Trans. Inst. Indian Geographers
ISSN 0970-9851
Indexed in Scopus

Opencast coal mining induced land use land cover change: A case study of Pandabeswar block, West Bengal, India through images available from Google Earth

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Abstract

The main objective of the present research is to identify the land use land cover change in the Pandabeswar Block of the Raniganj coalfield as a consequence of opencast coal mining practiced here. Geographical Information System (GIS) is used to identify the land use land cover change for the years 2011 and 2019. The study uses freely available satellite imageries from Google Earth for a detailed study of land use land cover changes. The result shows that the rapid and widespread development of opencast mining in the Pandabeswar block from the year 2011 to 2019 has resulted in rapid changes in land use and land cover of the block. The research highlights a decline in agricultural and forested areas, accompanied by an increase in fallow land and abandoned mine dumps, resulting in reduced land productivity. In addition, the lack of proper backfilling practices after mining worsens the harmful effects on the environment. Consequently, the research emphasizes the urgent need for improved planning and management in the study area by addressing the issues related to land reclamation and minimizing the negative impacts of opencast mining.

Keywords: *Opencast coal mining, land use land cover change, anthropogenic landform.*

Introduction

As a traditional energy source, coal is extremely important to a nation's overall economic development. Coal is a major source of power production in emerging economies like India. Currently, coal-based power plants in India supply 53.6 percent of the country's total energy consumption (Government of India, Ministry of Power, 2021). Coal is extracted primarily by two methods: underground mining and opencast (OC) mining. Opencast mining is particularly useful for near-surface and horizontal coal seams. This method allows the extraction of a larger portion of the coal deposits compared to underground mining. However, Opencast mining has various environmental impacts. The opencast method is responsible for the removal of huge amounts of waste materials (overburdens) and the formation of anthropogenic landforms like mine dumps and mine pits. After the completion of mining, the abandoned mines are left without any restoration of topography which is responsible for land degradation. Along with land degradation, other significant impacts of opencast mining include damage to flora and fauna, destruction of agricultural land, population displacement, blasting-induced vibration, land subsidence, mine fire, loss of groundwater, deterioration of ground and surface water quality, and dust dispersal (Bian & Lu, 2013; Chitade & Katyar, 2010).

The extraction of coal using the opencast method involves the removal of overlaying materials, including soil, rocks, vegetation, and water bodies, in order to facilitate the extraction process. As a consequence, various infrastructure and cultural features such as schools, offices, buildings, roads, and industries are unavoidably destroyed. Consequently, opencast mining has a profound and transformative impact on the LULC of the mining site. Furthermore, the environmental implications of opencast mining compel local communities to readjust their livelihoods. Due to the extensive spatial extent of opencast mines, the effects are felt over a large geographical area. Notably, the Pandabeswar block has experienced significant growth in opencast mines, resulting in substantial changes in the LULC pattern.

The evaluation of LULC changes in coal mining areas is very crucial for effective environmental management. Therefore, it is important to thoroughly investigate the patterns of LULC change as a consequence of opencast mining in order to comprehensively understand the consequences of this mining practice. The main focus of this paper is to investigate the nature and pattern of LULC changes in the Pandabeswar block resulting from opencast coal mining. The findings of this study are expected to contribute to a better understanding of the impact of opencast mining on land use and land cover, aiding in the management and mitigation of environmental issues associated with coal mining operations.

Objectives and significance

The main objective of the present study is to examine the nature of LULC changes in the Pandabeswar block during 2011 to 2019. During this period, the block experienced significant growth in opencast mining activities (Table 1). The aim of this research is to get insight into the nature of specific LULC changes that occurred in the Pandabeswar block during the specified timeframe. A key focus of this analysis is to establish the cause-and-effect relationship between these LULC changes and the practices of opencast mining using the Geographical Information System (GIS) method. The study used freely available satellite imageries from Google Earth for a detailed study of land use land cover changes. The findings of this study will contribute to a better understanding of the complex interactions between opencast mining and LULC changes, ultimately guiding effective land management strategies and facilitating sustainable development in the Pandabeswar block.

