.00	0.00	72.98	0.02	0.00	0.00	0.00	0.10	0.00	**73.09**
	Built Up	0.00	0.00	1.21	395.74	0.57	0.00	0.00	1.27	0.00	**398.80**
	Water Bodies	0.00	0.05	0.10	0.34	82.57	0.00	0.00	0.39	0.00	**83.45**
	VDF	0.00	0.00	0.00	0.00	0.00	179.33	0.93	0.00	0.00	**180.26**
	MDF	0.00	0.35	0.79	0.10	0.00	12.03	799.49	14.34	84.95	**912.05**
	Agriculture	0.10	5.10	24.35	88.86	3.36	0.00	0.81	7528.06	1.85	**7652.49**
	OF	0.78	1.56	12.73	6.46	1.94	0.00	2.37	25.92	1890.36	**1942.13**
	Grand Total	**30.18**	**66.58**	**113.51**	**494.50**	**88.47**	**191.36**	**803.60**	**7572.52**	**1977.52**	**11338.25**
	CHANGE	**-2.41**	**3.18**	**40.42**	**95.71**	**5.02**	**11.10**	**-108.45**	**-79.96**	**35.40**	
	CHANGE (%)	**-7.39 %**	**5.02 %**	**55.29 %**	**24.00 %**	**6.01 %**	**6.16 %**	**-11.89 %**	**-1.04 %**	**1.82 %**	

55.29 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	8300.79	0.00	0.81	2.21	**8303.81**
VDF	0.00	179.33	0.93	0.00	**180.26**
MDF	15.58	12.03	799.49	84.95	**912.05**
OF	49.39	0.00	2.37	1890.36	**1942.13**
TOTAL 2019	**8365.77**	**191.36**	**803.60**	**1977.52**	**11338.25**
CHANGE	**61.95**	**11.10**	**-108.45**	**35.40**	
CHANGE %	**0.75 %**	**6.16 %**	**-11.89 %**	**1.82 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.93	0.51%
VDF TO OF	0.00	0.00%
VDF TO NF	0.00	0.00%
MDF TO VDF	12.03	1.32%
MDF TO OF	84.95	9.31%
MDF TO NF	15.58	1.71%
OF TO VDF	0.00	0.00%
OF TO MDF	2.37	0.12%
OF TO NF	49.39	2.54%

1.32 %
MDF → VDF

9.31 %
MDF → OF

2.54 %
OF → NF

Increase in Coal Mine Area

33.35 %
Forest Land

60.07 %
Agriculture Land

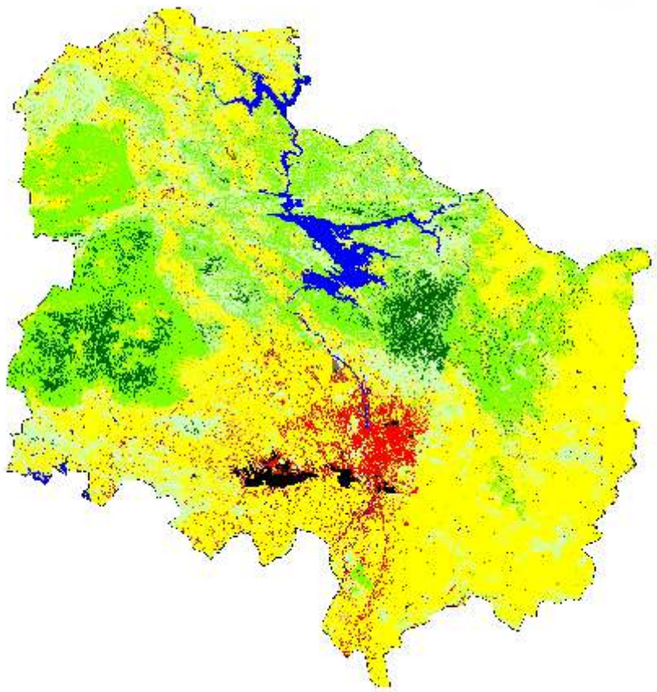
6.58 %
Other Land

KORBA

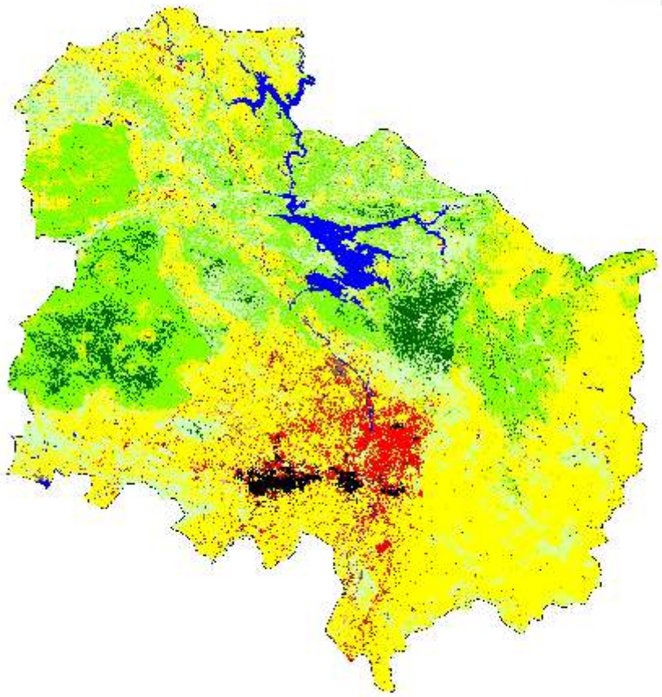
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	20.61	22.49	1.88	9.12 %
Wasteland	28.89	33.12	4.23	14.64 %
Coal Mine	48.45	59.37	10.92	22.55 %
Built Up	260.68	278.11	17.43	6.69 %
Water Bodies	187.41	182.96	-4.45	-2.37 %
VDF	267.74	271.67	3.93	1.47 %
MDF	1505.69	1473.81	-31.88	-2.12 %
Agriculture	3187.67	3168.31	-19.36	-0.61 %
OF	1131.84	1151.05	19.21	1.70 %

2004



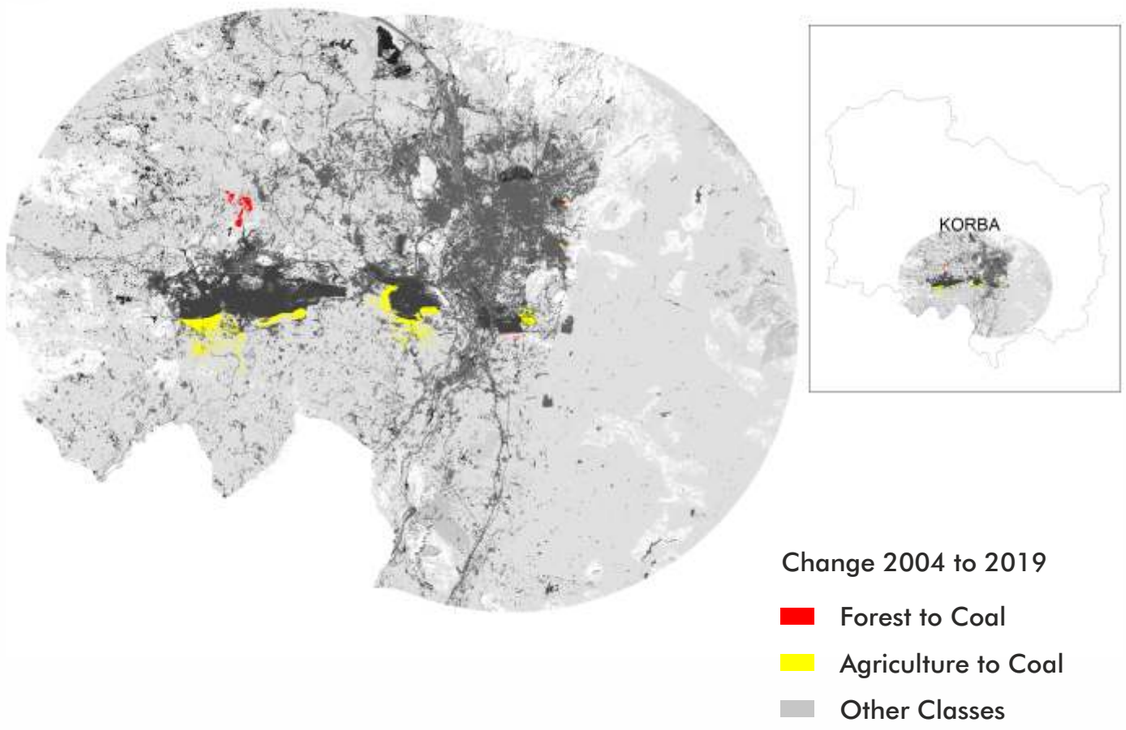
2019



- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

2004 Coal Mining Areas 2019

Change within the Periphery (20 km) of Coal Mines



Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	14.91	0.00	0.33	0.00	0.00	0.00	0.00	0.11	0.00	**15.35**
Waste Land	0.00	9.60	0.35	0.01	0.00	0.00	0.00	0.15	0.00	**10.12**
Coal Mine	0.00	0.00	48.45	0.00	0.00	0.00	0.00	0.00	0.00	**48.45**
Built Up	0.00	0.00	0.00	213.74	0.00	0.00	0.00	0.00	0.00	**213.74**
Water Bodies	0.00	0.05	0.00	0.34	10.53	0.00	0.00	0.37	0.00	**11.30**
VDF	0.00	0.00	0.00	0.00	0.00	3.48	0.03	0.00	0.00	**3.51**
MDF	0.00	0.00	0.00	0.10	0.00	0.13	16.52	0.00	6.22	**22.97**
Agriculture	0.10	2.37	8.93	13.23	0.11	0.00	0.00	1150.92	0.00	**1175.66**
OF	0.07	0.77	1.31	3.55	0.00	0.00	0.13	1.92	199.75	**207.50**
Grand Total	**15.08**	**12.80**	**59.37**	**230.97**	**10.64**	**3.61**	**16.68**	**1153.48**	**205.96**	**1708.60**
CHANGE	**-0.27**	**2.67**	**10.92**	**17.23**	**-0.65**	**0.10**	**-6.29**	**-22.18**	**-1.54**	
CHANGE (%)	**-1.78 %**	**26.43 %**	**22.55 %**	**8.06 %**	**-5.79 %**	**2.81 %**	**-27.37 %**	**-1.89 %**	**-0.74 %**	

22.55 %
Increase in Coal Mine Area

KORBA

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	1474.61	0.00	0.00	0.00	**1474.61**
VDF	0.00	3.48	0.03	0.00	**3.51**
MDF	0.10	0.13	16.52	6.22	**22.97**
OF	7.63	0.00	0.13	199.75	**207.50**
TOTAL 2019	**1482.34**	**3.61**	**16.68**	**205.96**	**1708.60**
CHANGE	**7.73**	**0.10**	**-6.29**	**-1.54**	
CHANGE %	**0.52 %**	**2.81 %**	**-27.37 %**	**-0.74 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.03	0.94%
VDF TO OF	0.00	0.00%
VDF TO NF	0.00	0.00%
MDF TO VDF	0.13	0.57%
MDF TO OF	6.22	27.06%
MDF TO NF	0.10	0.43%
OF TO VDF	0.00	0.00%
OF TO MDF	0.13	0.06%
OF TO NF	7.63	3.68%

0.94 %
VDF → MDF

27.06 %
MDF → OF

3.68 %
OF → NF

Increase in Coal Mine Area

12.01 %
Forest Land

81.75 %
Agriculture Land

6.24 %
Other Land

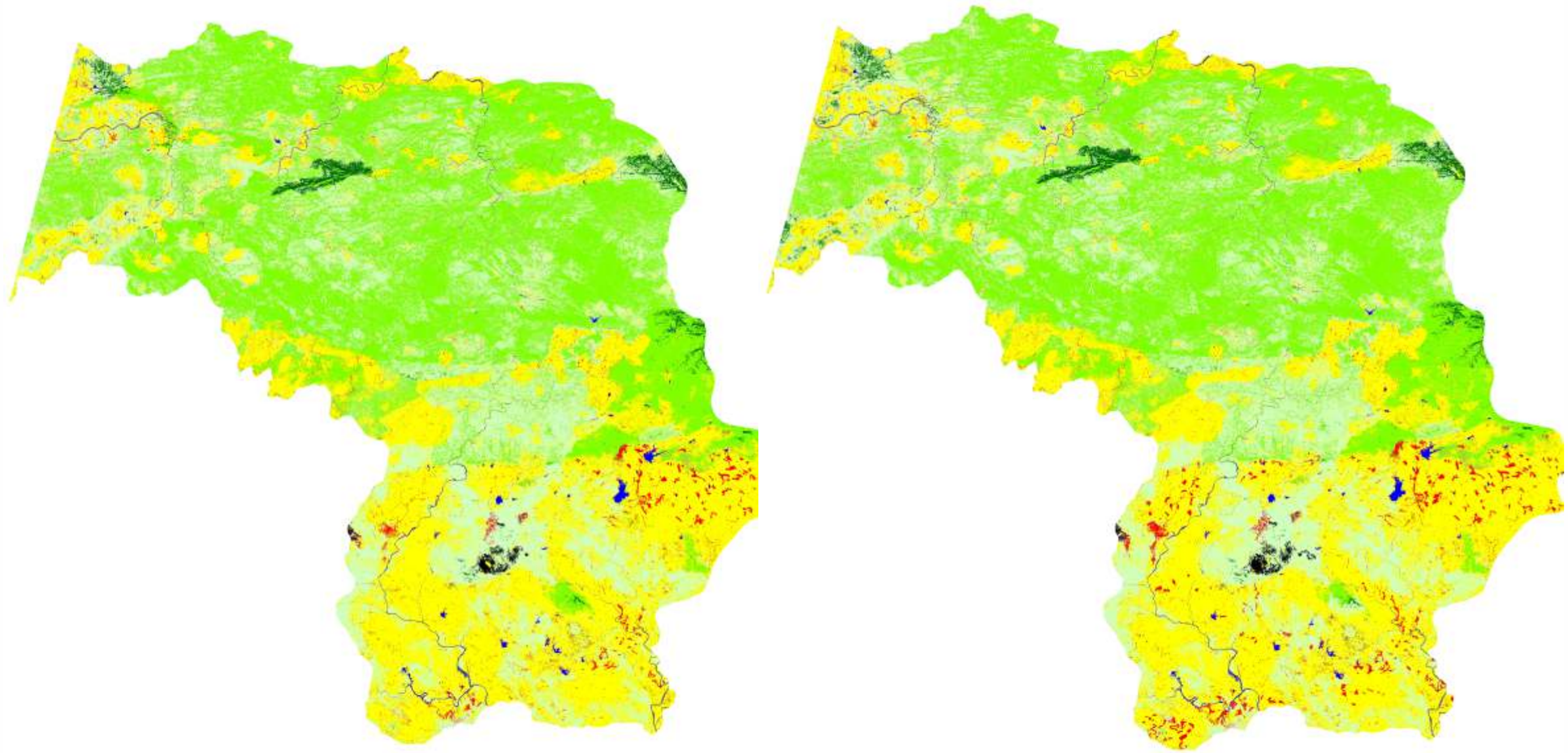
KORIYA

Assessment of Land-use

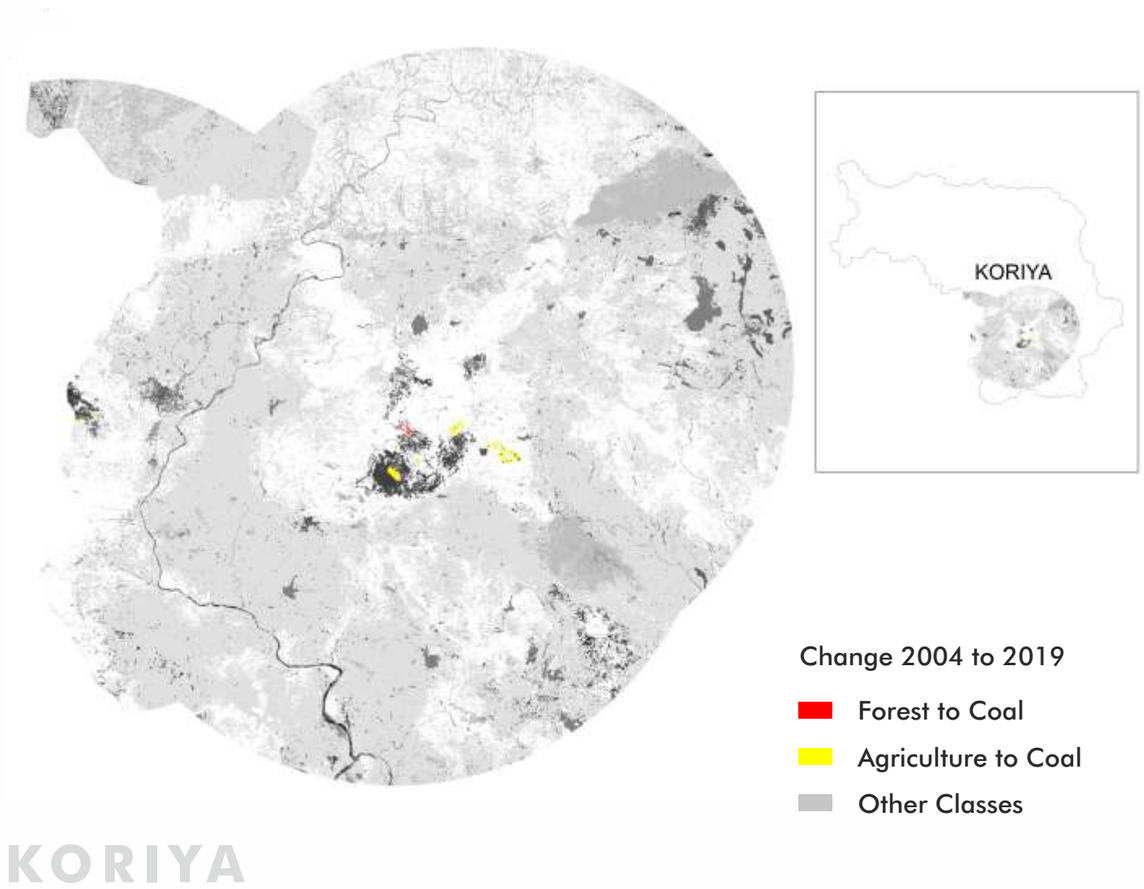
Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	39.94	39.81	-0.13	-0.33 %
Wasteland	21.84	23.59	1.75	8.01%
Coal Mine	12.65	14.11	1.46	11.50 %
Built Up	85.61	107.52	21.91	25.59 %
Water Bodies	40.64	39.97	-0.67	-1.65 %
VDF	63.88	70.84	6.96	10.90 %
MDF	2261.01	2169.73	-91.28	- 4.04 %
Agriculture	2061.99	2092.32	30.33	1.47 %
OF	1801.36	1830.84	29.48	1.64 %

2004

2019



Change within the Periphery (20 km) of Coal Mines



Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	1.35	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	**1.36**
	Waste Land	0.00	9.93	0.05	0.00	0.00	0.00	0.00	0.00	0.00	**9.98**
	Coal Mine	0.00	0.00	12.65	0.00	0.00	0.00	0.00	0.00	0.00	**12.65**
	Built Up	0.00	0.00	0.00	31.34	0.00	0.00	0.00	0.00	0.00	**31.34**
	Water Bodies	0.00	0.00	0.00	0.00	16.20	0.00	0.00	0.02	0.00	**16.22**
	VDF	0.00	0.00	0.00	0.00	0.00	2.95	0.00	0.00	0.00	**2.95**
	MDF	0.00	0.00	0.00	0.00	0.00	0.06	96.12	4.35	6.96	**107.50**
	Agriculture	0.00	0.00	1.18	12.41	0.00	0.00	0.00	894.92	0.00	**908.51**
	OF	0.00	0.04	0.22	0.20	0.00	0.00	0.26	3.16	585.95	**589.82**
	Grand Total	**1.35**	**9.97**	**14.11**	**43.95**	**16.20**	**3.01**	**96.38**	**902.45**	**592.91**	**1680.33**
	CHANGE	**-0.01**	**-0.01**	**1.46**	**12.61**	**-0.02**	**0.06**	**-11.12**	**-6.09**	**3.09**	
	CHANGE (%)	**-1.02**	**-0.10**	**11.50**	**40.23**	**-0.14**	**2.17**	**-10.34**	**-0.67**	**0.52**	

11.50 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	980.07	0.00	0.00	0.00	**980.07**
VDF	0.00	2.95	0.00	0.00	**2.95**
MDF	4.35	0.06	96.12	6.96	**107.50**
OF	3.62	0.00	0.26	585.95	**589.82**
TOTAL 2019	**988.03**	**3.01**	**96.38**	**592.91**	**1680.33**
CHANGE	**7.96**	**0.06**	**-11.12**	**3.09**	
CHANGE %	**0.81 %**	**2.17 %**	**-10.34 %**	**0.52 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0	0.00%
VDF TO OF	0	0.00%
VDF TO NF	0	0.00%
MDF TO VDF	0.06	0.06%
MDF TO OF	6.96	6.48%
MDF TO NF	4.35	4.04%
OF TO VDF	0	0.00%
OF TO MDF	0.26	0.04%
OF TO NF	3.62	0.61%

6.48 %
MDF → OF

4.04 %
MDF → NF

Increase in Coal Mine Area

15.31 %
Forest Land

81.40 %
Agriculture Land

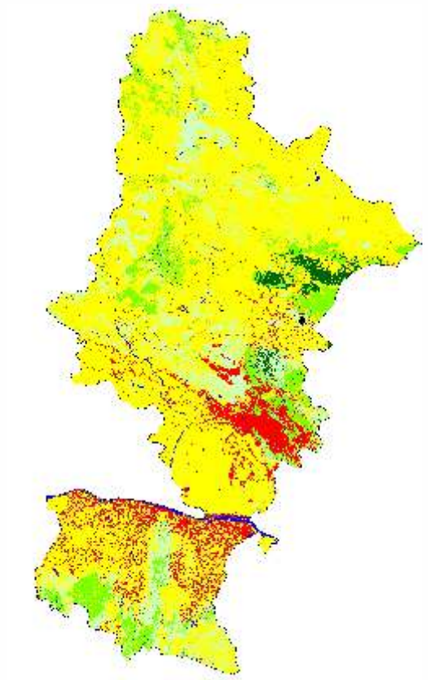
3.29%
Other Land

RAIGARH

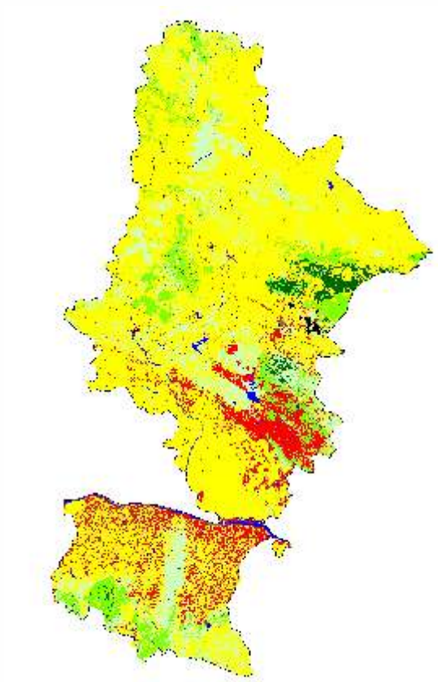
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	29.80	28.01	-1.79	-6.01 %
Wasteland	37.27	40.00	2.73	7.32 %
Coal Mine	5.77	18.13	12.36	214.40 %
Built Up	545.97	611.44	65.47	11.99 %
Water Bodies	56.43	70.08	13.65	24.19 %
VDF	113.19	124.58	11.39	10.06 %
MDF	603.80	539.29	-64.51	-10.68 %
Agriculture	4722.64	4656.04	-66.60	-1.41 %
OF	977.13	1004.44	27.31	2.79 %

2004



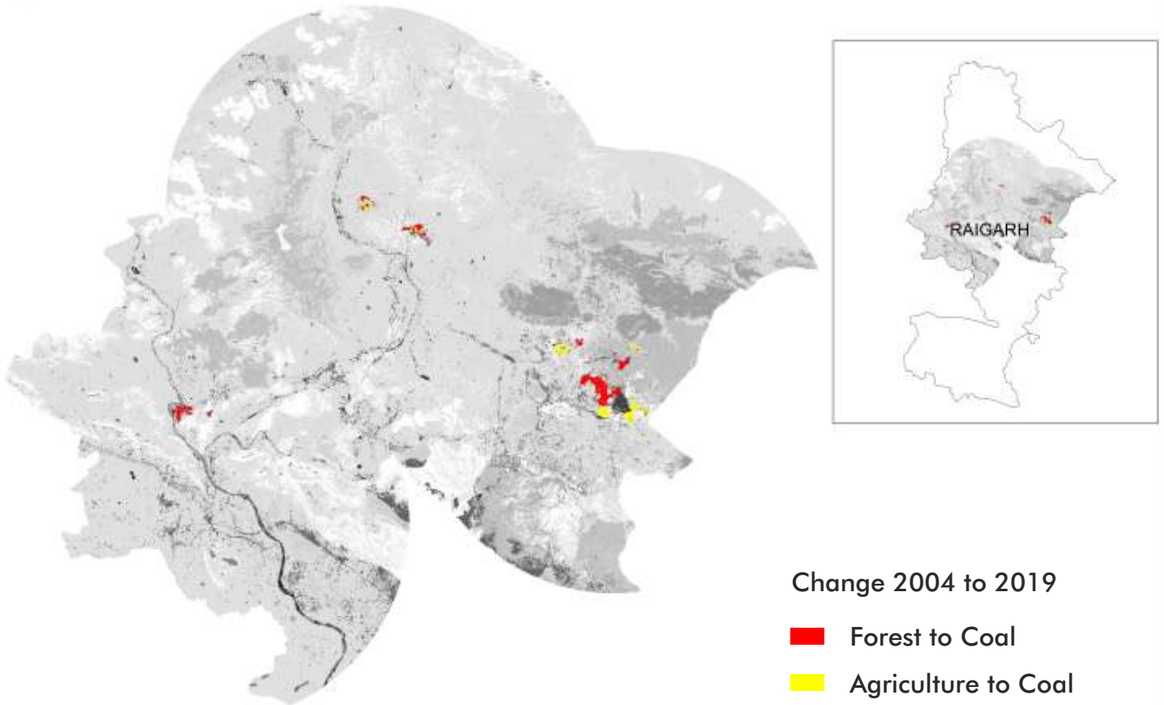
2019



- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

2004 — Coal Mining Areas — 2019

Change within the Periphery (20 km) of Coal Mines



Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	3.66	0.02	0.12	0.01	0.02	0.00	0.00	0.45	0.00	**4.27**
Waste Land	0.00	18.85	0.31	0.00	0.00	0.00	0.00	0.02	0.00	**19.17**
Coal Mine	0.00	0.00	5.77	0.00	0.00	0.00	0.00	0.00	0.00	**5.77**
Built Up	0.00	0.00	0.00	94.92	0.57	0.00	0.00	0.00	0.00	**95.49**
Water Bodies	0.00	0.00	0.00	0.00	11.74	0.00	0.00	0.00	0.00	**11.74**
VDF	0.00	0.00	0.00	0.00	0.00	104.55	0.73	0.00	0.00	**105.28**
MDF	0.00	0.00	0.79	0.00	0.00	5.85	255.35	0.00	27.36	**289.35**
Agriculture	0.00	2.30	4.06	25.21	3.22	0.00	0.00	2134.05	0.00	**2168.84**
OF	0.00	0.73	7.08	2.40	1.94	0.00	0.77	0.00	425.41	**438.34**
Grand Total	**3.66**	**21.90**	**18.13**	**122.53**	**17.49**	**110.40**	**256.84**	**2134.52**	**452.77**	**3138.24**
CHANGE	**-0.61**	**2.73**	**12.36**	**27.04**	**5.75**	**5.12**	**-32.51**	**-34.32**	**14.44**	
CHANGE (%)	**-14.34**	**14.22**	**214.40**	**28.32**	**49.03**	**4.86**	**-11.23**	**-1.58**	**3.29**	

214.40 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	2305.28	0.00	0.00	0.00	**2305.28**
VDF	0.00	104.55	0.73	0.00	**105.28**
MDF	0.79	5.85	255.35	27.36	**289.35**
OF	12.16	0.00	0.77	425.41	**438.34**
TOTAL 2019	**2318.22**	**110.40**	**256.84**	**452.77**	**3138.24**
CHANGE	**12.95**	**5.12**	**-32.51**	**14.44**	
CHANGE %	**0.56 %**	**4.86 %**	**-11.23 %**	**3.29 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.73	0.70%
VDF TO OF	0.00	0.00%
VDF TO NF	0.00	0.00%
MDF TO VDF	5.85	2.02%
MDF TO OF	27.36	9.46%
MDF TO NF	0.79	0.27%
OF TO VDF	0.00	0.00%
OF TO MDF	0.77	0.17%
OF TO NF	12.16	2.77%

2.02 % MDF → VDF

9.46 % MDF → OF

2.77 % OF → NF

Increase in Coal Mine Area

63.66 % Forest Land

32.88 % Agriculture Land

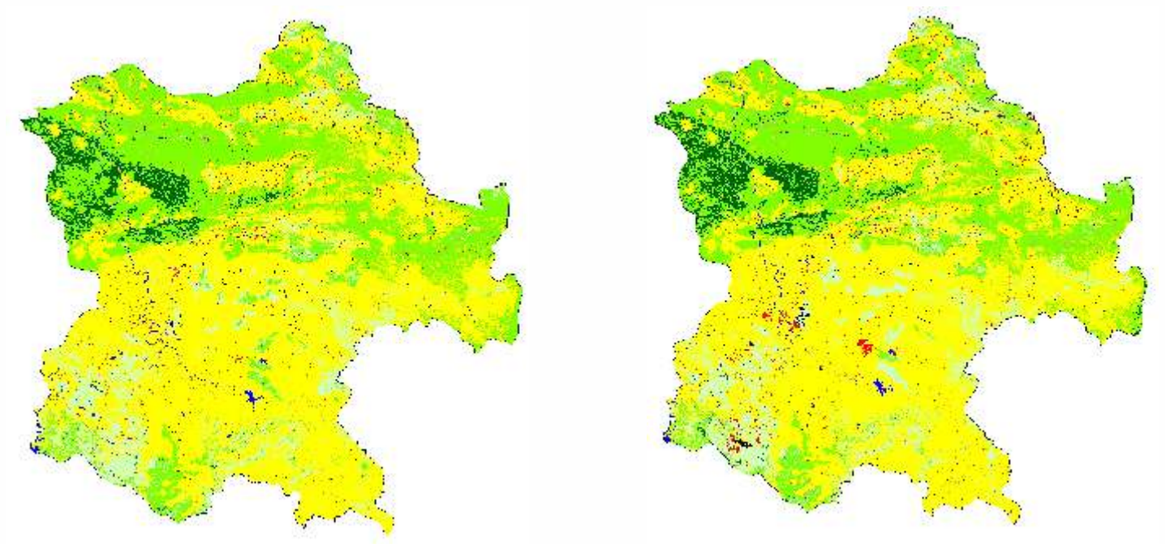
3.46 % Other Land

SARGUJA

Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	73.46	75.79	2.33	3.17 %
Wasteland	45.75	43.87	-1.88	-4.11 %
Coal Mine	6.23	21.90	15.67	251.59 %
Built Up	148.69	210.48	61.79	41.56 %
Water Bodies	122.91	123.08	0.17	0.14 %
VDF	534.71	626.77	92.06	17.22 %
MDF	4338.96	4052.00	-286.96	-6.61 %
Agriculture	8974.88	9001.68	26.80	0.30 %
OF	1522.63	1612.65	90.02	5.91 %

2004 2019



- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

2004 Coal Mining Areas 2019

Change within the Periphery (20 km) of Coal Mines

SARGUJA

Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	9.37	0.00	0.17	0.39	0.00	0.00	0.00	1.62	0.05	**11.61**
Waste Land	0.00	21.13	0.03	2.57	0.00	0.00	0.00	0.09	0.31	**24.13**
Coal Mine	0.00	0.00	6.11	0.02	0.00	0.00	0.00	0.10	0.00	**6.23**
Built Up	0.00	0.00	1.21	55.74	0.00	0.00	0.00	1.27	0.00	**58.23**
Water Bodies	0.00	0.00	0.10	0.00	44.08	0.00	0.00	0.01	0.00	**44.19**
VDF	0.00	0.00	0.00	0.00	0.00	68.36	0.16	0.00	0.00	**68.53**
MDF	0.00	0.35	0.00	0.00	0.00	5.98	431.50	9.99	44.41	**492.23**
Agriculture	0.00	0.43	10.17	38.02	0.03	0.00	0.81	3348.18	1.85	**3399.48**
OF	0.71	0.01	4.11	0.31	0.00	0.00	1.22	20.84	679.25	**706.46**
Grand Total	**10.08**	**21.92**	**21.90**	**97.05**	**44.11**	**74.34**	**433.69**	**3382.11**	**725.88**	**4811.09**
CHANGE	**-1.52**	**-2.21**	**15.67**	**38.82**	**-0.08**	**5.82**	**-58.54**	**-17.37**	**19.41**	
CHANGE (%)	**-13.11**	**-9.16**	**251.59**	**66.67**	**-0.18**	**8.49**	**-11.89**	**-0.51**	**2.75**	

251.59 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	3540.84	0.00	0.81	2.21	**3543.86**
VDF	0.00	68.36	0.16	0.00	**68.53**
MDF	10.34	5.98	431.50	44.41	**492.23**
OF	25.99	0.00	1.22	679.25	**706.46**
TOTAL 2019	**3577.18**	**74.34**	**433.69**	**725.88**	**4811.09**
CHANGE	**33.31**	**5.82**	**-58.54**	**19.41**	
CHANGE %	**0.94 %**	**8.49 %**	**-11.89 %**	**2.75 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.16	0.23%
VDF TO OF	0.00	0.00%
VDF TO NF	0.00	0.00%
MDF TO VDF	5.98	1.22%
MDF TO OF	44.41	9.02%
MDF TO NF	10.34	2.10%
OF TO VDF	0.00	0.00%
OF TO MDF	1.22	0.17%
OF TO NF	25.99	3.68%

1.22 %
MDF → VDF

9.02 %
MDF → OF

3.68 %
OF → NF

Increase in Coal Mine Area

26.04 %
Forest Land

64.40 %
Agriculture Land

9.56 %
Other Land

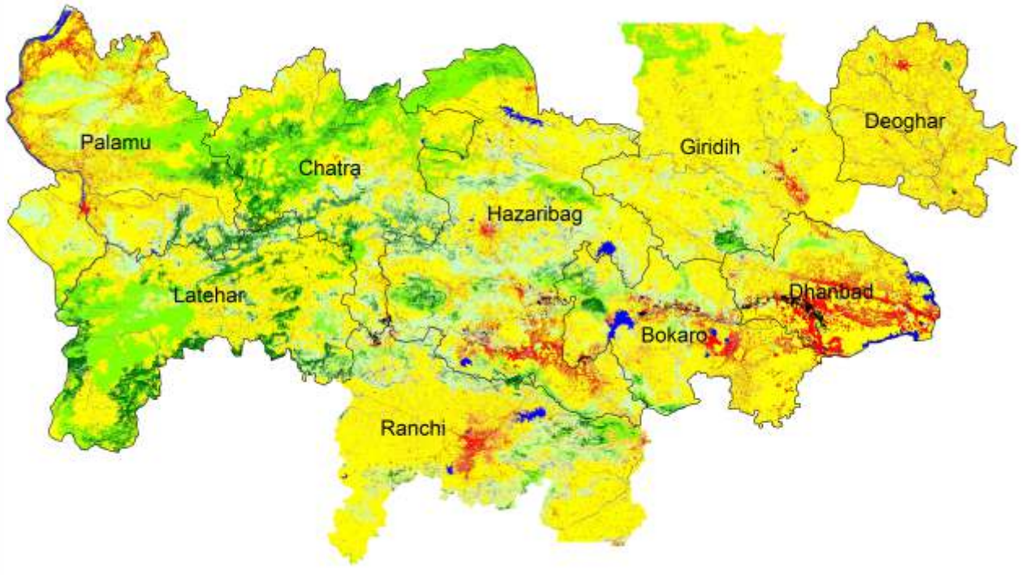
JHARKHAND

Assessment of Land-use/ Land cover Changes at District Scale

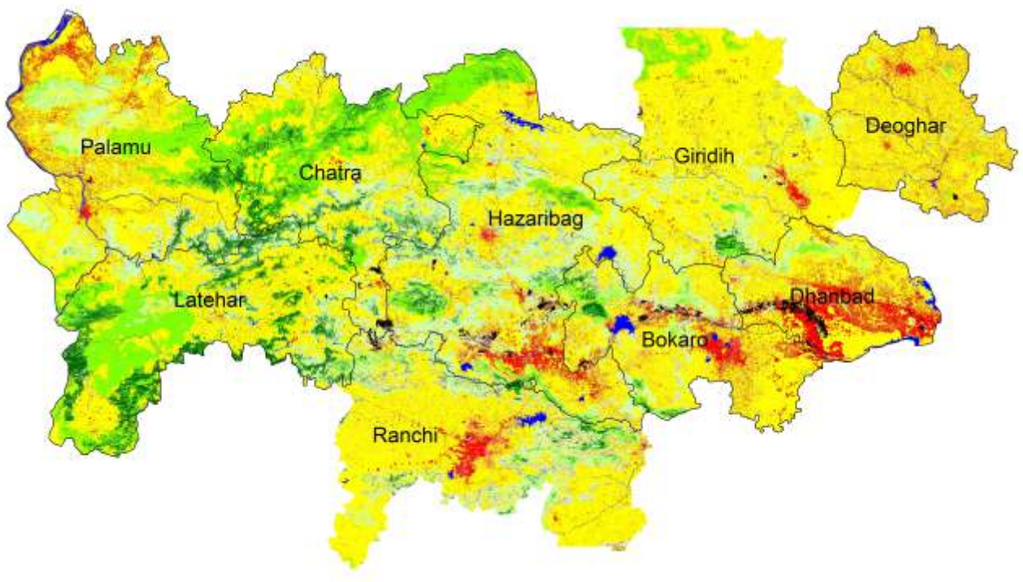
PALAMU, CHATRA, LATEHAR, RANCHI, HAZARIBAG, BOKARO, DHANBAD, GIRIDIH, DEOGHAR

	2004	2019		
Class	**Area** (sq km)	**Area** (sq km)	**Change** (sq km)	**Change** (%)
Plantation	1100.98	1090.06	-10.92	-0.99
Wasteland	346.3	365.15	18.85	5.44
Coal Mine	111.45	171.70	60.24	54.05
Built Up	1614.33	2014.38	400.05	24.78
Water Bodies	413.79	395.03	-18.76	-4.53
VDF	1516.56	1580.35	63.79	4.20
MDF	4210.71	3989.7	-221.01	-5.24
Agriculture	20508.4	20274.33	-234.07	-1.14
OF	5232.4	5172.63	-59.77	-1.142

2004

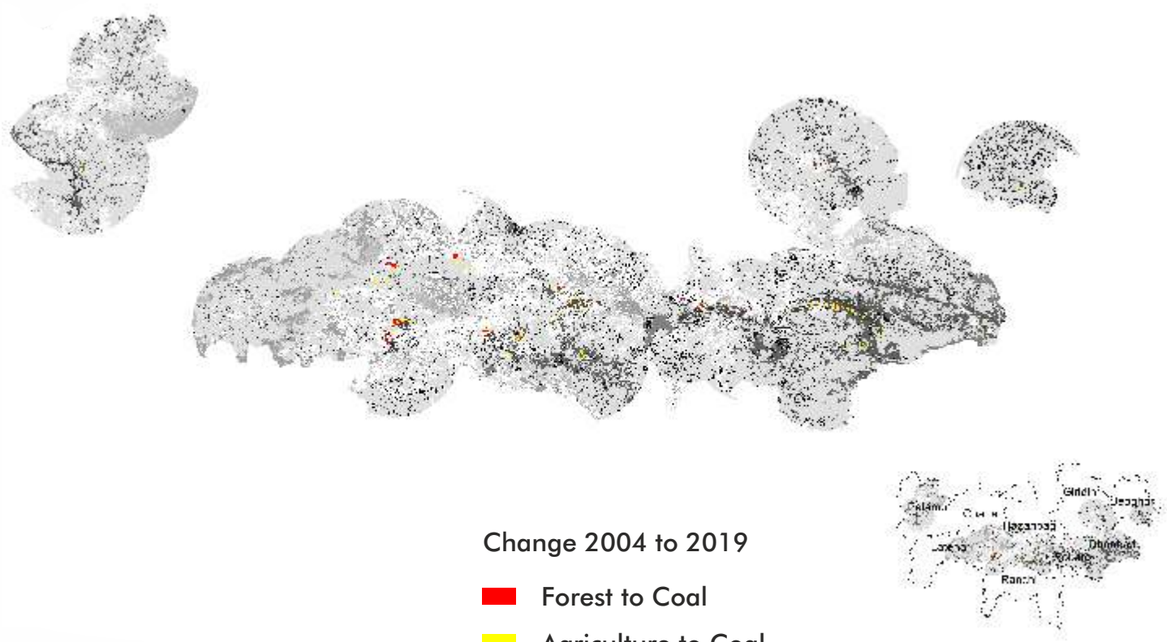


2019



- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

Change within the Periphery (20 km) of Coal Mines



Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	453.29	0.20	1.46	3.77	0.00	0.00	0.02	6.26	0.02	**465.03**
Waste Land	0.46	134.25	1.01	0.17	0.83	0.00	0.00	0.16	1.03	**137.92**
Coal Mine	0.34	0.07	110.57	0.07	0.35	0.00	0.01	0.03	0.02	**111.45**
Built Up	0.37	0.67	2.68	1093.39	0.04	0.00	0.00	0.89	0.02	**1098.06**
Water Bodies	3.50	0.14	0.18	1.12	181.61	0.00	0.05	21.88	0.11	**208.60**
VDF	0.00	0.00	0.00	0.00	0.00	460.76	8.60	0.76	0.49	**470.61**
MDF	0.14	0.07	0.09	0.31	0.00	5.64	822.06	21.89	51.30	**901.51**
Agriculture	2.50	11.08	35.47	258.01	6.11	0.07	0.98	8502.34	7.00	**8823.55**
OF	1.85	5.25	20.24	6.18	0.36	0.13	5.20	62.53	2451.17	**2552.91**
Grand Total	**462.43**	**151.73**	**171.70**	**1363.0**	**189.31**	**466.60**	**836.93**	**8616.74**	**2511.16**	**14769.64**
CHANGE	**-2.59**	**13.82**	**60.24**	**264.97**	**-19.29**	**-4.01**	**-64.58**	**-206.81**	**-41.75**	
CHANGE (%)	**-0.56**	**10.02**	**54.05**	**24.13**	**-9.25**	**-0.85**	**-7.16**	**-2.34**	**-1.64**	