Study area

Pandabeswar block is situated in the Paschim Bardhaman District of West Bengal State of India (Fig. 1). The total area of the block is 98.13 km^2 and the total population is 161891 as per the 2011 Census. In this block, coal mining is mainly operated by Eastern Coalfield Limited (ECL).

Among the various blocks and municipal corporations of Raniganj Coalfield, the expansion of the area under opencast coal mines has been measured using Landsat images for the years 1990, 2000, 2010, and 2020, and the results are presented in Table 1which reveals significant and rapid expansion in the area under opencast

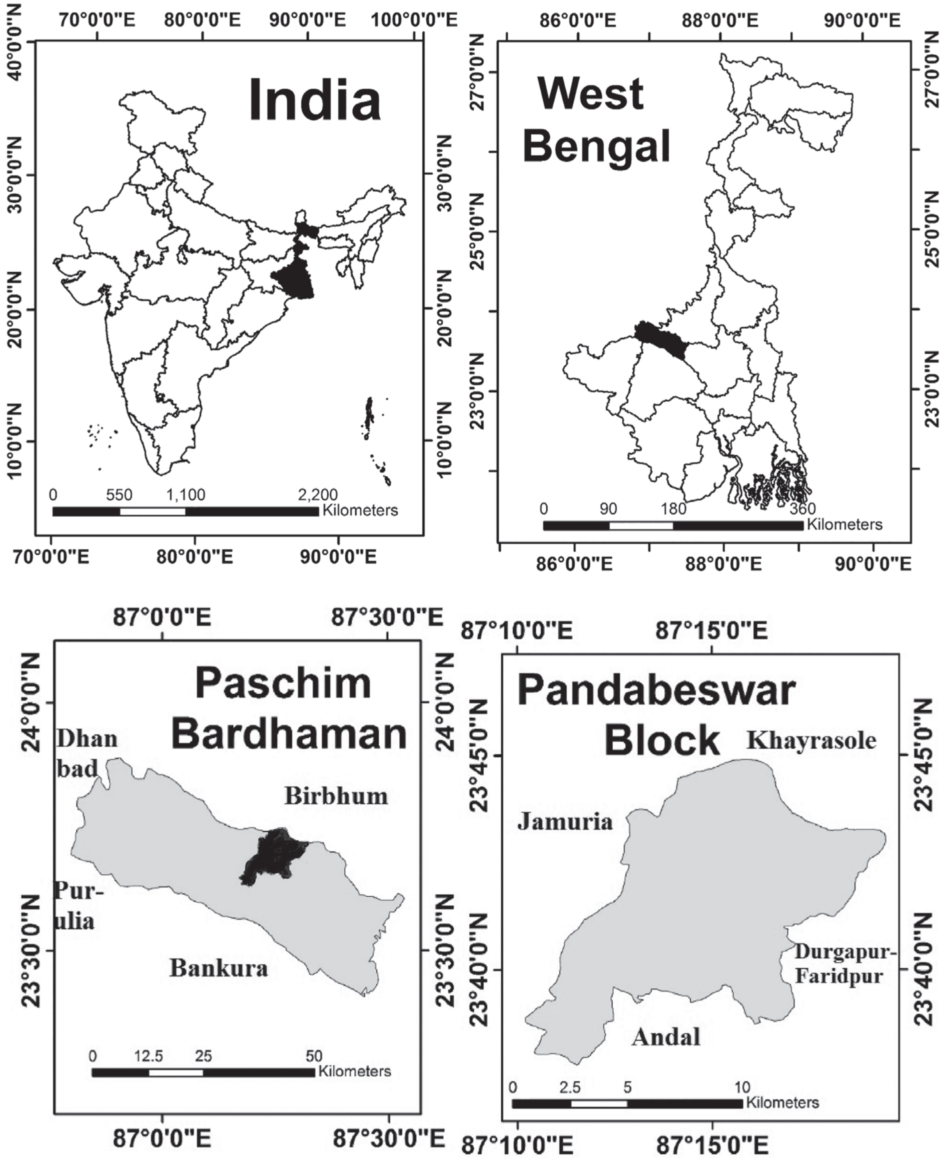


Fig. 1: Location of the study area.