54.05 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	10835.28	0.07	1.06	8.20	**10844.61**
VDF	0.76	460.76	8.60	0.49	**470.61**
MDF	22.50	5.64	822.06	51.30	**901.51**
OF	96.41	0.13	5.20	2451.17	**2552.91**
TOTAL 2019	**10954.95**	**466.60**	**836.93**	**2511.16**	**14769.64**
CHANGE	**110.34**	**-4.01**	**-64.58**	**-41.75**	
CHANGE %	**1.02**	**-0.85**	**-7.16**	**-1.64**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	8.60	1.83%
VDF TO OF	0.49	0.10%
VDF TO NF	0.76	0.16%
MDF TO VDF	5.64	0.63%
MDF TO OF	51.30	5.69%
MDF TO NF	22.50	2.50%
OF TO VDF	0.13	0.01%
OF TO MDF	5.20	0.20%
OF TO NF	96.41	3.78%
NF TO OF	8.20	0.08%

1.83 % VDF → MDF

5.69 % MDF → OF

2.50 % MDF → NF

3.78 % OF → NF

Increase in Coal Mine Area

33.26 %
Forest Land

58.02 %
Agriculture Land

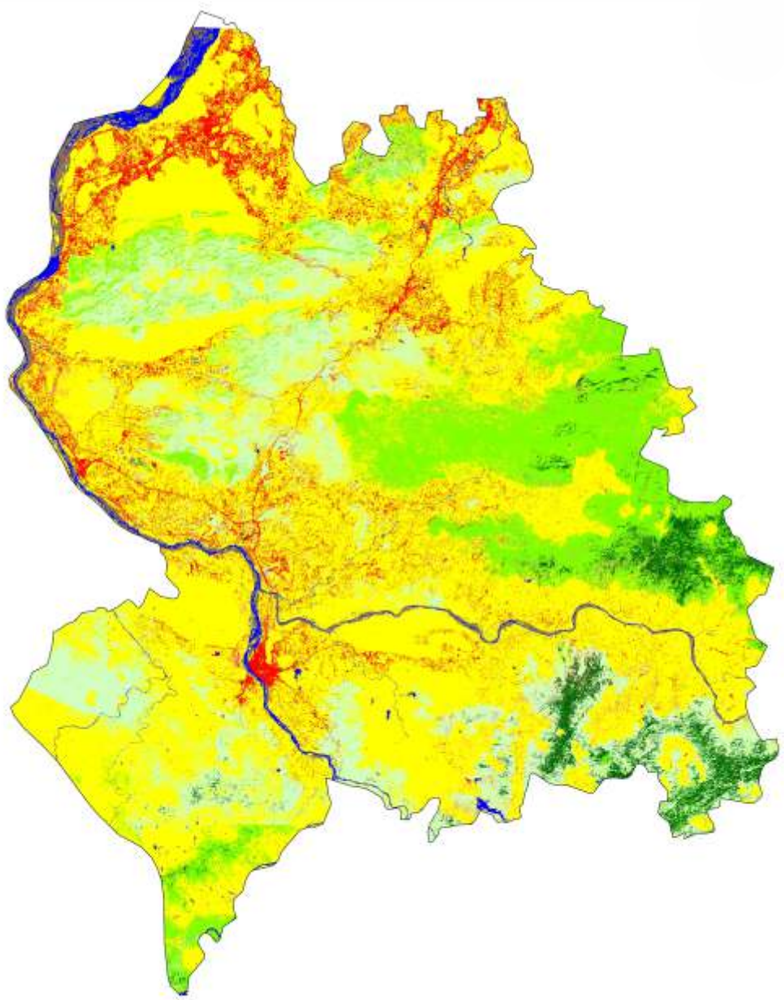
8.72 %
Other Land

PALAMU

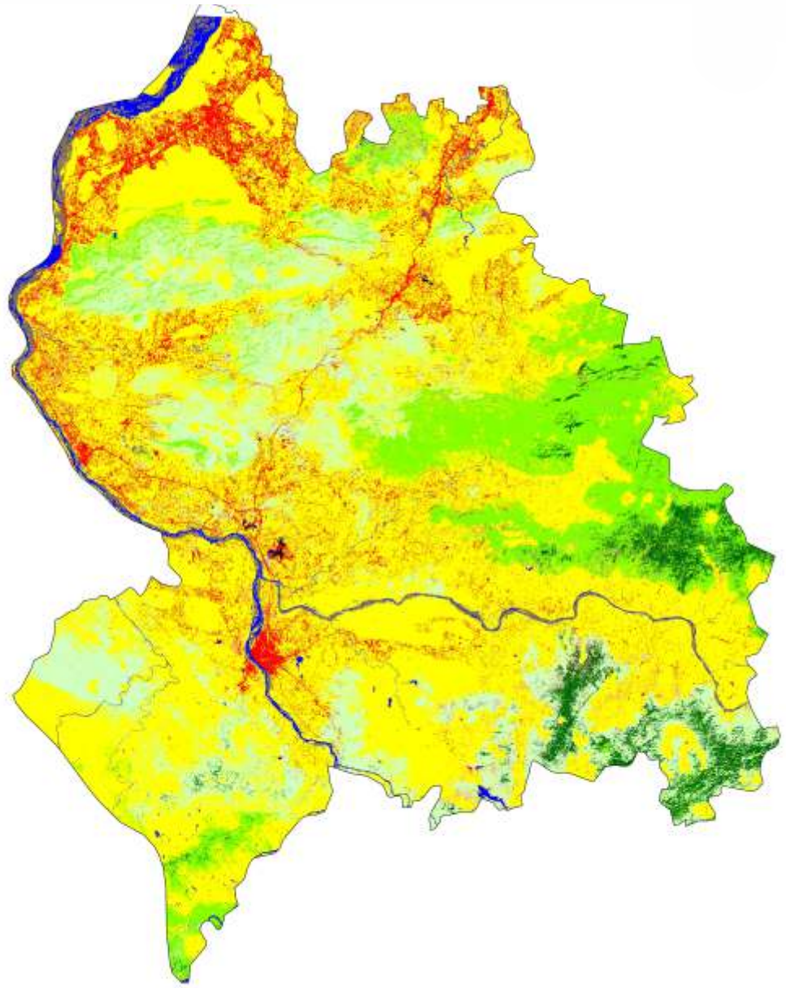
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	46.14	43.25	-2.89	-6.26 %
Wasteland	59.17	60.82	1.65	2.79 %
Coal Mine	1.27	2.70	1.43	112.48 %
Built Up	261.51	289.53	28.02	10.71 %
Water Bodies	69.86	70.02	0.16	0.23 %
VDF	124.66	124.63	-0.03	-0.02 %
MDF	572.89	561.40	-11.49	-2.01 %
Agriculture	2644.68	2634.65	-10.03	-0.38 %
OF	686.68	679.86	-6.82	-0.99 %

2004

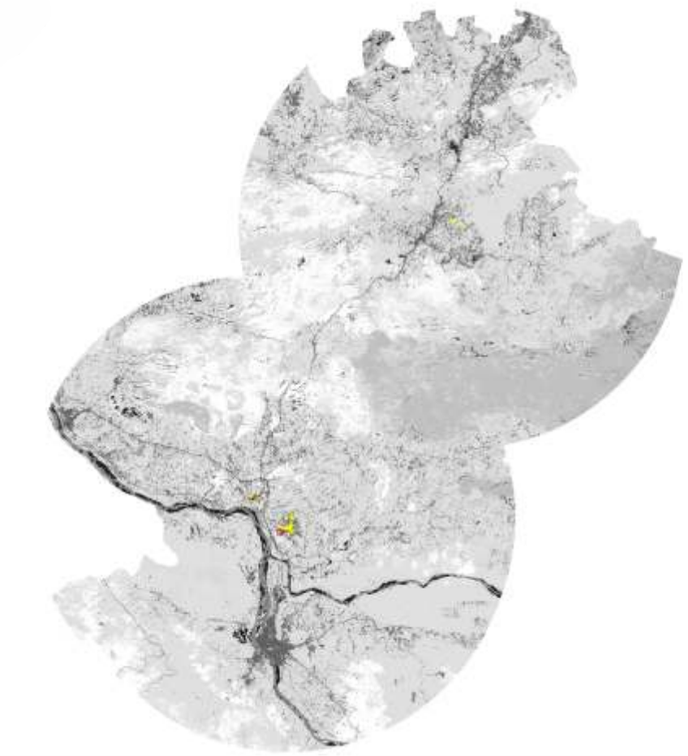


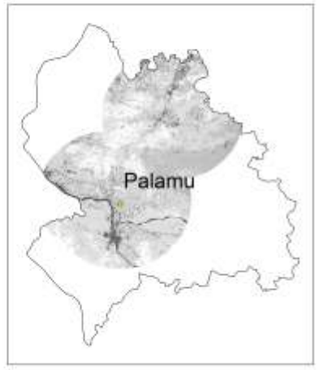
2019



- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

Change within the Periphery (20 km) of Coal Mines





Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

PALAMU

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	8.51	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	**9.53**
	Waste Land	0.00	21.99	0.06	0.00	0.03	0.00	0.00	0.06	0.00	**22.14**
	Coal Mine	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.01	0.00	**1.27**
	Built Up	0.00	0.16	0.02	156.97	0.00	0.00	0.00	0.04	0.00	**157.20**
	Water Bodies	0.00	0.14	0.00	0.11	23.82	0.00	0.00	0.00	0.00	**24.08**
	VDF	0.00	0.00	0.00	0.00	0.00	2.53	0.00	0.02	0.00	**2.56**
	MDF	0.00	0.00	0.00	0.04	0.00	1.17	215.71	3.79	26.72	**247.42**
	Agriculture	0.00	0.47	1.18	11.65	0.30	0.00	0.12	1401.37	0.12	**1415.21**
	OF	0.00	0.05	0.17	0.24	0.00	0.12	2.37	3.99	320.45	**327.38**
	Grand Total	**8.51**	**22.81**	**2.70**	**169.01**	**24.16**	**3.82**	**218.20**	**1410.30**	**347.28**	**2206.78**
	CHANGE	**-1.02**	**0.67**	**1.43**	**11.81**	**0.08**	**1.27**	**-29.22**	**-4.91**	**19.90**	
	CHANGE (%)	**-10.71**	**3.02**	**112.48**	**7.52**	**0.33**	**49.53**	**-11.81**	**-0.35**	**6.08**	

112 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	1629.19	0.00	0.12	0.12	**1629.42**
VDF	0.02	2.53	0.00	0.00	**2.56**
MDF	3.82	1.17	215.71	26.72	**247.42**
OF	4.45	0.12	2.37	320.45	**327.38**
TOTAL 2019	**1637.48**	**3.82**	**218.20**	**347.28**	**2206.78**
CHANGE	**8.06**	**1.27**	**-29.22**	**19.90**	
CHANGE %	**0.49 %**	**49.53 %**	**-11.81 %**	**6.08 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0	0.00%
VDF TO OF	0	0.00%
VDF TO NF	0.02	0.83%
MDF TO VDF	1.17	0.47%
MDF TO OF	26.72	10.80%
MDF TO NF	3.82	1.55%
OF TO VDF	0.12	0.04%
OF TO MDF	2.37	0.73%
OF TO NF	4.45	1.36%

10.80 %
MDF → OF

1.55 %
MDF → NF

1.36 %
OF → NF

Increase in Coal Mine Area

11.93 %
Forest Land

82.36 %
Agriculture Land

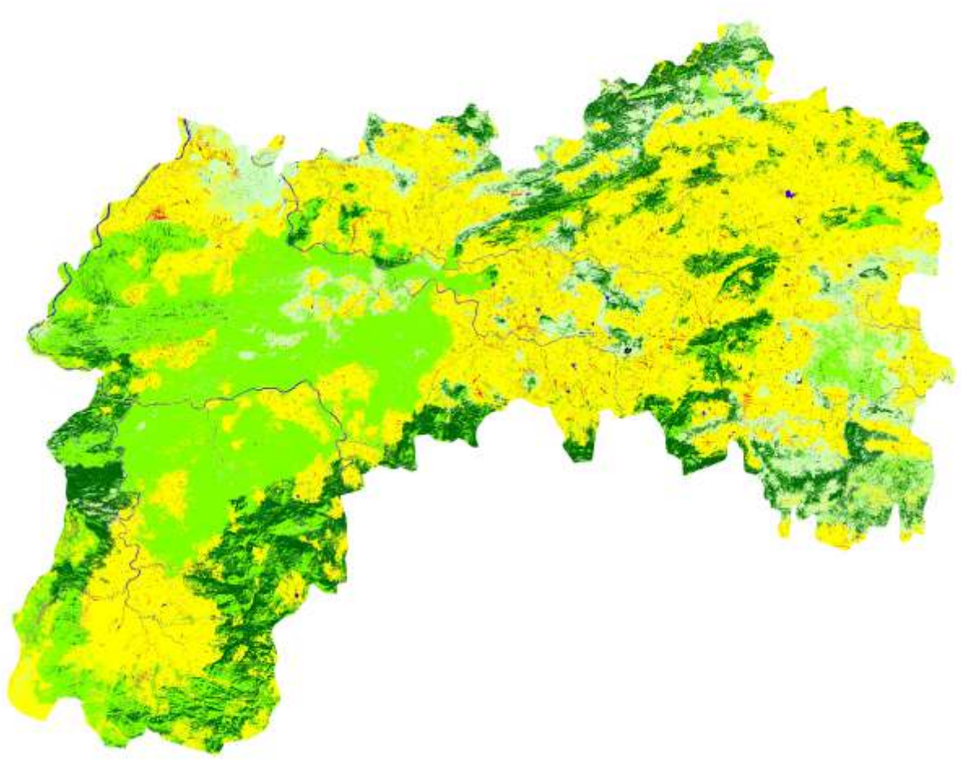
5.71 %
Other Land

LATEHAR

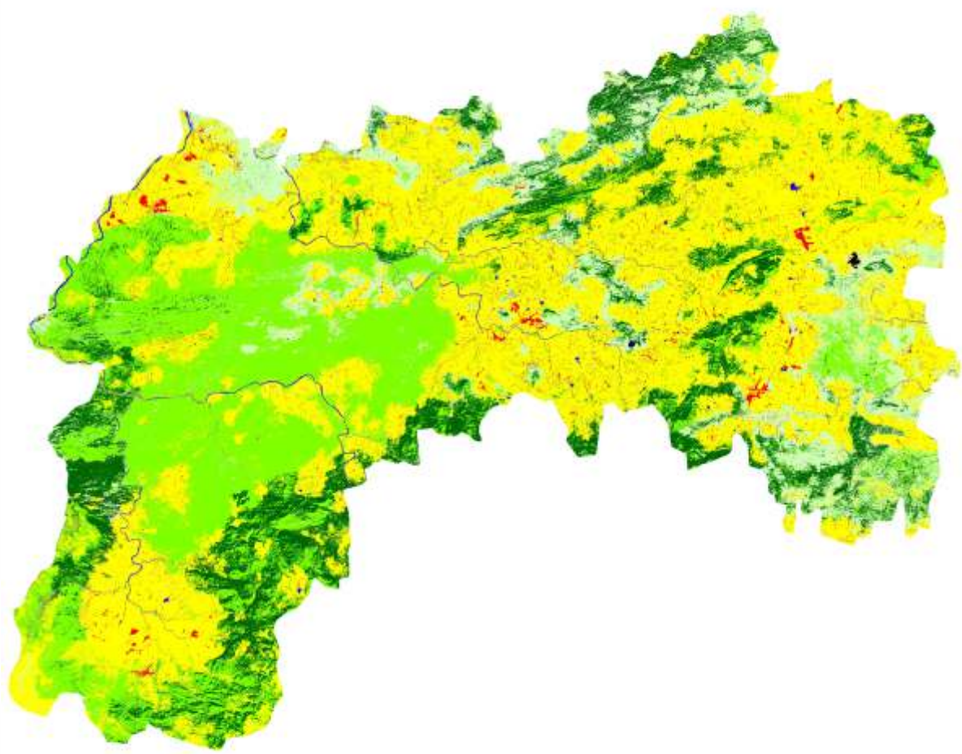
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	28.93 29.	43	0.50	1.73%
Wasteland	12.21	13.52	1.31	10.73%
Coal Mine	1.90	3.05	1.15	60.63%
Built Up	45.06	57.76	12.70	28.18%
Water Bodies	30.81	30.87	0.06	0.19%
VDF	578.77	577.55	-1.22	-0.21%
MDF	1181.15	1151.23	-29.92	-2.53%
Agriculture	1924.61	1949.73	25.12	1.31%
OF	475.88	466.16	-9.72	-2.04%

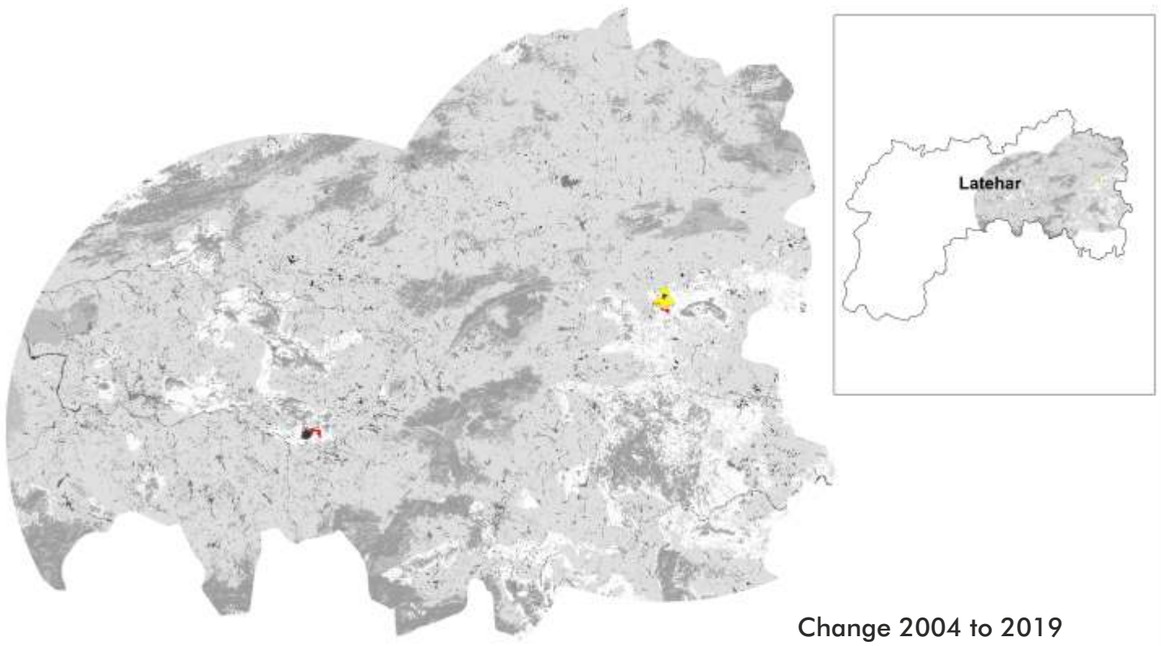
2004



2019



Change within the Periphery (20 km) of Coal Mines



Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

LATEHAR

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	10.25	0.00	0.03	0.00	0.00	0.00	0.00	0.03	0.00	**10.31**
	Waste Land	0.00	8.00	0.02	0.00	0.08	0.00	0.00	0.00	0.00	**8.10**
	Coal Mine	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	**1.90**
	Built Up	0.00	0.00	0.00	23.46	0.00	0.00	0.00	0.00	0.00	**23.46**
	Water Bodies	0.00	0.00	0.00	0.01	9.55	0.00	0.00	0.37	0.01	**9.94**
	VDF	0.00	0.00	0.00	0.00	0.00	185.25	3.44	0.00	0.17	**188.87**
	MDF	0.00	0.06	0.00	0.27	0.00	2.01	144.08	9.81	1.72	**157.97**
	Agriculture	0.21	1.01	0.76	6.59	0.22	0.00	0.00	1012.95	0.00	**1021.73**
	OF	0.03	0.34	0.34	0.64	0.01	0.00	0.69	1.39	171.14	**174.57**
	Grand Total	**10.48**	**9.41**	**3.05**	**30.97**	**9.87**	**187.27**	**148.21**	**1024.54**	**173.04**	**1596.83**
	CHANGE	**0.17**	**1.31**	**1.15**	**7.50**	**-0.07**	**-1.60**	**-9.76**	**2.82**	**-1.53**	
	CHANGE (%)	**1.65 %**	**16.23 %**	**60.63 %**	**31.98 %**	**-0.74 %**	**-0.85 %**	**-6.18 %**	**0.28 %**	**-0.87 %**	

60.63 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	1075.42	0.00	0.00	0.01	**1075.43**
VDF	0.00	185.25	3.44	0.17	**188.87**
MDF	10.15	2.01	144.08	1.72	**157.97**
OF	2.74	0.00	0.69	171.14	**174.57**
TOTAL 2019	**1088.31**	**187.27**	**148.21**	**173.04**	**1596.83**
CHANGE	**12.88**	**-1.60**	**-9.76**	**-1.53**	
CHANGE %	**1.20 %**	**-0.85 %**	**-6.18 %**	**-0.87 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	3.44	1.82%
VDF TO OF	0.17	0.09%
VDF TO NF	0.00	0.00%
MDF TO VDF	2.01	1.27%
MDF TO OF	1.72	1.09%
MDF TO NF	10.15	6.43%
OF TO VDF	0.00	0.00%
OF TO MDF	0.69	0.40%
OF TO NF	2.74	1.57%

1.82 %
VDF → MDF

6.43 %
MDF → NF

Increase in Coal Mine Area

29.24 %
Forest Land

66.30 %
Agriculture Land

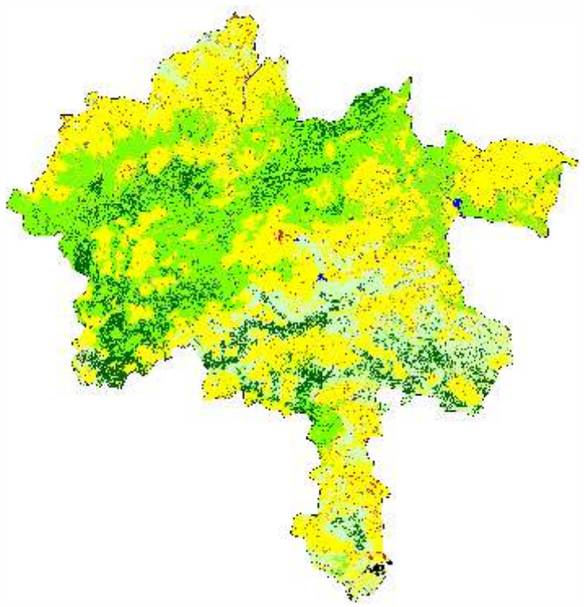
4.46 %
Other Land

CHATRA

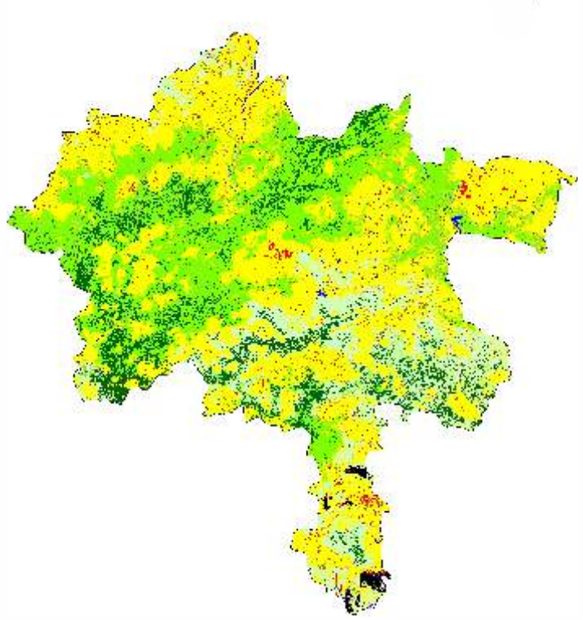
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	64.53	63.33	-1.20	-1.86 %
Wasteland	35.10	37.22	2.12	6.04 %
Coal Mine	5.42	19.63	14.21	262.26 %
Built Up	36.93	50.59	13.66	36.99 %
Water Bodies	16.97	17.15	0.18	1.06 %
VDF	369.66	365.84	-3.82	-1.03 %
MDF	1067.56	1050.72	-16.84	-1.58 %
Agriculture	1663.44	1668.29	4.85	0.29 %
OF	509.71	496.55	-13.16	-2.58 %

2004



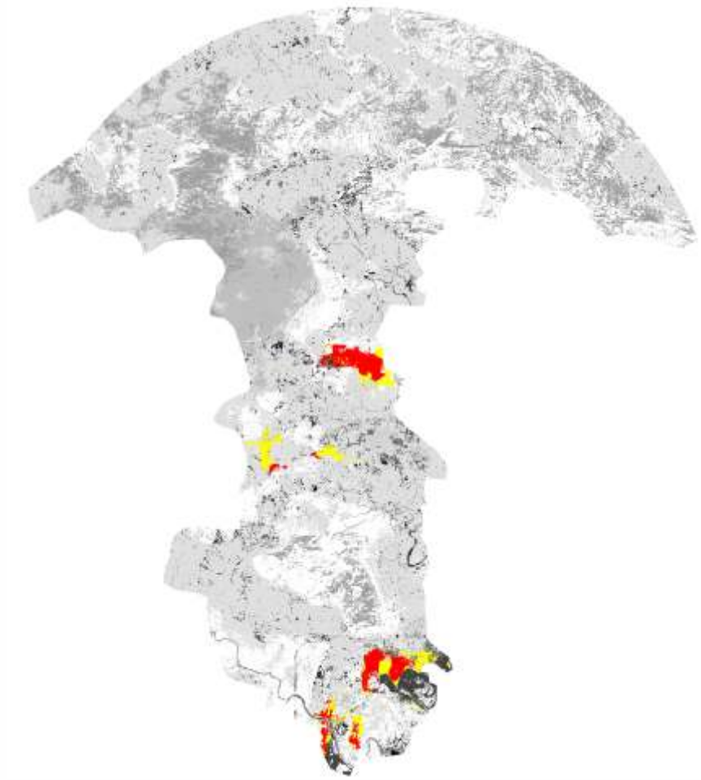
2019



- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

2004 — Coal Mining Areas — 2019

Change within the Periphery (20 km) of Coal Mines



CHATRA

Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	8.09	0.01	0.05	0.00	0.00	0.00	0.00	0.20	0.00	**8.34**
Waste Land	0.00	6.25	0.05	0.04	0.00	0.00	0.00	0.03	0.00	**6.37**
Coal Mine	0.00	0.00	5.41	0.00	0.00	0.00	0.00	0.00	0.00	**5.42**
Built Up	0.00	0.00	0.02	10.38	0.01	0.00	0.00	0.00	0.00	**10.40**
Water Bodies	0.00	0.00	0.00	0.01	1.83	0.00	0.00	0.00	0.00	**1.84**
VDF	0.00	0.00	0.00	0.00	0.00	67.38	2.35	0.00	0.00	**69.73**
MDF	0.00	0.00	0.00	0.00	0.00	0.26	53.35	0.14	3.34	**57.07**
Agriculture	0.00	1.77	6.38	2.83	0.24	0.00	0.00	282.76	0.00	**293.98**
OF	0.01	0.49	7.73	0.46	0.18	0.00	0.25	3.04	173.67	**185.83**
Grand Total	**8.09**	**8.51**	**19.63**	**13.73**	**2.27**	**67.63**	**55.95**	**286.17**	**177.01**	**638.98**
CHANGE	**-0.24**	**2.14**	**14.21**	**3.33**	**0.42**	**-2.09**	**-1.12**	**-7.81**	**-8.83**	
CHANGE (%)	**-2.92 %**	**33.59 %**	**262.26 %**	**32.01 %**	**22.93 %**	**-3.00 %**	**-1.97%**	**-2.66 %**	**-4.75 %**	

262.26 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	326.34	0.00	0.00	0.00	**326.34**
VDF	0.00	67.38	2.35	0.00	**69.73**
MDF	0.14	0.26	53.35	3.34	**57.07**
OF	11.91	0.00	0.25	173.67	**185.83**
TOTAL 2019	**338.39**	**67.63**	**55.95**	**177.01**	**638.98**
CHANGE	**12.05**	**-2.09**	**-1.12**	**-8.83**	
CHANGE %	**3.69 %**	**-3.00 %**	**-1.97 %**	**-4.75 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	2.35	3.37%
VDF TO OF	0.00	0.00%
VDF TO NF	0.00	0.00%
MDF TO VDF	0.26	0.46%
MDF TO OF	3.34	5.85%
MDF TO NF	0.14	0.25%
OF TO VDF	0.00	0.00%
OF TO MDF	0.25	0.13%
OF TO NF	11.91	6.41%

3.37 %
VDF → MDF

5.85 %
MDF → OF

6.41 %
OF → NF

Increase in Coal Mine Area

54.38 %
Forest Land

44.86%
Agriculture Land

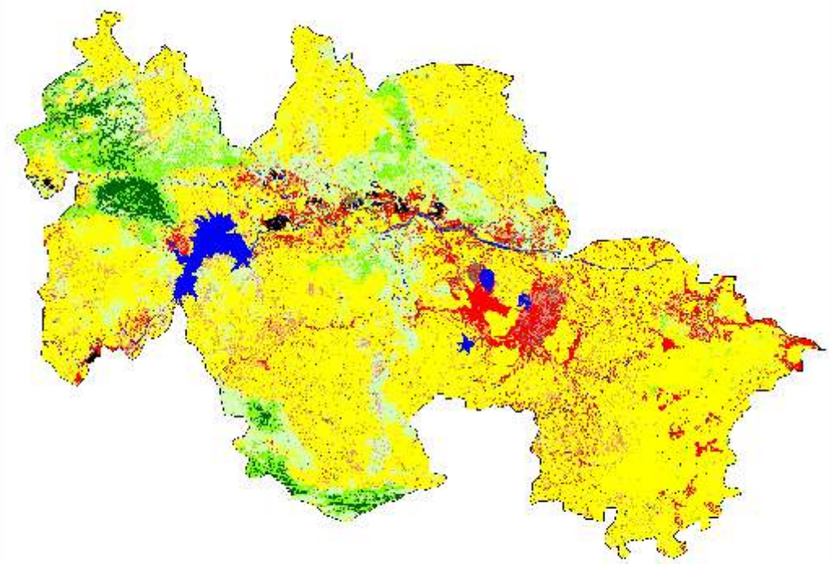
0.77 %
Other Land

BOKARO

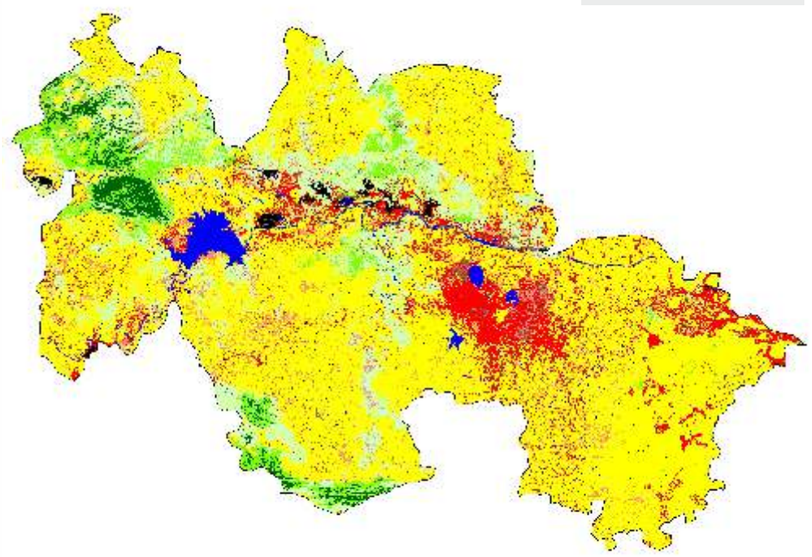
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	156.21	159.42	3.21	2.05 %
Wasteland	29.78	31.11	1.33	4.47 %
Coal Mine	18.2	23.50	5.30	29.09 %
Built Up	195.55	260.01	64.46	32.96 %
Water Bodies	61.26	56.61	-4.65	-7.59 %
VDF	58.9	59.75	0.85	1.44 %
MDF	164.11	150.78	-13.33	-8.12 %
Agriculture	1788.74	1747.6	-41.14	-2.30 %
OF	405.14	389.12	-16.02	-3.95 %

2004



2019



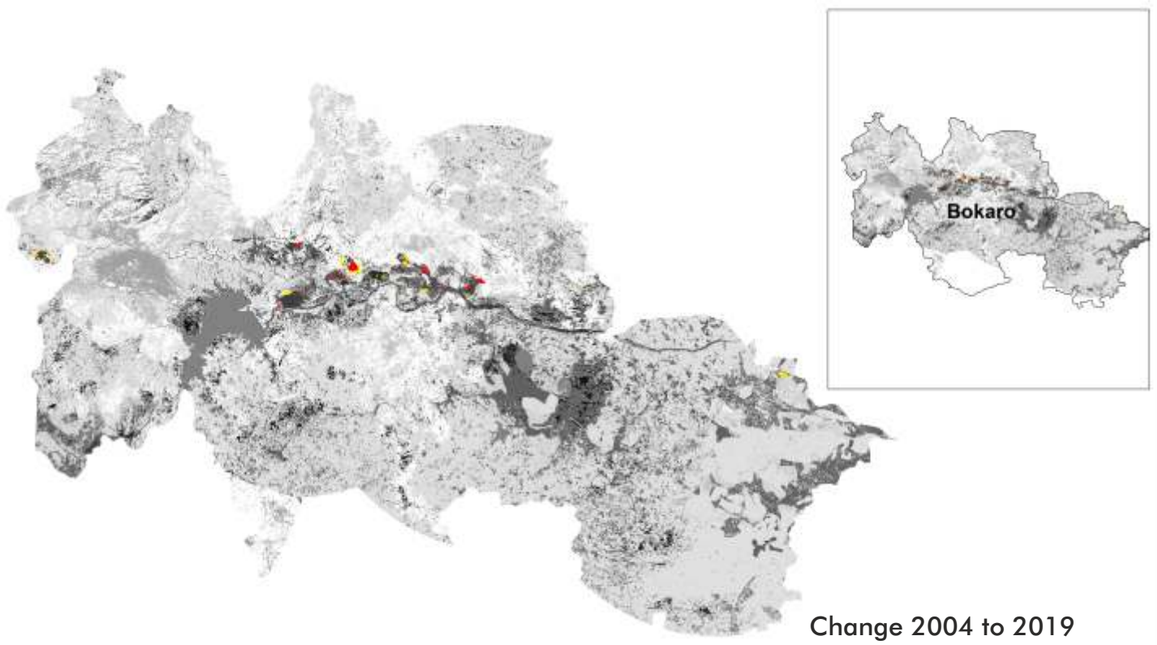
- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

Coal Mining Areas

2004

2019

Change within the Periphery (20 km) of Coal Mines



Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	147.17	0.00	0.10	0.00	0.00	0.00	0.02	0.28	0.00	**147.57**
	Waste Land	0.05	27.01	0.21	0.11	0.20	0.00	0.00	0.00	0.00	**27.60**
	Coal Mine	0.00	0.00	17.98	0.00	0.22	0.00	0.00	0.00	0.00	**18.20**
	Built Up	0.00	0.00	0.00	192.77	0.00	0.00	0.00	0.02	0.00	**192.79**
	Water Bodies	1.46	0.00	0.10	0.31	55.44	0.00	0.05	3.18	0.10	**60.63**
	VDF	0.00	0.00	0.00	0.00	0.00	48.52	0.17	0.64	0.02	**49.35**
	MDF	0.09	0.00	0.07	0.00	0.00	1.55	131.32	4.77	7.56	**145.36**
	Agriculture	0.22	1.64	2.50	63.58	0.11	0.00	0.00	1594.39	0.52	**1662.95**
	OF	1.79	0.28	2.54	0.48	0.00	0.01	0.83	15.09	349.06	**370.07**
	Grand Total	**150.78**	**28.92**	**23.50**	**257.24**	**55.98**	**50.08**	**132.39**	**1618.36**	**357.26**	**2674.52**
	CHANGE	**3.21**	**1.33**	**5.30**	**64.46**	**-4.66**	**0.72**	**-12.97**	**-44.58**	**-12.81**	
	CHANGE (%)	**2.18 %**	**4.82 %**	**29.09 %**	**33.43 %**	**-7.68 %**	**1.46 %**	**-8.92 %**	**-2.68 %**	**-3.46 %**	

29.09 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	2109.04	0.00	0.07	0.62	**2109.74**
VDF	0.64	48.52	0.17	0.02	**49.35**
MDF	4.93	1.55	131.32	7.56	**145.36**
OF	20.17	0.01	0.83	349.06	**370.07**
TOTAL 2019	**2134.79**	**50.08**	**132.39**	**357.26**	**2674.52**
CHANGE	**25.05**	**0.72**	**-12.97**	**-12.81**	
CHANGE %	**1.19 %**	**1.46 %**	**-8.92 %**	**-3.46 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.17	0.34%
VDF TO OF	0.02	0.04%
VDF TO NF	0.64	1.30%
MDF TO VDF	1.55	1.07%
MDF TO OF	7.56	5.20%
MDF TO NF	4.93	3.39%
OF TO VDF	0.01	0.00%
OF TO MDF	0.83	0.22%
OF TO NF	20.17	5.45%
NF TO OF	0.62	0.03%

1.07 % MDF → VDF

5.20 % MDF → OF

3.39 % MDF → NF

5.45 % OF → NF

Increase in Coal Mine Area

47.22 % Forest Land

45.28 % Agriculture Land

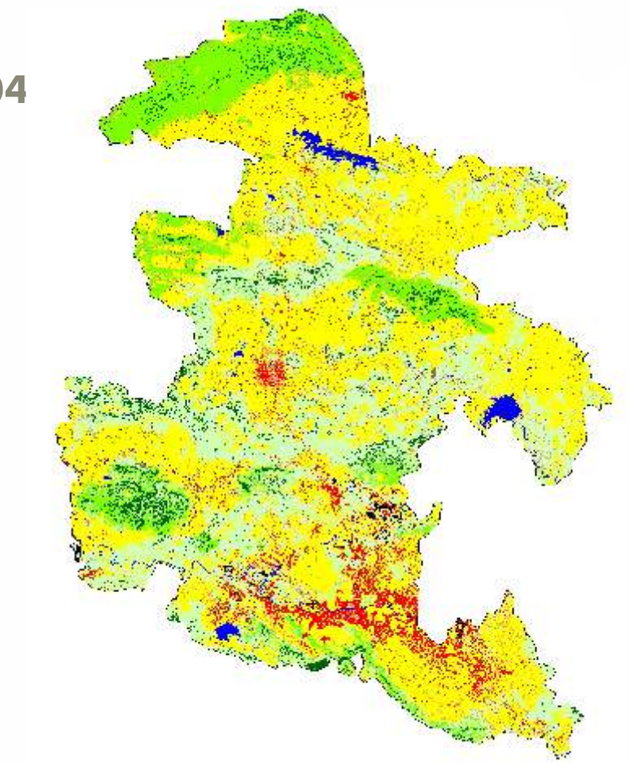
7.50 % Other Land

HAZARIBAG

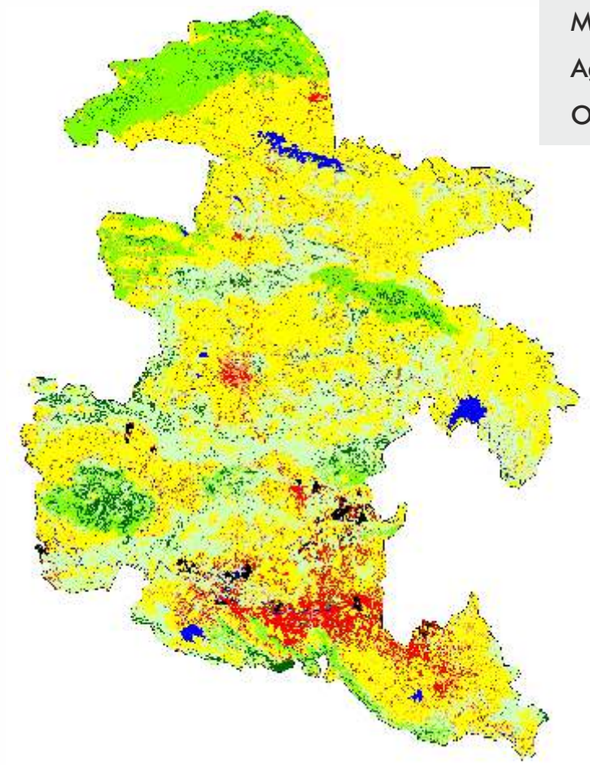
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	202.26	201.35	-0.91	-0.45 %
Wasteland	61.19	64.40	3.21	5.25 %
Coal Mine	25.51	46.77	20.26	86.15 %
Built Up	271.26	316.97	45.71	16.85 %
Water Bodies	90.59	92.68	2.09	2.31 %
VDF	217.96	216.51	-1.45	-0.67 %
MDF	711.93	699.26	-12.67	-1.78 %
Agriculture	3051.55	3026.96	-24.59	-0.81 %
OF	1543.96	1511.36	-32.60	-2.11 %