mines within Raniganj Coalfield as well as in Pandabeswar block. The total area of opencast mines (including mine dumps and mine pits) in Raniganj Coalfield increased to 52.26 km^2 in 2020 from a mere 18.59 km^2 in 1990 within a span of three decades much of during the last decade (Table 1). The growth rate is over 181 percent. The rapid expansion in the opencast area in Pandabeswar block is even more intense with a growth rate as high as 434 percent, increasing from 4.61 km^2 in 1990 to 24.62 km^2 in 2020 (Table 1). This is why the Pandabeswar block has been selected for an intensive study on mining-induced

Table 1: Raniganj coalfield: Opencast coal mines area in different blocks and Municipalities (in km^2)

Block/Municipality	Area in1990	Area in 2000	Area in 2010	Area in 2020
Salanpur Block	2.23	1.85	1.15	2.23
Kulti Municipality	1.00	2.17	2.05	3.84
Barabani Block	1.26	1.12	2.15	3.84
Jamuria Municipality	0	0	0	0.61
Andal Block	0	0.57	0.73	0.78
Asansol Municipal Corporation	0	0	0	1.1
Jamuria Block	0.09	1.36	7.47	8.12
Pandabeswar Block	4.61	6.31	12.14	24.62
Raniganj Block	0	0.84	0.633	1.09
Nirsa Block	8.64	6.11	3.30	6.04
Raniganj Municipality	0.77	0.70	0.4	0
Total	18.59	21.02	30.03	52.26

Source: Landsat images, 1990, 2000, 2010, 2020

LULC changes. Table 1 reveals the maximum increase in opencast mining areas compared to other blocks or municipalities under the Raniganj coalfield. Google Earth Images of 2011 and 2019 have been profitably used for LULC change analysis.

Methodology

Unlike satellite images, Google Earth does not allow processing of images or downloading them with spatial information such as latitude, longitude, and electromagnetic radiation values (DN values), it does offer the option to download images in JPEG format through the Google Earth software. This enables the application of GIS operations on these images, providing a wide range of possibilities.

Additionally, the historical imagery tool provided by Google Earth permits temporal assessment of temporal changes in surface features over time. This feature is particularly useful for conducting LULC change studies, as it allows researchers to observe and analyze the alterations in the Earth's surface over different periods. In summary, Google Earth images serve as a valuable resource for conducting LULC change detection, despite the inherent limitations.

In this study, Google Earth images were downloaded from the Google Earth software and georeferenced using the place-mark point method. This method involved saving place-mark points with their corresponding latitude and longitude values as labels at the four corners of the downloaded images. The latitude and longitude labels were used to georeference these images. The georeferenced images were then re-projected to the Universal Transverse Mercator Projection (UTM) and WGS-84 datum, which are commonly used for coordinate systems.

Different LULC classes were identified and measured by digitizing the images. Once all the changes in the LULC classes were measured, a final analysis was done to establish the relationship between LULC change and opencast coal mining in the study area. Field visits were conducted to verify and validate the accuracy of the LULC change assessment. During these field visits, efforts were made to match the LULC classes identified from Google Earth with their corresponding locations on the ground.

Result and discussion

Specific images of the years 2011 and 2019 were chosen due to their superior visibility and clarity compared to the images of the previous years. The selected images were free from cloud cover which can be a hindrance in analyzing LULC changes. It is important to note that cloud presence in Google Earth images is difficult to remove.

LULC classes have been identified from the field survey as well and through change detection analysis using the historical imagery tool provided by Google Earth. The area of LULC classes has been measured using ArcGIS 10.2 software from the Google Earth Images of 2011 and 2019 and is represented in Table 2 and Fig. 2. A total of nine classes were identified such as fallow land, active opencast mines, built-up areas, agricultural land, abandoned mine dumps, abandoned mine pits, brick kiln industries, forests, and water bodies (Fig. 2).

Increase in the area of opencast mines

The area occupied by active mines in relation to the total area of the Pandabeswar block (98.13 km^2) shows a substantial increase (Fig. 2). In 2011, active mines accounted for 10.27 percent of the total area, while in 2019, their share increased significantly to 20.23 percent (Table 2). This indicates a significant areal expansion and growth in active mining activities within the block during this period.