2004



2019



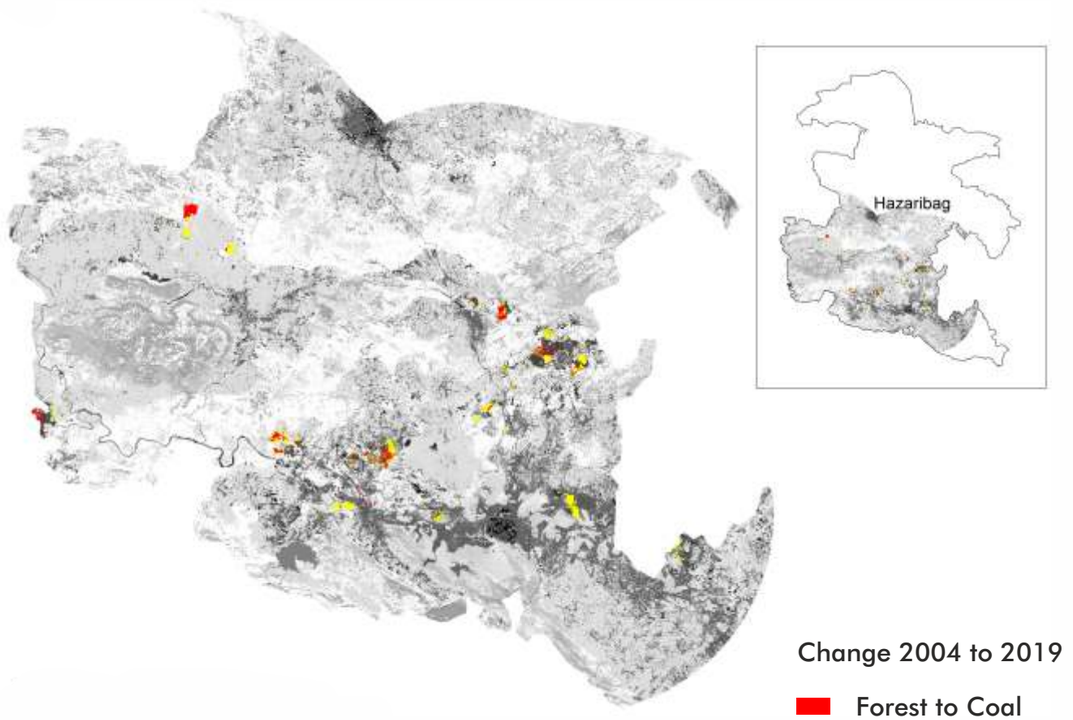
- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

2004

Coal Mining Areas

2019

Change within the Periphery (20 km) of Coal Mines



HAZARIBAG

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	92.55	0.01	0.34	0.00	0.00	0.00	0.00	0.26	0.00	**93.16**
	Waste Land	0.00	20.77	0.26	0.00	0.00	0.00	0.00	0.01	1.03	**22.08**
	Coal Mine	0.00	0.07	23.35	0.04	0.05	0.00	0.00	0.00	0.00	**23.51**
	Built Up	0.00	0.24	1.03	219.63	0.02	0.00	0.00	0.28	0.00	**221.20**
	Water Bodies	0.00	0.00	0.08	0.07	29.95	0.00	0.00	0.34	0.00	**30.44**
	VDF	0.00	0.00	0.00	0.00	0.00	130.89	1.62	0.06	0.28	**132.85**
	MDF	0.00	0.00	0.02	0.00	0.00	0.60	163.23	0.33	6.90	**171.07**
	Agriculture	0.00	1.19	12.20	42.88	2.52	0.00	0.01	1199.03	0.08	**1257.91**
	OF	0.00	3.00	6.49	1.81	0.00	0.00	0.60	18.65	910.53	**941.08**
	Grand Total	**92.55**	**25.28**	**43.77**	**264.43**	**32.53**	**131.49**	**165.47**	**1218.96**	**918.81**	**2893.31**
	CHANGE	**-0.61**	**3.21**	**20.26**	**43.24**	**2.09**	**-1.36**	**-5.60**	**-38.95**	**-22.27**	
	CHANGE (%)	**-0.65 %**	**14.53 %**	**86.15 %**	**19.55 %**	**6.87 %**	**-1.02 %**	**-3.28 %**	**-3.10 %**	**-2.37 %**	

86.15 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	1647.17	0.00	0.02	1.11	**1648.30**
VDF	0.06	130.89	1.62	0.28	**132.85**
MDF	0.35	0.60	163.23	6.90	**171.07**
OF	29.95	0.00	0.60	910.53	**941.08**
TOTAL 2019	**1677.53**	**131.49**	**165.47**	**918.81**	**2893.31**
CHANGE	**29.23**	**-1.36**	**-5.60**	**-22.27**	
CHANGE %	**1.77 %**	**-1.02 %**	**-3.28 %**	**-2.37 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	1.62	1.22%
VDF TO OF	0.28	0.21%
VDF TO NF	0.06	0.05%
MDF TO VDF	0.60	0.35%
MDF TO OF	6.90	4.03%
MDF TO NF	0.35	0.20%
OF TO VDF	0.00	0.00%
OF TO MDF	0.60	0.06%
OF TO NF	29.95	3.18%
NF TO OF	1.11	0.07%

1.22 %
VDF → MDF

4.03 %
MDF → OF

3.18 %
OF → NF

Increase in Coal Mine Area

31.86 %
Forest Land

59.72 %
Agriculture Land

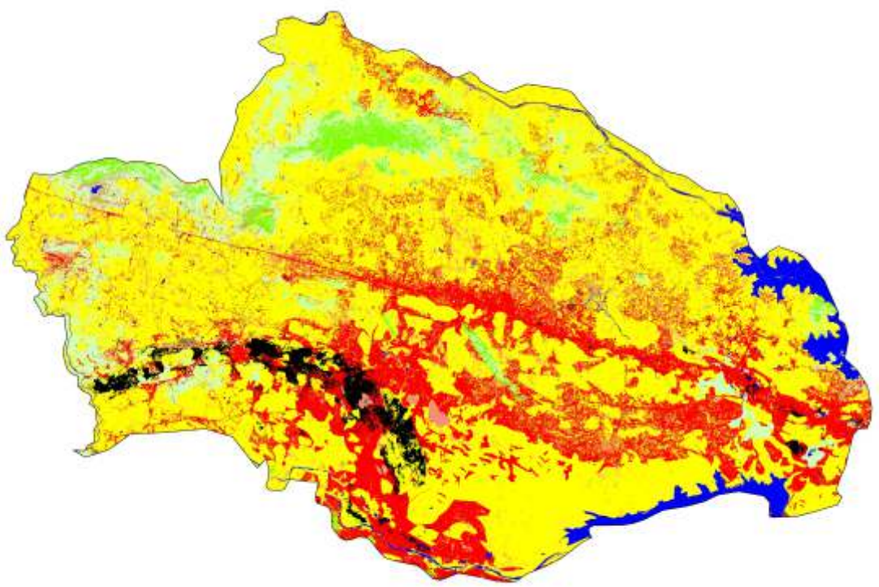
8.42 %
Other Land

DHANBAD

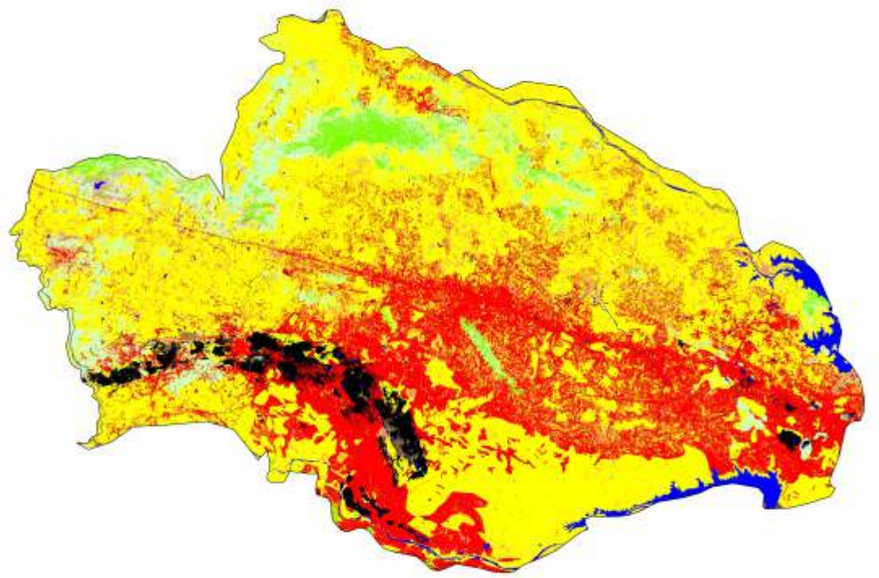
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	86.56	84.00	-2.56	-2.96
Wasteland	8.25	11.14	2.89	35.03
Coal Mine	52.92	68.96	16.03	30.29
Built Up	396.48	504.19	107.71	27.17
Water Bodies	62.16	43.23	-18.93	-30.45
VDF	0.00	0.00	0.00	0.00
MDF	57.89	53.21	-4.68	-8.08
Agriculture	1250.36	1161.45	-88.91	-7.11
OF	172.76	161.22	-11.54	-6.68

2004

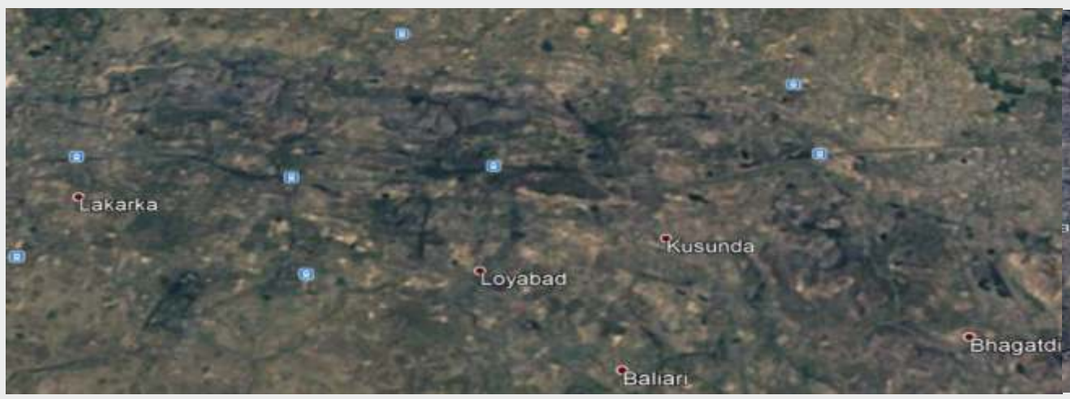


2019

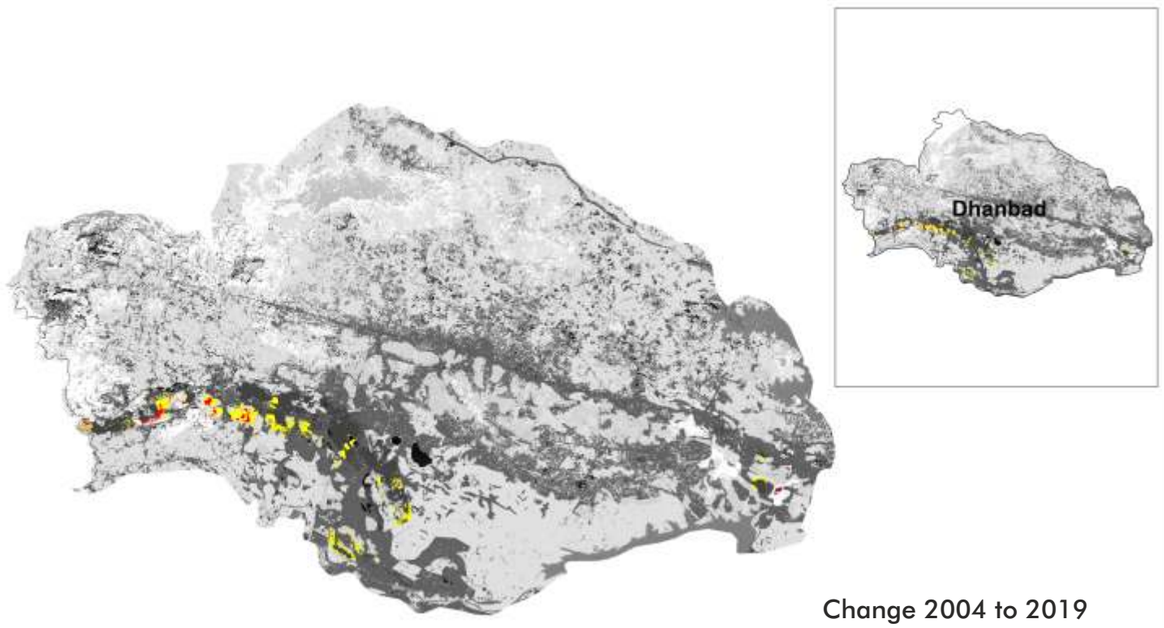


- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

2004 — Coal Mining Areas — 2019



Change within the Periphery (20 km) of Coal Mines



Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

DHANBAD

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	80.05	0.18	0.92	1.89	0.00	0.00	0.00	2.71	0.00	**85.75**
	Waste Land	0.00	7.60	0.33	0.02	0.27	0.00	0.00	0.04	0.00	**8.24**
	Coal Mine	0.34	0.00	52.54	0.02	0.00	0.00	0.01	0.01	0.01	**52.93**
	Built Up	0.18	0.27	1.60	393.23	0.02	0.00	0.00	0.20	0.02	**395.51**
	Water Bodies	2.03	0.00	0.00	0.62	41.51	0.00	0.00	17.63	0.00	**61.79**
	VDF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	MDF	0.00	0.00	0.00	0.00	0.00	0.00	52.49	2.56	2.53	**57.58**
	Agriculture	0.59	2.47	11.36	104.93	1.06	0.00	0.06	1095.31	0.62	**1216.42**
	OF	0.00	0.38	2.21	2.51	0.00	0.00	0.35	8.81	150.59	**164.86**
	Grand Total	**83.19**	**10.90**	**68.96**	**503.22**	**42.85**	**0.00**	**52.91**	**1127.26**	**153.77**	**2043.07**
	CHANGE	**-2.56**	**2.66**	**16.03**	**107.71**	**-18.94**	**0.00**	**-4.67**	**-89.15**	**-11.09**	
	CHANGE (%)	**-2.99 %**	**32.28 %**	**30.29 %**	**27.23 %**	**-30.65 %**	**0.00 %**	**-8.11 %**	**-7.33 %**	**-6.72 %**	

30.29 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	1819.92	0.00	0.06	0.65	**1820.64**
VDF	0.00	0.00	0.00	0.00	**0.00**
MDF	2.56	0.00	52.49	2.53	**57.58**
OF	13.91	0.00	0.35	150.59	**164.86**
TOTAL 2019	**1836.39**	**0.00**	**52.91**	**153.77**	**2043.07**
CHANGE	**15.75**	**0.00**	**-4.67**	**-11.09**	
CHANGE %	**0.87 %**	**0.00 %**	**-8.11 %**	**-6.72 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.00	0.00%
VDF TO OF	0.00	0.00%
VDF TO NF	0.00	0.00%
MDF TO VDF	0.00	0.00%
MDF TO OF	2.53	4.39%
MDF TO NF	2.56	4.45%
OF TO VDF	0.00	0.00%
OF TO MDF	0.35	0.21%
OF TO NF	13.91	8.44%
NF TO OF	0.65	0.04%

4.39 %
MDF → OF

4.45 %
MDF → NF

8.44 %
OF → NF

Increase in Coal Mine Area

13.45 %
Forest Land

69.20 %
Agriculture Land

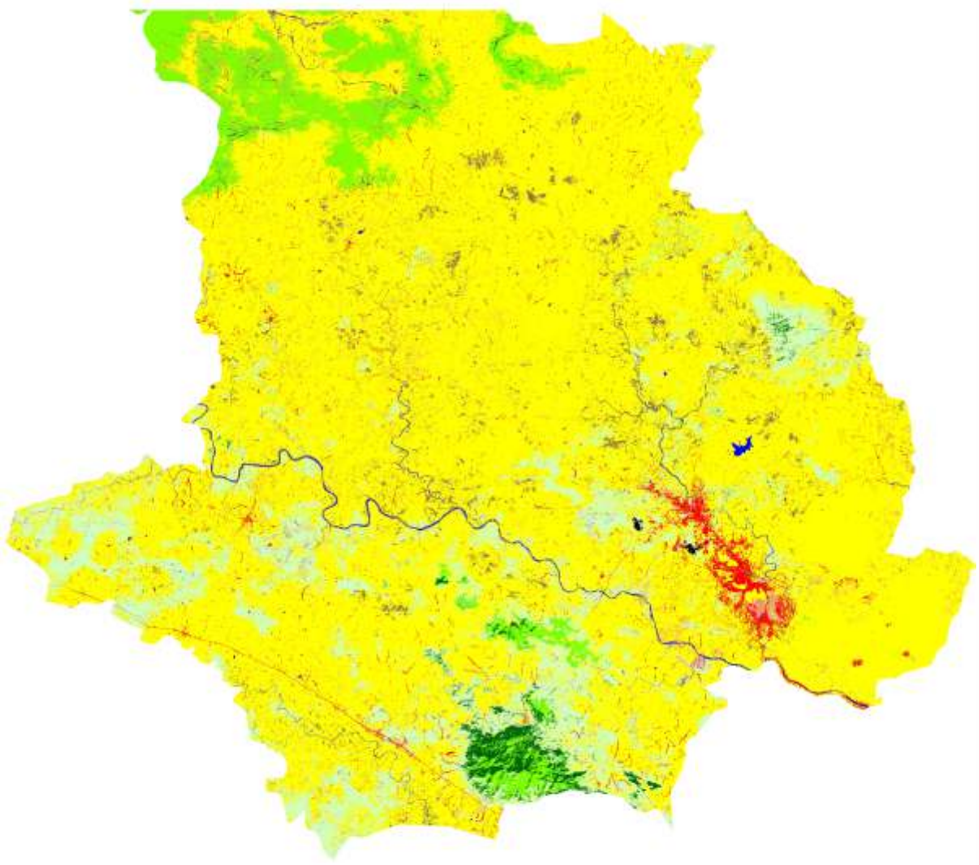
17.35 %
Other Land

GIRIDIH

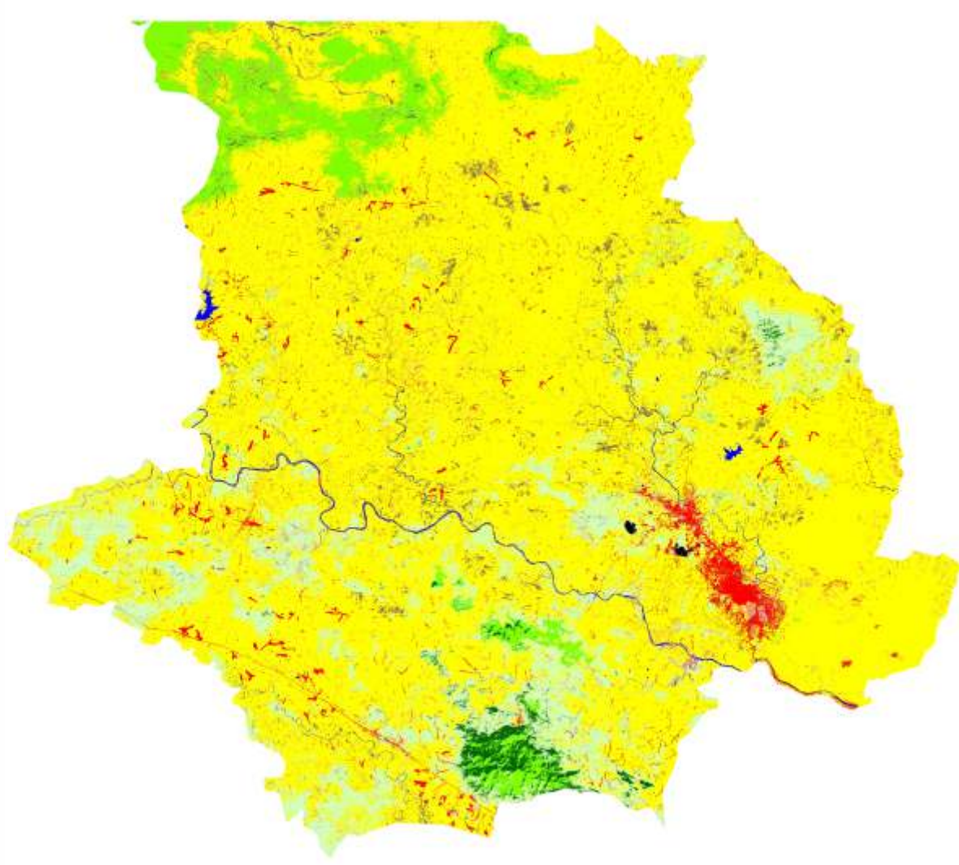
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	93.69	93.28	-0.41	-0.44
Wasteland	94.06	96.52	2.46	2.62
Coal Mine	2.45	3.06	0.61	24.81
Built Up	93.00	123.34	30.34	32.62
Water Bodies	19.83	21.94	2.11	10.64
VDF	44.62	43.60	-1.02	-2.29
MDF	252.18	252.88	0.70	0.28
Agriculture	3431.85	3387.60	-44.25	-1.29
OF	481.58	491.03	9.45	1.96

2004

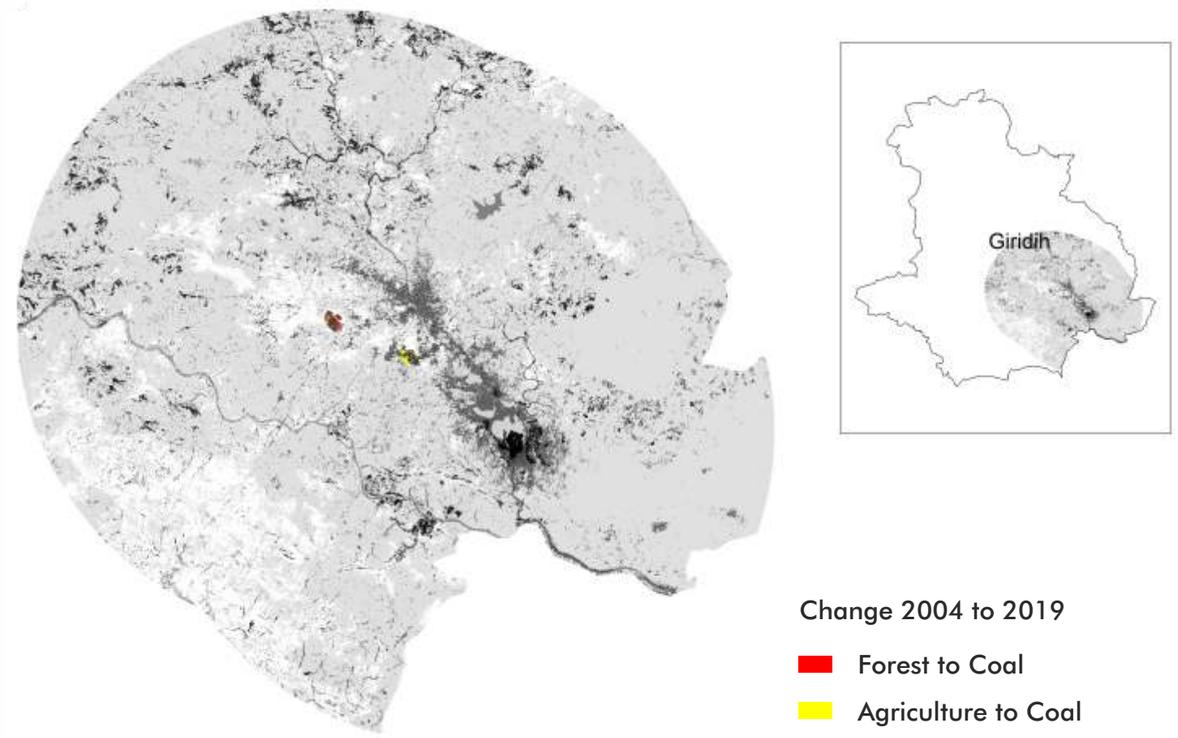


2019



Plantation
Wasteland
Coal Mine
Built Up
Water Bodies
VDF
MDF
Agriculture
OF

Change within the Periphery (20 km) of Coal Mines



GIRIDIH

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	28.51	0.00	0.00	1.87	0.00	0.00	0.00	0.33	0.00	**30.71**
	Waste Land	0.00	33.17	0.08	0.00	0.00	0.00	0.00	0.00	0.00	**33.26**
	Coal Mine	0.00	0.00	2.45	0.00	0.00	0.00	0.00	0.00	0.00	**2.45**
	Built Up	0.19	0.00	0.00	50.18	0.00	0.00	0.00	0.35	0.00	**50.72**
	Water Bodies	0.00	0.00	0.00	0.00	9.76	0.00	0.00	0.34	0.00	**10.10**
	VDF	0.00	0.00	0.00	0.00	0.00	5.79	0.26	0.00	0.01	**6.07**
	MDF	0.05	0.00	0.00	0.00	0.00	0.01	23.93	0.00	1.45	**25.44**
	Agriculture	0.57	1.88	0.27	7.87	0.09	0.05	0.73	1149.24	5.50	**1166.21**
	OF	0.00	0.01	0.25	0.01	0.00	0.00	0.00	1.30	174.26	**175.83**
	Grand Total	**29.32**	**35.07**	**3.06**	**59.92**	**9.85**	**5.85**	**24.92**	**1151.57**	**181.22**	**1500.78**
	CHANGE	**-1.39**	**1.81**	**0.61**	**9.21**	**-0.25**	**-0.21**	**-0.52**	**-14.64**	**5.39**	
	CHANGE (%)	**-4.54 %**	**5.44 %**	**24.81 %**	**18.16 %**	**-2.48 %**	**-3.50 %**	**-2.04 %**	**-1.26 %**	**3.07 %**	

24.81 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	1287.16	0.05	0.73	5.50	**1293.45**
VDF	0.00	5.79	0.26	0.01	**6.07**
MDF	0.05	0.01	23.93	1.45	**25.44**
OF	1.57	0.00	0.00	174.26	**175.83**
TOTAL 2019	**1288.78**	**5.85**	**24.92**	**181.22**	**1500.78**
CHANGE	**-4.66**	**-0.21**	**-0.52**	**5.39**	
CHANGE %	**-0.36 %**	**-3.50 %**	**-2.04 %**	**3.07 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.26	4.29%
VDF TO OF	0.01	0.16%
VDF TO NF	0.00	0.00%
MDF TO VDF	0.01	0.04%
MDF TO OF	1.45	5.70%
MDF TO NF	0.05	0.20%
OF TO VDF	0.00	0.00%
OF TO MDF	0.35	0.20%
OF TO NF	1.57	0.89%
NF TO OF	5.50	0.43%

4.29 %
VDF → MDF

5.70 %
MDF → OF

Increase in
Coal Mine Area

41.52 %
Forest Land

44.83 %
Agriculture Land

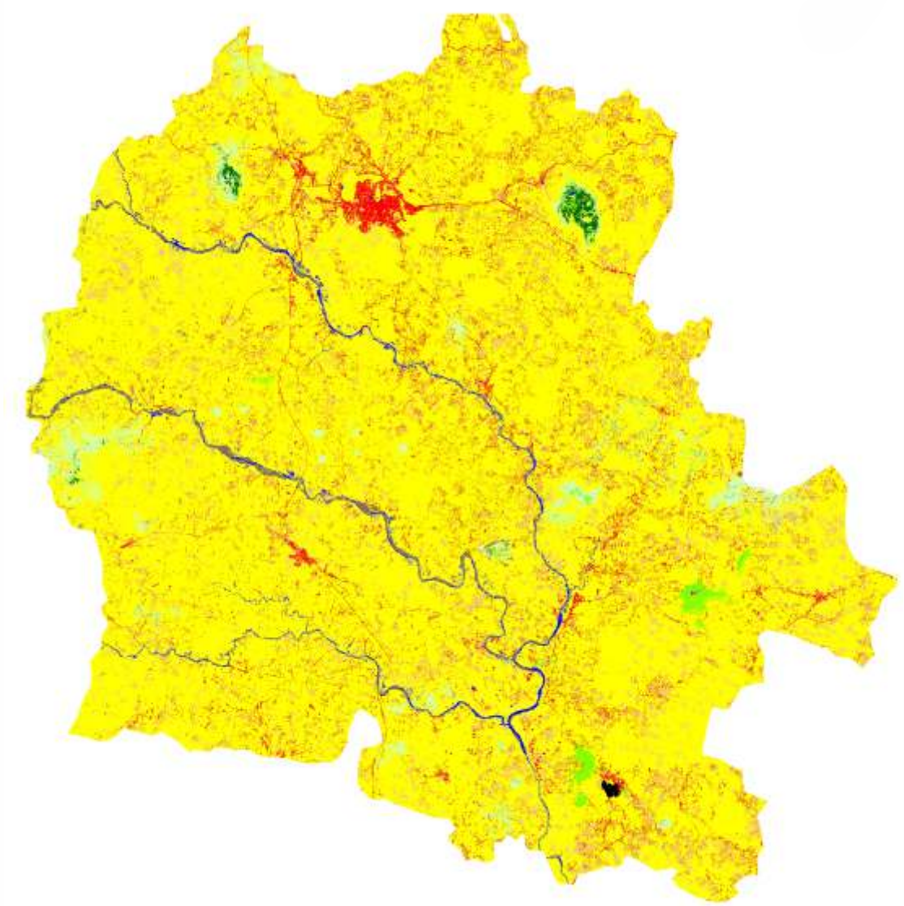
13.65 %
Other Land

DEOGHAR

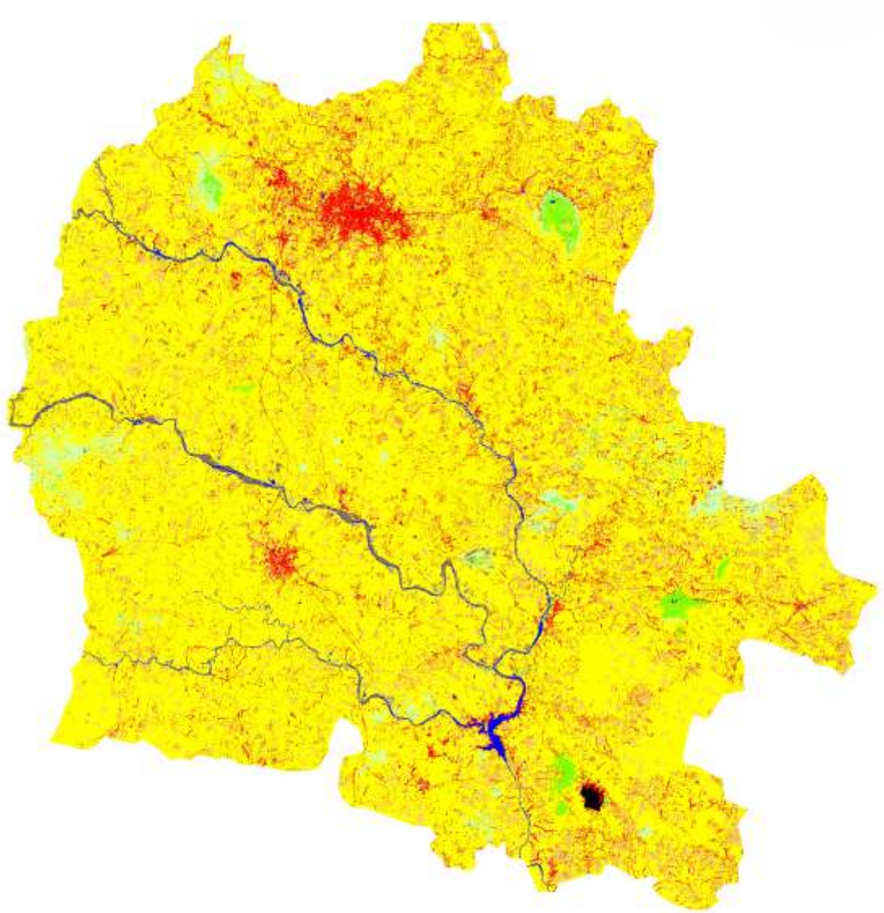
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	174.03	170.71	-3.32	-1.91
Wasteland	18.03	21.16	3.13	17.36
Coal Mine	1.21	2.04	0.83	68.62
Built Up	137.65	194.37	56.72	41.21
Water Bodies	20.05	21.85	1.8	8.98
VDF	3.87	0.18	-3.69	-95.35
MDF	16.34	20.82	4.48	27.42
Agriculture	2022.37	1966.49	-55.88	-2.76
OF	49.79	47.71	-2.08	-4.18

2004

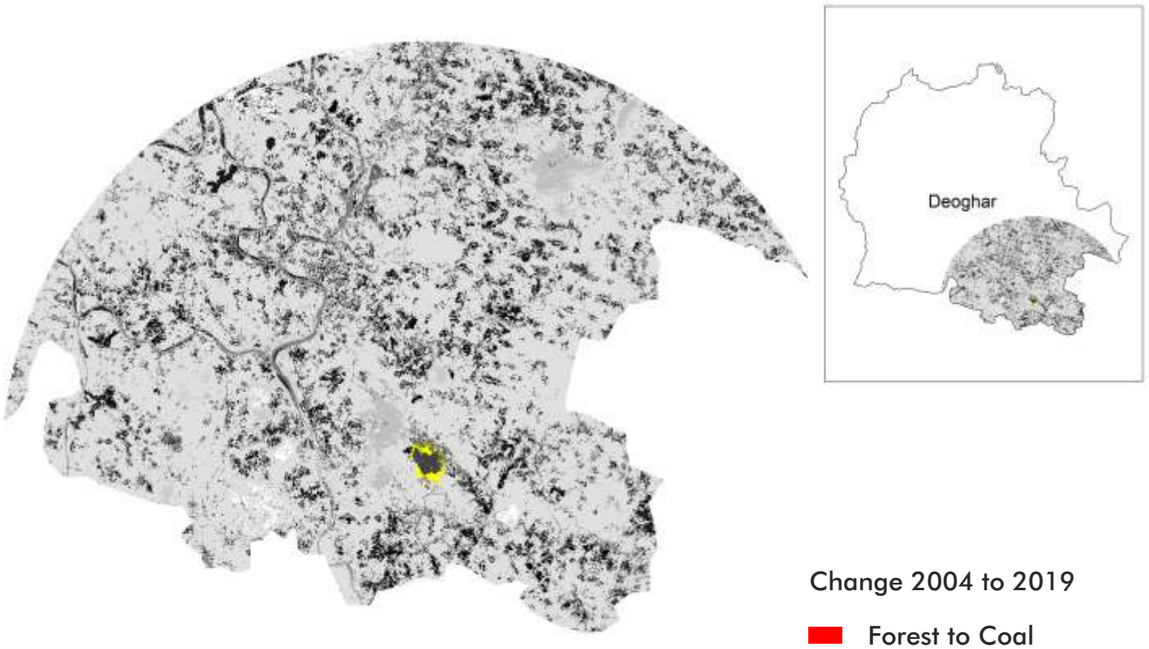


2019



Plantation
Wasteland
Coal Mine
Built Up
Water Bodies
VDF
MDF
Agriculture
OF

Change within the Periphery (20 km) of Coal Mines



DEOGHAR

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	55.94	0.00	0.02	0.01	0.00	0.00	0.00	1.25	0.00	**57.22**
Waste Land	0.00	3.96	0.00	0.00	0.25	0.00	0.00	0.00	0.00	**4.21**
Coal Mine	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00	0.00	**1.21**
Built Up	0.00	0.00	0.00	35.02	0.00	0.00	0.00	0.00	0.00	**35.02**
Water Bodies	0.00	0.00	0.00	0.00	7.33	0.00	0.00	0.00	0.00	**7.33**
VDF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
MDF	0.00	0.00	0.00	0.00	0.00	0.00	9.77	0.23	0.24	**10.25**
Agriculture	0.91	0.11	0.81	15.21	1.55	0.00	0.03	495.83	0.01	**514.47**
OF	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.26	7.12	**7.44**
Grand Total	**56.86**	**4.07**	**2.04**	**50.24**	**9.13**	**0.00**	**9.86**	**497.57**	**7.37**	**637.13**
CHANGE	**-0.36**	**-0.14**	**0.83**	**15.22**	**1.80**	**0.00**	**-0.39**	**-16.89**	**-0.07**	
CHANGE (%)	**-0.63**	**-3.35**	**68.62**	**43.46**	**24.62**	**0.00**	**-3.78**	**-3.28**	**-0.91**	

68.62 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	619.41	0.00	0.03	0.01	**619.45**
VDF	0.00	0.00	0.00	0.00	**0.00**
MDF	0.23	0.00	9.77	0.24	**10.25**
OF	0.26	0.00	0.05	7.12	**7.44**
TOTAL 2019	**619.90**	**0.00**	**9.86**	**7.37**	**637.13**
CHANGE	**0.46**	**0.00**	**-0.39**	**-0.07**	
CHANGE %	**0.07**	**0.00**	**-3.78**	**-0.91**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.00	0.00%
VDF TO OF	0.00	0.00%
VDF TO NF	0.00	0.00%
MDF TO VDF	0.00	0.00%
MDF TO OF	0.24	2.34%
MDF TO NF	0.23	2.24%
OF TO VDF	0.00	0.00%
OF TO MDF	0.05	0.67%
OF TO NF	0.26	3.50%

2.34 %
MDF → OF

3.50 %
OF → NF

Increase in
Coal Mine Area

0.00 %
Forest Land

97.50 %
Agriculture Land

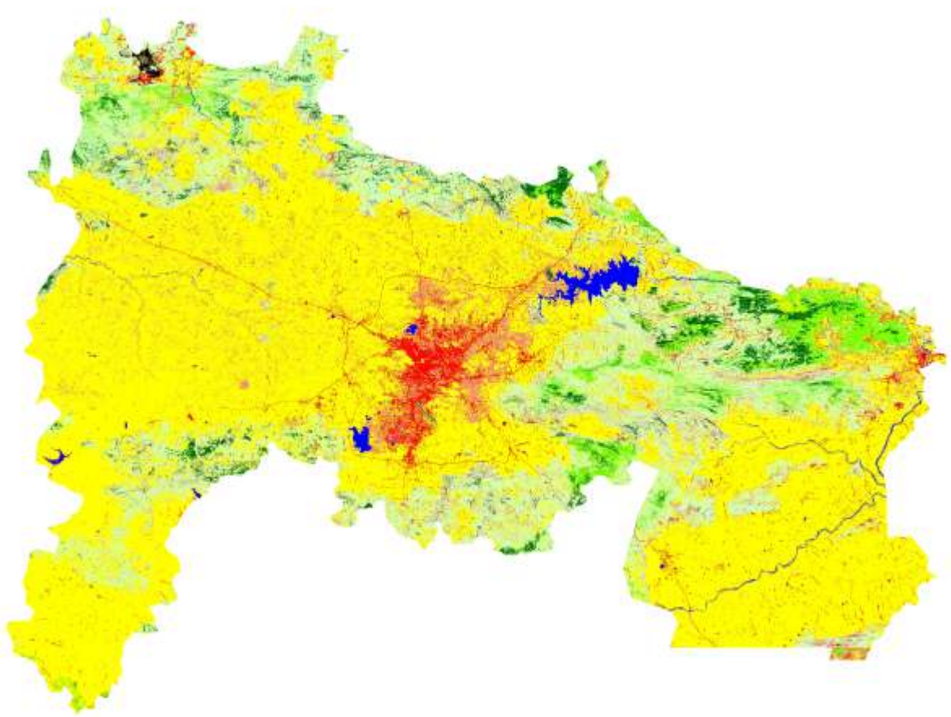
2.50 %
Other Land

RANCHI

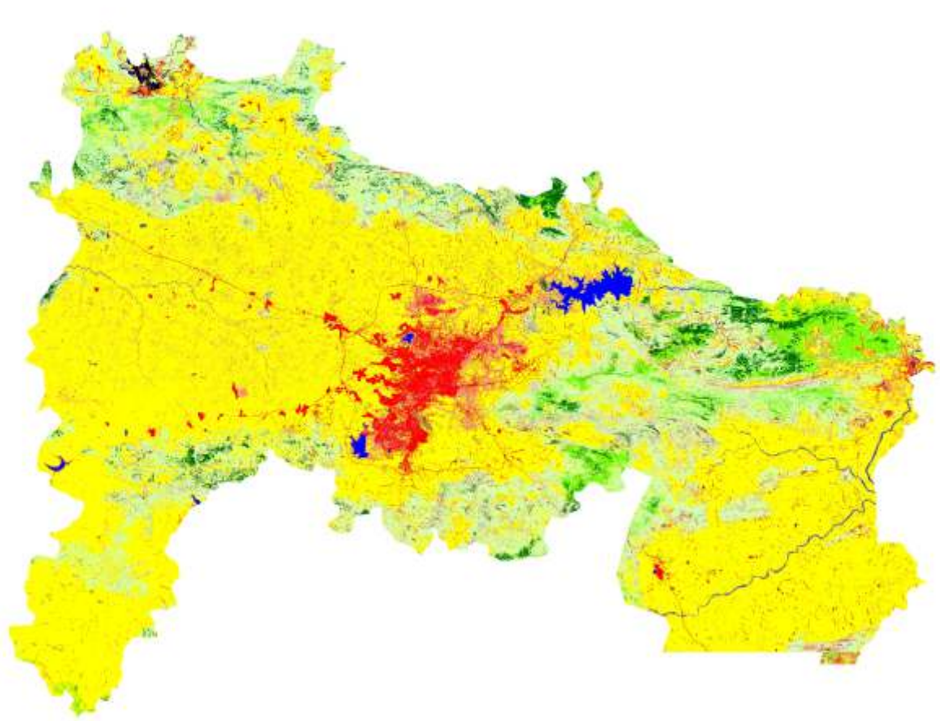
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	249.71	246.88	-2.83	-1.13
Wasteland	28.83	29.72	0.89	3.09
Coal Mine	4.75	5.37	0.61	12.90
Built Up	178.83	219.66	40.83	22.83
Water Bodies	42.80	41.23	-1.57	-3.67
VDF	120.65	118.88	-1.77	-1.47
MDF	191.73	189.03	-2.70	-1.41
Agriculture	2753.76	2754.47	0.71	0.03
OF	920.33	886.15	-34.18	-3.71