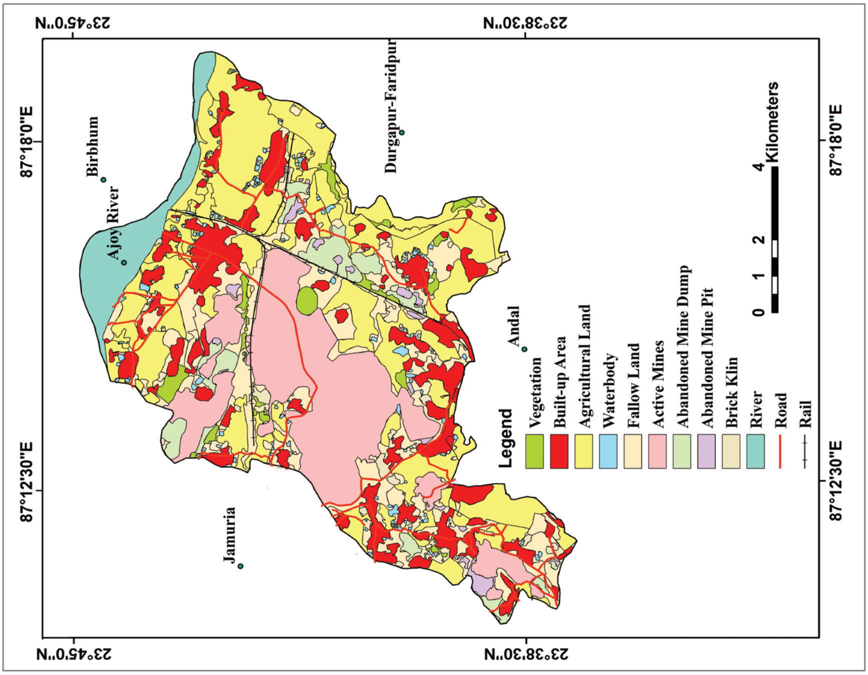
A number of large and important opencast mines like Sonepur-Bazari, Shankarpur, Bilpahari, Mahalaxmi, Jambad, and Khottadihi are situated in Pandabeswar block (Fig. 3). Table 3 shows that area of active opencast mines has rapidly increased from 10.08 km^2 in 2011 to 19.85 km^2 in 2019- almost doubling in a span of 9 years. The expansion of the Sonepur-Bazari opencast (9.943 km^2) mine and Mahalaxmi opencast (0.934 km^2) mine is the highest among the opencast mines in Pandabeswar block (Table 3).

Changes in built-up area

The built-up area, which includes settlements and infrastructure, has witnessed a marginal decrease from 13.85 km^2 in 2011 to 13.52 km^2 in 2019 (Table 2). The expansion of opencast mines has led to the destruction of various habitations such as Bhaluka, Dahuka, Hansdiha, Punjabidanga, Bhatmura, and others. Additionally, the adverse effects of opencast mining, including vibrations caused by blasting, groundwater exploitation leading to scarcity, and the issue of dust dispersion from opencast projects, have rendered the area unsuitable for habitation. Consequently, the built-up area has decreased (Table 2). Only a few rehabilitation sites, namely Sonepur-Bazari and Bilpahari, have been developed for the purpose of relocation. However, a number of habitations and roads have been destroyed for the purpose of opencast mining which decreased the built-up area.

Reduction in the area under vegetation

One of the major impacts of opencast coal mining within the Raniganj coalfield is deforestation (Lahiri-Dutt, 2001). Formation of new opencast mines or expansion of earlier