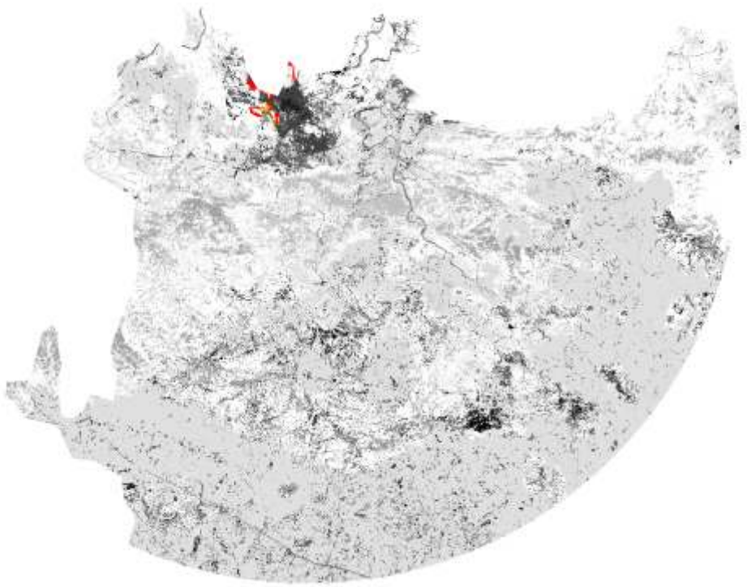
2004



2019



Change within the Periphery (20 km) of Coal Mines



Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

RANCHI

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	22.64	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	**22.83**
Waste Land	0.40	5.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**6.12**
Coal Mine	0.00	0.00	4.67	0.00	0.08	0.00	0.00	0.00	0.00	**4.75**
Built Up	0.00	0.00	0.00	13.19	0.00	0.00	0.00	0.00	0.00	**13.19**
Water Bodies	0.00	0.00	0.00	0.00	2.57	0.00	0.00	0.00	0.00	**2.57**
VDF	0.00	0.00	0.00	0.00	0.00	21.04	0.71	0.01	0.00	**21.76**
MDF	0.00	0.00	0.00	0.00	0.00	0.00	29.01	0.24	0.83	**30.09**
Agriculture	0.00	0.52	0.12	2.47	0.00	0.00	0.00	279.39	0.00	**282.51**
OF	0.00	0.71	0.57	0.04	0.16	0.00	0.04	9.82	198.70	**210.05**
Grand Total	**23.04**	**6.95**	**5.37**	**15.70**	**2.81**	**21.04**	**29.77**	**289.66**	**199.53**	**593.86**
CHANGE	**0.21**	**0.83**	**0.61**	**2.51**	**0.24**	**-0.72**	**-0.32**	**7.15**	**-10.52**	
CHANGE (%)	**0.94**	**13.63**	**12.90**	**19.04**	**9.34**	**-3.32**	**-1.07**	**2.53**	**-5.01**	

12.90 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	331.96	0.00	0.00	0.00	331.96
VDF	0.01	21.04	0.71	0.00	21.76
MDF	0.24	0.00	29.01	0.83	30.09
OF	11.31	0.00	0.04	198.70	210.05
TOTAL 2019	343.52	21.04	29.77	199.53	593.86
CHANGE	11.56	-0.72	-0.32	-10.52	
CHANGE %	3.48	-3.32	-1.07	-5.01	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.71	3.26%
VDF TO OF	0.00	0.00%
VDF TO NF	0.01	0.05%
MDF TO VDF	0.00	0.00%
MDF TO OF	0.83	2.76%
MDF TO NF	0.24	0.80%
OF TO VDF	0.00	0.00%
OF TO MDF	0.04	0.02%
OF TO NF	11.31	5.38%

3.26 %
VDF → MDF

5.38 %
OF → NF

Increase in Coal Mine Area

82.64 %
Forest Land

17.36 %
Agriculture Land

0.00 %
Other Land

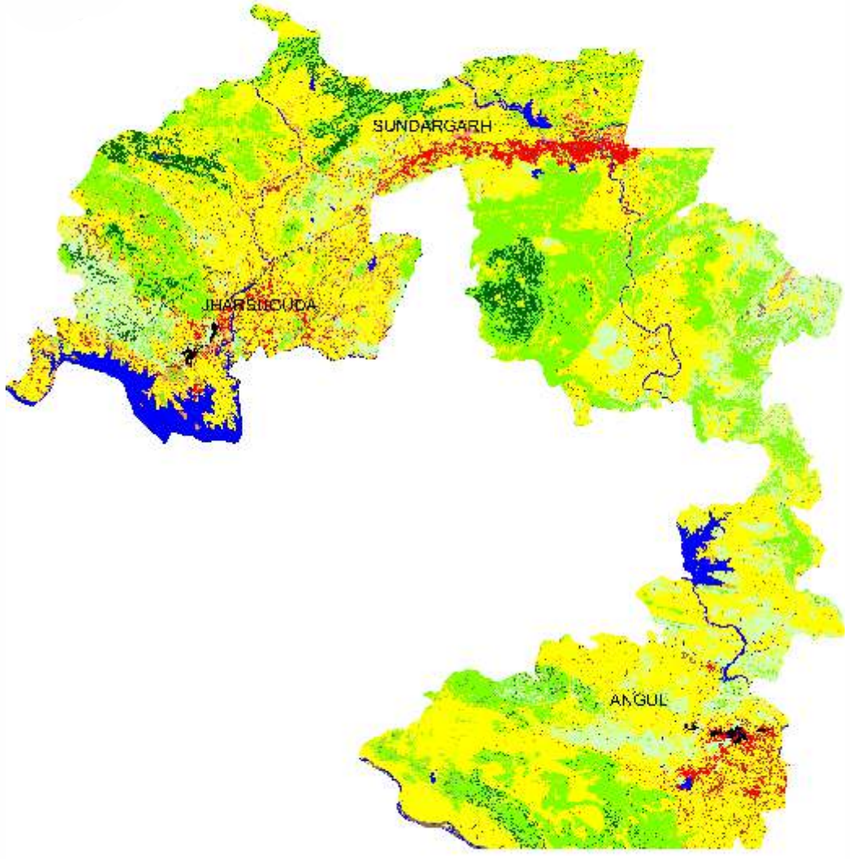
ODISHA

Assessment of Land-use/ Land cover Changes at District Scale

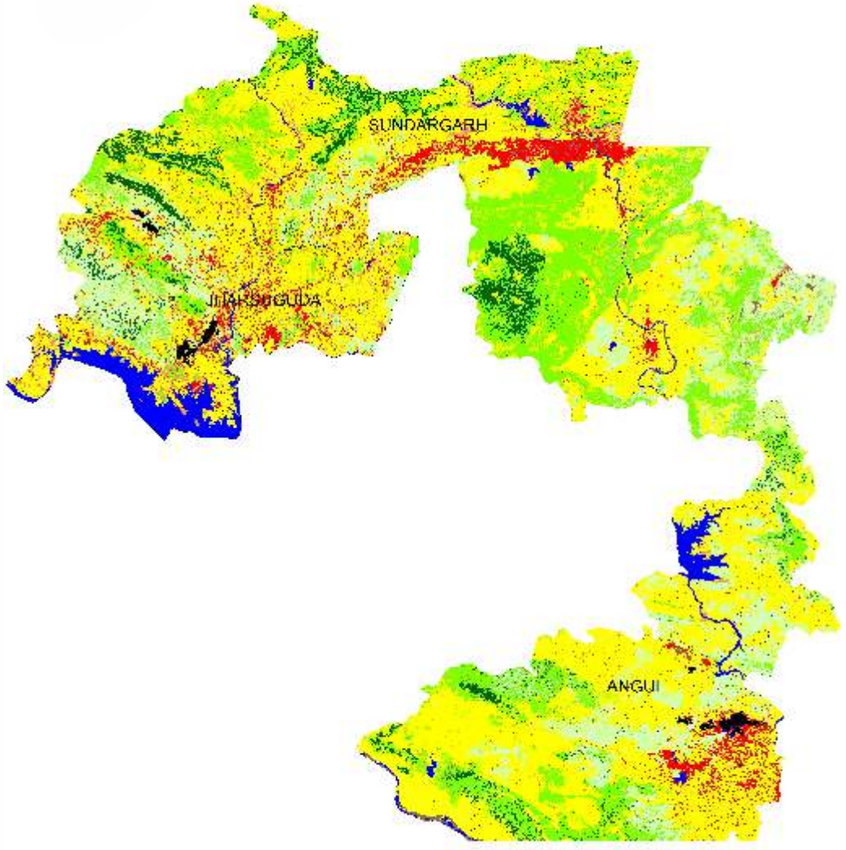
SUNDARGARH, JHARSUGUDA, ANGUL

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	284.10	280.49	-3.61	-1.27 %
Wasteland	145.71	157.23	11.52	7.91 %
Coal Mine	36.67 74.	82	38.15	104.03 %
Built Up	726.10	910.98	184.88	25.46 %
Water Bodies	609.87	608.42	-1.45	-0.24 %
VDF	588.90	703.72	114.82	19.50 %
MDF	3906.23	3260.69	-645.54	-16.53 %
Agriculture	8744.79	8612.59	-132.20	-1.51 %
OF	2014.43	2448.16	433.73	21.53 %

2004

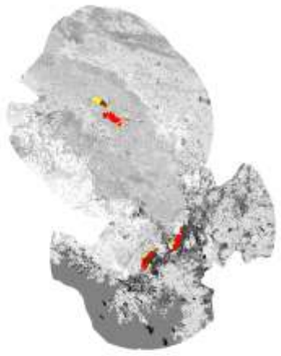


2019



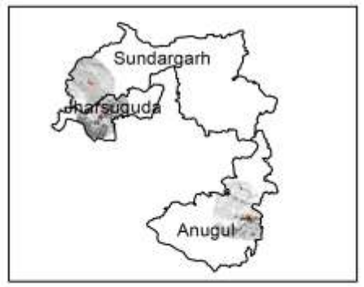
- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

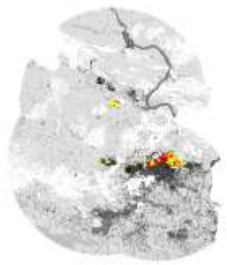
Change within the Periphery (20 km) of Coal Mines



Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes





ODISHA

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
Plantation	70.13	0.15	1.69	0.91	0.00	0.00	0.04	1.49	0.05	**74.46**
Waste Land	0.19	32.13	4.38	0.29	0.41	0.00	0.07	0.26	0.20	**37.93**
Coal Mine	1.01	0.97	31.87	1.37	1.17	0.00	0.00	0.20	0.08	**36.67**
Built Up	0.00	0.29	2.76	313.66	0.06	0.00	0.00	0.00	0.04	**316.82**
Water Bodies	0.00	0.00	0.22	0.27	279.23	0.00	0.00	2.21	0.00	**281.93**
VDF	0.00	0.00	0.00	0.03	0.02	126.56	11.48	0.00	0.00	**138.10**
MDF	0.00	0.09	6.14	4.40	0.01	44.57	310.28	8.67	217.40	**591.56**
Agriculture	0.16	3.50	14.91	61.54	1.53	0.00	0.14	2145.77	7.80	**2235.35**
OF	0.23	0.13	12.84	9.96	0.13	0.00	3.23	11.40	622.60	**660.51**
Grand Total	**71.72**	**37.25**	**74.82**	**392.44**	**282.56**	**171.14**	**325.23**	**2170.00**	**848.16**	**4373.32**
CHANGE	**-2.74**	**-0.68**	**38.15**	**75.62**	**0.63**	**33.04**	**-266.32**	**-65.35**	**187.66**	
CHANGE (%)	**-3.68 %**	**-1.79 %**	**104.03 %**	**23.87 %**	**0.22 %**	**23.92 %**	**-45.02 %**	**-2.92 %**	**28.41 %**	

104 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	2974.75	0.00	0.25	8.16	**2983.16**
VDF	0.05	126.56	11.48	0.00	**138.10**
MDF	19.31	44.57	310.28	217.40	**591.56**
OF	34.68	0.00	3.23	622.60	**660.51**
TOTAL 2019	**3028.79**	**171.14**	**325.23**	**848.16**	**4373.32**
CHANGE	**45.63**	**33.04**	**-266.32**	**187.66**	
CHANGE %	**1.53 %**	**23.92 %**	**-45.02 %**	**28.41 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	11.48	8.31%
VDF TO OF	0	0.00%
VDF TO NF	0.05	0.04%
MDF TO VDF	44.57	7.53%
MDF TO OF	217.4	36.75%
MDF TO NF	19.31	3.26%
OF TO VDF	0	0.00%
OF TO MDF	3.23	0.49%
OF TO NF	34.68	5.25%
NF TO OF	8.16	0.27%

8.31 % VDF → MDF

7.53 % MDF → VDF

36.75 % MDF → OF

5.25 % OF → NF

Increase in Coal Mine Area

44.19 % Forest Land

34.71 % Agriculture Land

21.10 % Other Land

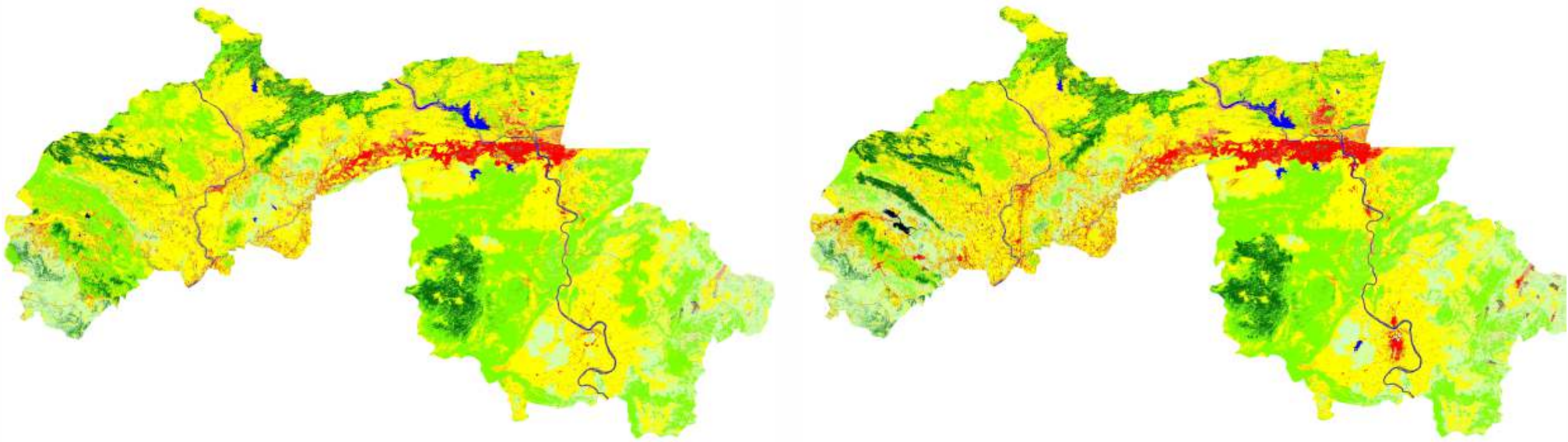
SUNDARGARH

Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	125.43	122.03	-3.40	-2.71 %
Wasteland	62.85	71.33	8.48	13.49 %
Coal Mine	1.03	10.45	9.43	917.95 %
Built Up	362.04	497.90	135.86	37.53 %
Water Bodies	99.67	98.63	-1.04	-1.04 %
VDF	514.49	552.52	38.03	7.39 %
MDF	2657.16	2335.90	-321.26	-12.09 %
Agriculture	4342.60	4218.85	-123.75	-2.85 %
OF	1082.48	1340.13	257.65	23.80 %

2004

2019

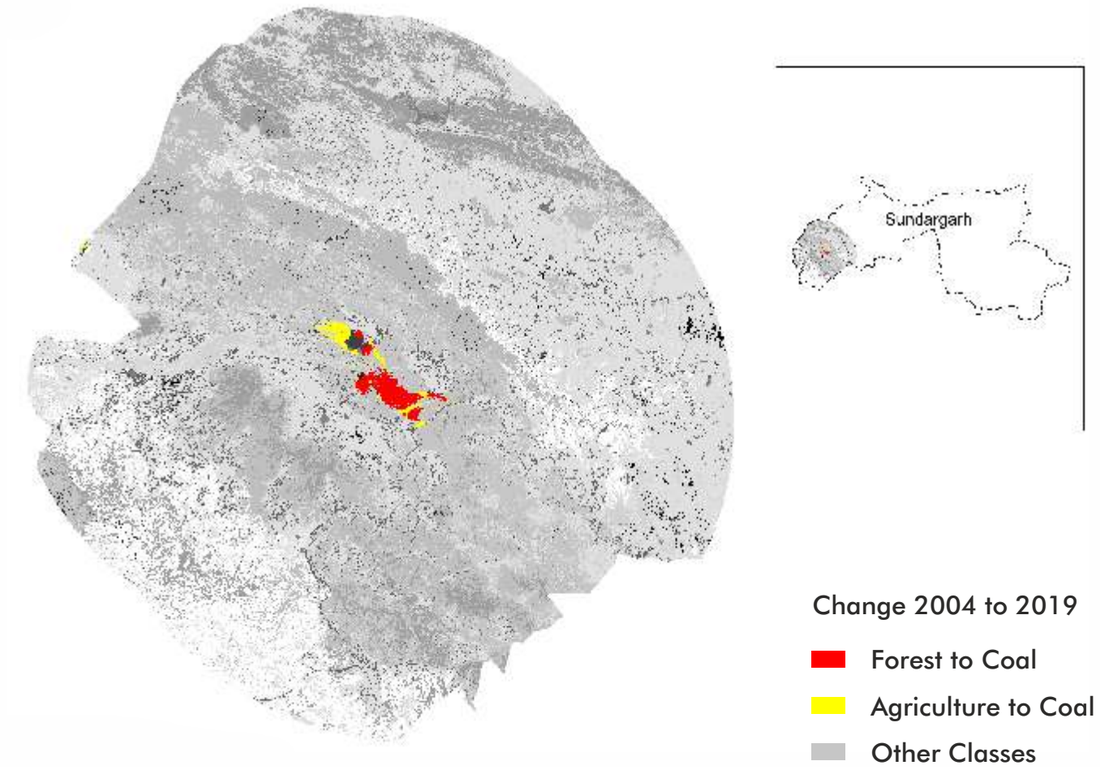


2004

Coal Mining Areas

2019

Change within the Periphery (20 km) of Coal Mines



SUNDARGARH

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	3.26	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	**3.33**
	Waste Land	0.00	3.12	0.19	0.00	0.00	0.00	0.00	0.03	0.00	**3.35**
	Coal Mine	0.00	0.00	1.03	0.00	0.00	0.00	0.00	0.00	0.00	**1.03**
	Built Up	0.00	0.00	0.04	51.67	0.00	0.00	0.00	0.00	0.00	**51.70**
	Water Bodies	0.00	0.00	0.00	0.00	4.89	0.00	0.00	1.40	0.00	**6.29**
	VDF	0.00	0.00	0.00	0.03	0.02	122.86	11.52	0.00	0.00	**134.43**
	MDF	0.00	0.09	5.91	4.39	0.01	40.28	196.03	0.03	172.06	**418.79**
	Agriculture	0.00	0.87	3.29	22.82	0.38	0.00	0.00	548.60	0.00	**575.95**
	OF	0.00	0.00	0.00	4.39	0.00	0.00	0.66	0.00	175.55	**180.60**
	Grand Total	**3.26**	**4.08**	**10.45**	**83.37**	**5.29**	**163.15**	**208.21**	**550.06**	**347.61**	**1375.48**
	CHANGE	**-0.07**	**0.73**	**9.43**	**31.66**	**-0.99**	**28.71**	**-210.59**	**-25.89**	**167.01**	
	CHANGE (%)	**-2.09 %**	**21.94 %**	**917.9 %**	**61.24 %**	**-15.82 %**	**21.36 %**	**-50.28 %**	**-4.50 %**	**92.47 %**	

917 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	641.65	0.00	0.00	0.00	**641.65**
VDF	0.05	122.86	11.52	0.00	**134.43**
MDF	10.42	40.28	196.03	172.06	**418.79**
OF	4.39	0.00	0.66	175.55	**180.60**
TOTAL 2019	**656.52**	**163.15**	**208.21**	**347.61**	**1375.48**
CHANGE	**14.87**	**28.71**	**-210.59**	**167.01**	
CHANGE %	**2.32 %**	**21.36 %**	**-50.28 %**	**92.47 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	11.52	8.57 %
VDF TO OF	0.00	0.00 %
VDF TO NF	0.05	0.04 %
MDF TO VDF	40.28	9.62 %
MDF TO OF	172.06	41.08 %
MDF TO NF	10.42	2.49 %
OF TO VDF	0.00	0.00 %
OF TO MDF	0.66	0.36 %
OF TO NF	4.39	2.43 %