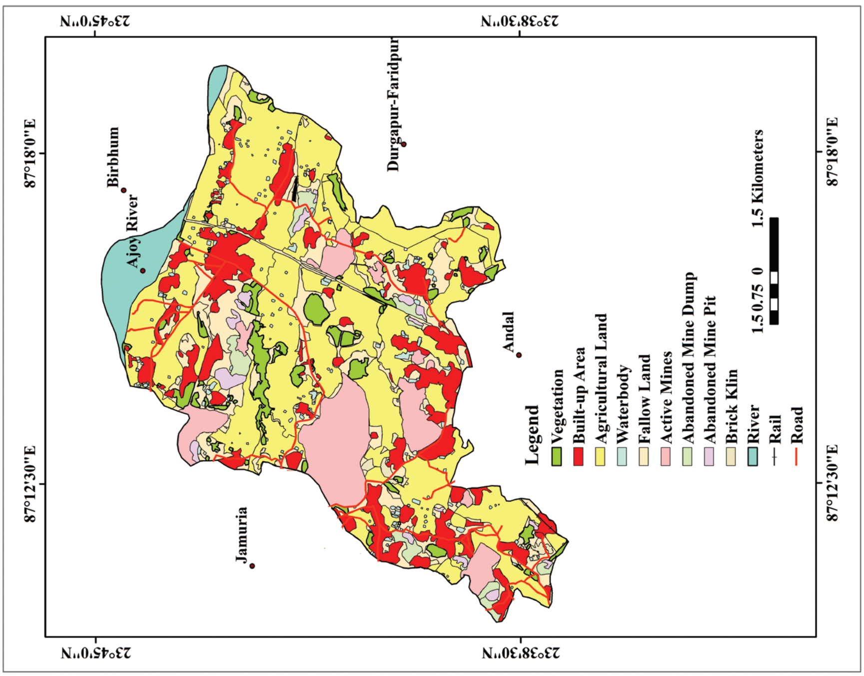


Fig. 2: LULC classes for the year 2011 and 2019

Source: Google Earth Images of 2011 and 2019

Table 2: LULC classes for the year 2011 and 2019

LULC Classes	Area 2011 (km^2)	% Area in 2011	Area 2019 (km^2)	% Area in 2019	Change	% LULC change
Built-up area	13.85	14.11	13.52	13.78	-0.33	-2.40
Vegetation	4.96	5.05	2.22	2.26	-2.74	-55.34
Agricultural land	45.09	45.95	32.05	32.66	-13.04	-28.91
Active mines	10.08	10.27	19.85	20.23	9.77	96.97
Fallow land	14.99	15.28	18.66	19.01	3.67	24.48
Abandoned mine Dump	1.84	1.88	3.71	3.78	1.88	102.33
Abandoned mine pit	1.40	1.43	1.13	1.15	-0.27	-19.35
Brick kiln Industries	0.60	0.61	1.38	1.41	0.79	131.66
Waterbody	5.32	5.42	5.61	5.72	0.29	5.45
Total	98.13	100	98.13	100		

Source: Google Earth Images (2011 and 2019)

opencast mines in Pandabeswar block has destroyed a large amount of forest land (Fig. 4). It is important to note that in 2011, the area of vegetation accounted for 5.05 percent of the total area of the block. However, by 2019, this proportion had decreased to 2.26 percent, reflecting a significant decrease in the percentage of area covered by vegetation (Table 2).

Table 2 shows that area of vegetation decreased from 4.96 km^2 in 2011 to 2.22 km^2 in 2019 registering a phenomenal -55.34 percent decrease. The expansion or development of new opencast mines in the forest areas is one of the major contributing factors to this (Fig. 4). Table 4 lists some of the major opencast mines of Pandabeswar block that are responsible for the destruction of forest areas. According to the table, the Mahalaxmi opencast project, Khottadhi opencast mine Bilpahari, and Sonepur-Bazari opencast mine have undergone development or expansion, resulting in the loss of 1.38 km^2 of forest area between 2011 and 2019.

Loss of agricultural land

Opencast mines require extensive land for various purposes, such as dumping, coal storage sites, road construction, office buildings, staff quarters, rehabilitation sites, and more. Consequently, agricultural land is acquired to accommodate the infrastructure and operations of opencast mining. One of the main impacts of opencast mining on agricultural land is the destruction caused during the mining process. Excavation and removal of soil and vegetation disrupt the natural balance and fertility of the land, making it unsuitable for agricultural activities.