8.57 % VDF → MDF

9.62 % MDF → VDF

41% MDF → OF

2.32 % OF → NF

Increase in Coal Mine Area

62.67 % Forest Land

34.88 % Agriculture Land

2.45 % Other Land

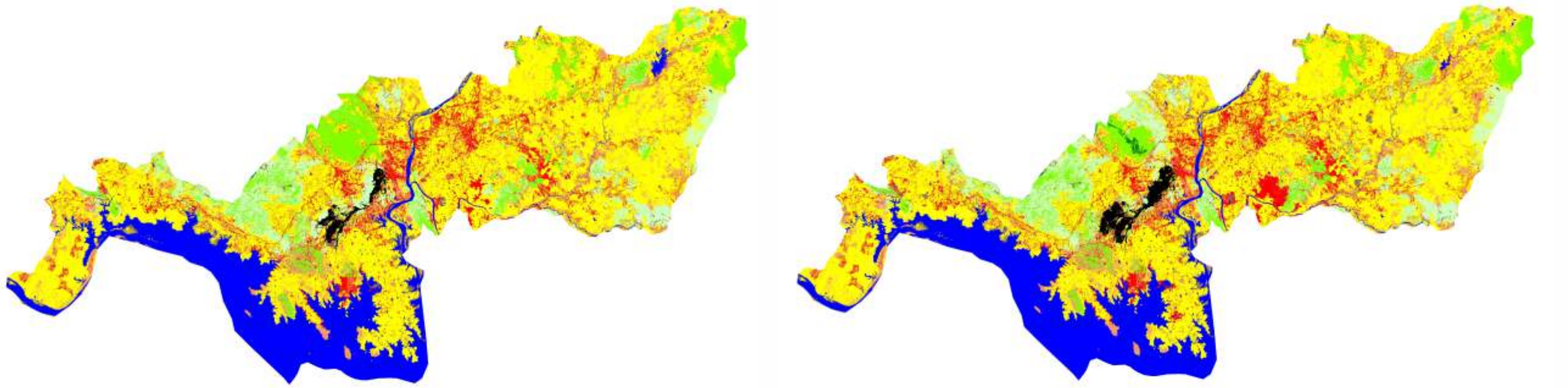
JHARSUGUDA

Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	125.30	126.09	0.79	0.63 %
Wasteland	28.93	29.49	0.56	1.94 %
Coal Mine	15.35	27.68	12.33	80.32 %
Built Up	179.61	199.41	19.80	11.02 %
Water Bodies	349.21	345.53	-3.68	-1.05 %
VDF	0.37	3.26	2.89	781.08 %
MDF	171.82	146.67	-25.15	-14.64 %
Agriculture	1095.33	1071.92	-23.41	-2.14 %
OF	165.86	181.74	15.88	9.57 %

2004

2019

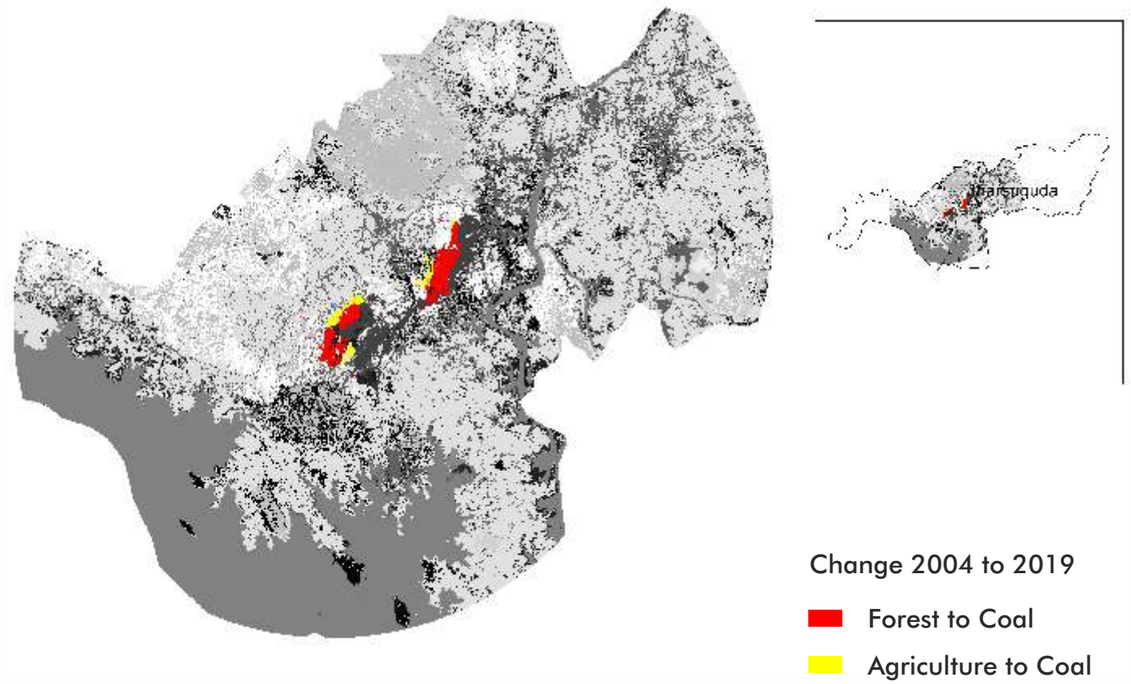


2004

Coal Mining Areas

2019

Change within the Periphery (20 km) of Coal Mines



Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	56.61	0.06	0.24	0.33	0.00	0.00	0.04	0.18	0.05	**57.51**
	Waste Land	0.17	19.63	1.77	0.07	0.41	0.00	0.07	0.23	0.20	**22.55**
	Coal Mine	0.00	0.00	15.32	0.03	0.00	0.00	0.00	0.00	0.00	**15.35**
	Built Up	0.00	0.00	0.03	113.34	0.03	0.00	0.00	0.00	0.00	**113.40**
	Water Bodies	0.00	0.00	0.00	0.26	237.17	0.00	0.00	0.81	0.00	**238.24**
	VDF	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	**0.38**
	MDF	0.00	0.00	0.23	0.02	0.00	2.88	76.56	0.00	24.07	**103.77**
	Agriculture	0.15	0.61	2.15	10.77	0.14	0.00	0.14	462.87	0.78	**477.61**
	OF	0.00	0.11	7.93	2.35	0.00	0.00	1.05	0.53	86.83	**98.80**
	Grand Total	**56.92**	**20.42**	**27.68**	**127.18**	**237.74**	**3.26**	**77.85**	**464.61**	**111.93**	**1127.60**
	CHANGE	**-0.59**	**-2.13**	**12.33**	**13.78**	**-0.50**	**2.88**	**-25.91**	**-13.00**	**13.14**	
	CHANGE (%)	**-1.02 %**	**-9.44 %**	**80.32 %**	**12.15 %**	**-0.21 %**	**768.10 %**	**-24.97 %**	**-2.72 %**	**13.30 %**	

80.32 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	923.38	0.00	0.25	1.03	**924.66**
VDF	0.00	0.38	0.00	0.00	**0.38**
MDF	0.25	2.88	76.56	24.07	**103.77**
OF	10.91	0.00	1.05	86.83	**98.80**
TOTAL 2019	**934.55**	**3.26**	**77.85**	**111.93**	**1127.60**
CHANGE	**9.89**	**2.88**	**-25.91**	**13.14**	
CHANGE %	**1.07 %**	**768.10 %**	**-24.97 %**	**13.30 %**	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0.00	0.00 %
VDF TO OF	0.00	0.00 %
VDF TO NF	0.00	0.00 %
MDF TO VDF	2.88	2.78 %
MDF TO OF	24.07	23.20 %
MDF TO NF	0.25	0.24 %
OF TO VDF	0.00	0.00 %
OF TO MDF	1.05	1.06 %
OF TO NF	10.91	11.05 %

2.78 %
MDF → VDF

23.20 %
MDF → OF

11.05 %
OF → NF

Increase in Coal Mine Area

66.07 %
Forest Land

17.40 %
Agriculture Land

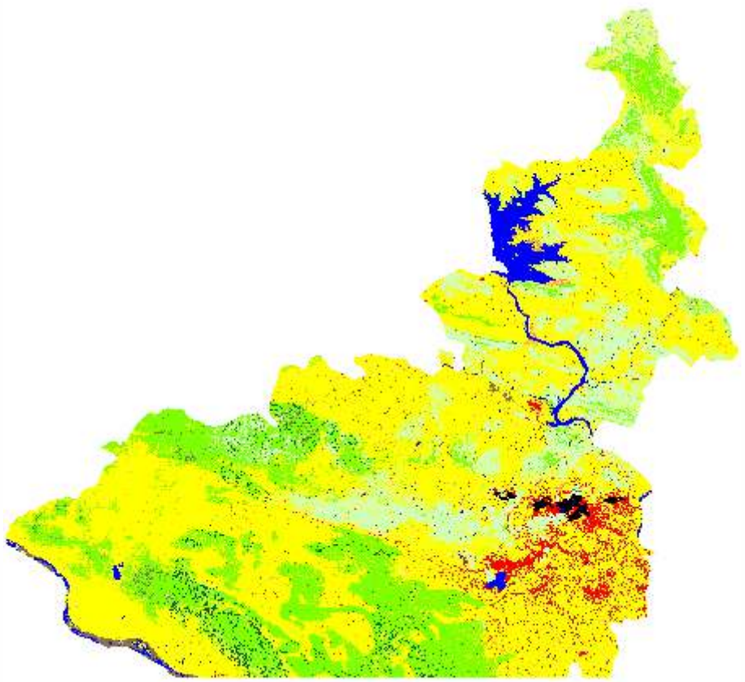
16.53 %
Other Land

ANGUL

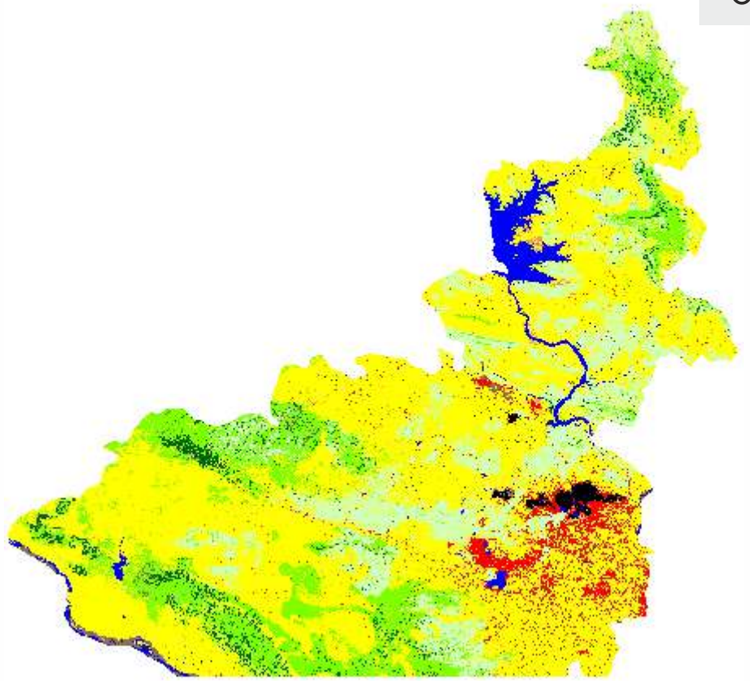
Assessment of Land-use

Class	2004 Area (sq km)	2019 Area (sq km)	Change (sq km)	Change (%)
Plantation	33.43	32.43	-1.00	-2.99 %
Wasteland	54.07	56.56	2.49	4.61 %
Coal Mine	20.30	36.69	16.39	80.78 %
Built Up	184.77	214.07	29.30	15.86 %
Water Bodies	161.24	164.51	3.27	2.03 %
VDF	74.44	148.30	73.86	99.22 %
MDF	1078.49	778.85	-299.64	-27.78 %
Agriculture	3309.21	3324.10	14.89	0.45 %
OF	767.49	928.20	160.71	20.94 %

2004



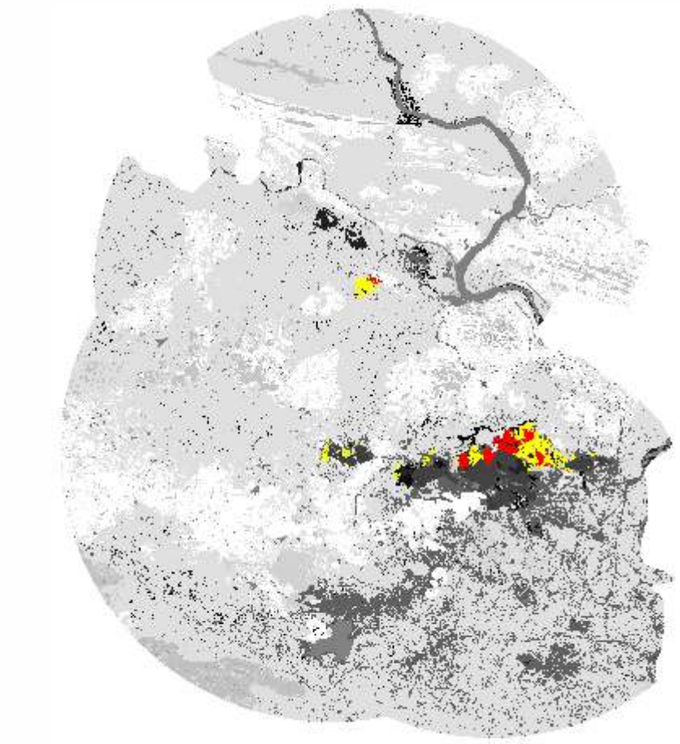
2019

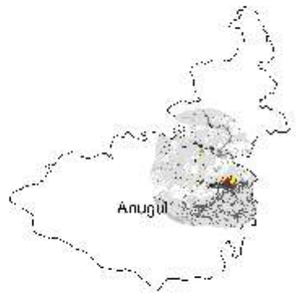


- Plantation
- Wasteland
- Coal Mine
- Built Up
- Water Bodies
- VDF
- MDF
- Agriculture
- OF

2004 — Coal Mining Areas — 2019

Change within the Periphery (20 km) of Coal Mines





Change 2004 to 2019

- Forest to Coal
- Agriculture to Coal
- Other Classes

Land Use Change Matrix (Area in km^2)

2019 \ 2004	Class	Plantation	Waste Land	Coal Mine	Built Up	Water Bodies	VDF	MDF	Agriculture	OF	Grand Total
	Plantation	10.26	0.09	1.45	0.51	0.00	0.00	0.00	1.31	0.00	**13.61**
	Waste Land	0.02	9.38	2.41	0.22	0.00	0.00	0.00	0.00	0.00	**12.04**
	Coal Mine	1.01	0.97	15.52	1.34	1.17	0.00	0.00	0.20	0.08	**20.30**
	Built Up	0.00	0.29	2.70	148.71	0.04	0.00	0.00	0.00	0.04	**151.77**
	Water Bodies	0.00	0.00	0.22	0.00	37.18	0.00	0.00	0.00	0.00	**37.40**
	VDF	0.00	0.00	0.00	0.00	0.00	3.52	0.00	0.00	0.00	**3.52**
	MDF	0.00	0.00	0.00	0.00	0.00	1.41	37.81	8.64	21.79	**69.64**
	Agriculture	0.01	2.02	9.47	27.98	1.01	0.00	0.00	1134.69	7.02	**1182.20**
	OF	0.23	0.02	4.91	3.22	0.13	0.00	1.53	10.87	360.39	**381.29**
	Grand Total	11.53	12.75	36.69	181.98	39.53	4.92	39.33	1155.71	389.32	1871.77
	CHANGE	-2.08	0.71	16.39	30.22	2.13	1.41	-30.31	-26.49	8.03	
	CHANGE (%)	-15.29 %	5.93 %	80.78 %	19.91 %	5.69 %	39.97 %	-43.53 %	-2.24 %	2.11 %	

80.78 %
Increase in Coal Mine Area

Change Matrix of Forest Area within the Periphery (20 km) of Coal Mines

CLASS	NF	VDF	MDF	OF	TOTAL 2004
NF	1410.19	0.00	0.00	7.13	**1417.32**
VDF	0.00	3.52	0.00	0.00	**3.52**
MDF	8.64	1.41	37.81	21.79	**69.64**
OF	19.37	0.00	1.53	360.39	**381.29**
TOTAL 2019	1438.20	4.92	39.33	389.32	1871.77
CHANGE	20.88	1.41	-30.31	8.03	
CHANGE %	1.47 %	39.97 %	-43.53 %	2.11 %	

CLASS	Area (Sq Km)	Change (%)
VDF TO MDF	0	0.00 %
VDF TO OF	0	0.00 %
VDF TO NF	0	0.00 %
MDF TO VDF	1.41	2.02 %
MDF TO OF	21.79	31.29 %
MDF TO NF	8.64	12.40 %
OF TO VDF	0	0.00 %
OF TO MDF	1.53	0.40 %
OF TO NF	19.37	5.08 %
NF TO OF	7.13	0.50 %

2.02 % MDF → VDF

31.29 % MDF → OF

12.40 % MDF → NF

5.08 % OF → NF

Increase in Coal Mine Area

23.20 % Forest Land

44.74 % Agriculture Land

32.06 % Other Land

CONCLUSION

A combined analysis of our study area shows that the land requirement for coal mining expanded by 62.75%. This expansion was observed to the tune of 55.29% in Chhattisgarh, 54.05% in Jharkhand, and 104.03% in Orissa, the three states that were a part of our study focus.

Our analysis also shows that of the 40.42 sq km of mine expansion that took place in Chhattisgarh between 2004-2019, 33.35% was on forest land, while 60.07% was on agricultural land. In the case of Jharkhand, coal mining expanded by 60.24 sq km between 2004-2019, and 33.26% of this land utilized for expansion was forest, while 58.02% of the land was agricultural land. In the case of Orissa, the land utilized for expansion of coal mining between 2004-2019 was 38.15 sq km, and 44.19% of this land was forest land, while 34.71% of this land was agricultural land. Overall, the loss of forests and agricultural land to expanded coal mining operations on 138.82 sq km in our study areas, was 39.66% (55.02 sq km) and 49.92% (68.32 sq km) respectively.

However, expansion of mining in itself is not the only issue in terms of impacts on forests and agricultural land. Expansion of mining operations entails expansion of offices and residential areas around mines, as well as expansion of ancillaries and feeder economic operations to provide services and goods to mines, offices and residences. In addition, expanded mining activities may also result in an expanded network of roads and motorized transport to evacuate the coal and send it to the places where there is a demand for it. Further, in many cases, there may also be a tendency for power producers to locate power plants close to the mining areas in order to minimize costs and logistical challenges associated with procurement of coal for power generation. All of this also means additional loss of natural resources as is borne out by our analysis of a 20 km radius around the coal mines that we were looking at. Thus, between 2004-2019, we found that in a 20 sq km radius from our mining focus areas, there had been a loss of 18.27% of Medium Dense Forests, while built up areas had expanded by 24.05%.

Thus, forests have borne the brunt of associated impacts of coal mining and this is an aspect that needs to be addressed, particularly because forests are essential for tribal populations for livelihoods and cultural practices and are required for meeting our international obligations for biodiversity conservation as well as climate change mitigation.

Landuse change statistics (Covering 20 km study area of all three states)

	Chhatisgarh		CHANGE (Sq km)	CHANGE (%)	Jharkhand		CHANGE (Sq km)	CHANGE (%)	Odisha		CHANGE (Sq km)	CHANGE (%)		Combine change		CHANGE (Sq km)	CHANGE (%)
	2004	2019			2004	2019			2004	2019				2004	2019		
Plantation	32.59	30.18	-2.41	-7.39%	465.03	462.43	-2.59	-0.56	74.46	71.72	-2.74	-3.68%	Plantation	572.08	564.33	-7.75	-1.35
Waste Land	63.4	66.58	3.18	5.02%	137.92	151.73	13.82	10.02	37.93	37.25	-0.68	-1.79%	Waste Land	239.25	255.56	16.31	6.82
Coal Mine	73.09	113.51	40.42	55.29%	111.45	171.7	60.24	54.05	36.67	74.82	38.15	104.03%	Coal Mine	221.21	360.03	138.82	62.75
Built Up	398.8	494.5	95.71	24.00%	1098.06	1363	264.97	24.13	316.82	392.44	75.62	23.87%	Built Up	1813.68	2249.94	436.26	24.05
Water Bodies	83.45	88.47	5.02	6.01%	208.6	189.31	-19.29	-9.25	281.93	282.56	0.63	0.22%	Water Bodies	573.98	560.34	-13.64	-2.38
VDF	180.26	191.36	11.1	6.16%	470.61	466.6	-4.01	-0.85	138.1	171.14	33.04	23.92%	VDF	788.97	829.1	40.13	5.09
MDF	912.05	803.6	-108.45	-11.89%	901.51	836.93	-64.58	-7.16	591.56	325.23	-266.32	-45.02%	MDF	2405.12	1965.76	-439.36	-18.27
Agriculture	7652.49	7572.52	-79.96	-1.04%	8823.55	8616.74	-206.81	-2.34	2235.35	2170	-65.35	-2.92%	Agriculture	18711.4	18359.3	-352.13	-1.88
OF	1942.13	1977.52	35.4	1.82%	2552.91	2511.16	-41.75	-1.64	660.51	848.16	187.66	28.41%	OF	5155.55	5336.84	181.29	3.52

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