Table 3: Expansion of the area of different opencast mines of Pandabeswar Block, 2011-2019

Opencast Mine	Area in 2011 (km^2)	Area in 2019 (km^2)	Expansion in area (km^2)
Jambad	0.878	1.269	0.391
Sonepur-Bazari	4.987	14.93	9.943
Khottadihi	1.10	1.89	0.79
Mahalakshmi	0.286	1.22	0.934

Source: Google Earth Image 2011 and 2019

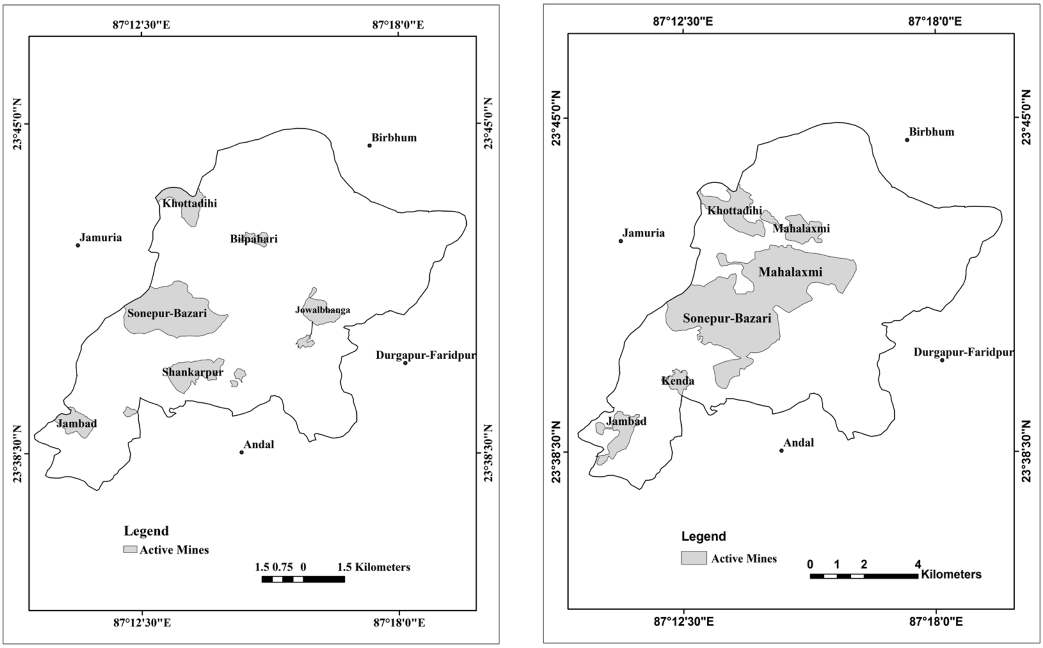


Fig. 3: Active opencast mines of Pandabeswar Block (2011 and 2019)

Source: Images available from Google Earth 2011 and 2019

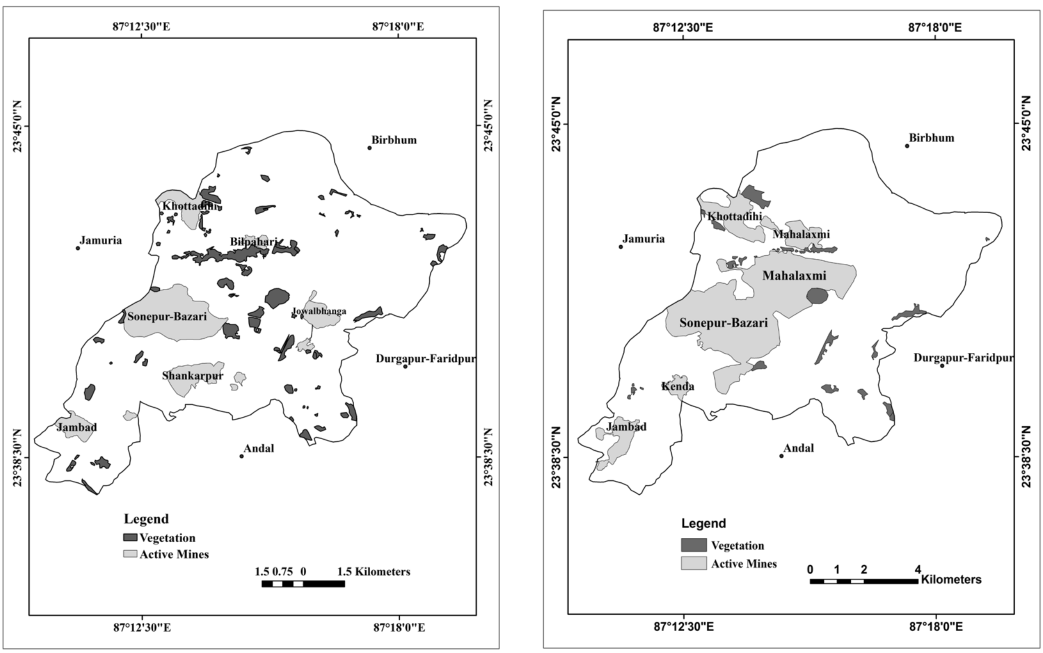


Fig. 4: Pandabeswar Block-Area under vegetation (2011 and 2019).

Source: Images available from Google Earth (2011 and 2019)

Table 4: Pandabeswar Block- Loss of forest land by some of the major opencast mines

Name of the opencast mine	Loss of forest land (km^2) during 2011-2019
Khottadihi	0.22
Bilpahari	0.12
Mahalaxmi	0.57
Sonepur-Bazari	0.46
Jambad	0.01
Total	1.38

Source: Images available from Google Earth (2011 and 2019)

Table 5: Pandabeswar Block: Loss of agricultural land by major opencast Mines, 2011-2019

	Loss of Agricultural Land (km2)
Kenda opencast Mine	0.57
Jowalbhanga opencast Mine	1.45
Jambad opencast Mine	0.33
Mahalaxmi opencast Mine	3.36
Sonepur-Bazari opencast Mine	2.19
Total	7.9

Source: Google Earth Images 2011 and 2019

It should be mentioned that agricultural land in 2011, accounted for 45.95 percent of the land cover. However, by 2019, it had significantly declined to 32.66 percent of the total area (Table 2). This shows a drastic fall in agricultural land within the block during this period as a consequence of increased opencast mining activity.

Expansion of earlier opencast mines and the development of new projects has resulted in the shrinking of agricultural land in the Pandabeswar block from 45.09 km^2 in 2011 to 32.05 km^2 in 2019 with a 28.91 percent decrease (Table 2). The majority of the opencast mines in Pandabeswar block are indeed expanding at the cost of the agricultural land.

Table 5 presents the extent of agricultural land destruction caused by several major opencast mines in the Pandabeswar block. According to the table, the expansion of Jowalbhanga opencast mine, Kenda opencast mine, Mahalaxmi opencast mine, and Sonepur-Bazari opencast mine has resulted in the diversion of a total of 7.9 km^2 of agricultural land. It was noteworthy that a part of the present agricultural land has already been acquired for the purpose of rehabilitation for Khottadihi, Sonepur, Bazri, Bilpahari, and other sites. Thus, it is very difficult to identify the actual area of present agricultural land (31.55 km^2). This difficulty arises from the fact that this acquired land is not detectable in the Google Earth image. As a result, accurately determining the precise extent of the remaining agricultural area became extremely difficult.

Increase in fallow land

It is important to note that the share of fallow land in relation to the total area of the block has increased from 15.28 percent in 2011 to 19.01 percent in 2019 (Table 2). The increase in the area of fallow from 14.99 km^2 in 2011 to 18.66 km^2 in 2019 is a direct consequence

Fig. 5 Abandoned mine pits are forming pit lakes near Damalia Village.

Fig. 6: Brick kiln developed adjacent to the Damagaria opencast mines to use the topsoil extracted from the mine.

of opencast mining activities. Opencast mining has several negative impacts on the surrounding agricultural land too, contributing to its degradation and conversion into fallow land.

Apart from the conversion of agricultural land, the increase in fallow land can also be attributed to various other negative impacts of opencast mining. For example, the deposition of coal-borne dust into the soil can affect its fertility and productivity. Lowering the groundwater table due to mining activities can lead to water scarcity, making irrigation difficult and impacting crop growth. Land subsidence, the presence of mine fires, and the sliding of materials from mine dumps also contribute to the degradation of the surrounding agricultural land.

Increase in the area of abandoned mine dump

The share of the area occupied by abandoned mine dumps, in relation to the total area of the block experienced a significant increase. In 2011, abandoned mine dumps accounted for 1.88 percent of the total area, while in 2019, this share had risen substantially to 3.78 percent (Table 2). This indicates a significant expansion and growth of abandoned mine dumps within the block during this period. Once the extraction process is completed, the abandoned mines are not reclaimed or backfilled, leading to the expansion of the area covered by mine dumps. The area of abandoned mine dumps has increased from 1.84 km^2 in 2011 to 3.71 km^2 in 2019 with a 102 percent increase (Table 2). Land degradation is a significant outcome of opencast mining. Once the coal extraction is completed or the coal deposits are depleted, it becomes imperative to restore the original topography and productivity of the land through effective reclamation methods. However, in the Pandabeswar block, abandoned opencast mines are left without proper restoration, resulting in land degradation and reduced productivity.

Changes in abandoned mine pit

The area of abandoned mine pits has decreased from 1.40 km^2 in 2011 to 1.13 km^2 in 2019- a decline of 19.35 percent (Table 2). This decline has taken place despite the significant increase in opencast mine area. This is due to the use of abandoned mine pits as a dumping ground for the overburdened materials extracted from the opencast mines. Instead of reclamation, mine pits have been used as a place of dumping of the overburden materials. The dumping activities are not aimed at restoring the original topography of the abandoned mine pits. Instead, materials are being dumped above the ground level; resulting in the conversion of the abandoned mine pits into mine dumps. This practice has resulted in the conversion of mine pits into mine dumps; leading to a decrease in the overall area occupied by abandoned mine pits. However, it is important to note that this process does not address the environmental concerns associated with abandoned mine dumps. While the area of abandoned mine pits may have decreased, the expansion of mine dumps still poses significant environmental challenges. Abandoned mine pits are forming pit lakes due to the storage of rainwater (Fig. 5). These pit lakes however used for fishing and as water storage for nearby communities. In contrast, the use of abandoned mine pits as dumping grounds is negatively impacting these pit lakes. Thus, the area occupied by abandoned mine pits has decreased from 2011 to 2019. This practice of improper dumping causing water pollution and habitat degradation, affects both the ecological balance and the usefulness of these lakes for the surrounding communities.

Increase in area under brick kiln industries

The appropriate utilization of topsoil exclusively for reclamation purposes is of utmost importance. However, in the Pandabeswar block, it has been observed that topsoil is being utilized by brick kiln industries instead. As a result, the area and number of brick kiln industries located adjacent to the active and abandoned topsoil dumps of the opencast mines have increased from 2011 to 2019 (Table 2). The share of the area occupied by brick kilns in relation to the total area of the block, has experienced a significant two-fold increase. Brick kilns in 2011, accounted for 0.61 percent of the total area, while in 2019, their share had risen significantly to 1.41 percent (Table 2).

The actual area of the brick kiln industry within the Pandabeswar block has experienced substantial growth from 0.60 km^2 in 2011 to 1.38 km^2 in 2019, reflecting a significant growth rate of 131.66 percent (Table 2). This growth can be attributed to the utilization of soil derived from the topsoil dumps specifically for brick production. Instead of being used for land reclamation purposes, the topsoil extracted from the mines is being used for brickmaking. Thus, brick kiln industries have developed adjacent to the opencast mines using the topsoil extracted from the mines (Fig. 6). Consequently, brick kiln industries have emerged in close proximity to the opencast mines, capitalizing on the readily available topsoil from these extraction sites. The demand for bricks within the region has been fueled by rehabilitation programmes and the development of new habitation sites, such as Sonepur-Bazari, Bilpahari, and others. This growing demand has further contributed to the rapid expansion of the brick kiln industry within the Pandabeswar block. It is important to highlight that the topsoil dumps should be conserved for their crucial role in land reclamation. The utilization of topsoil in the upper layer of reclaimed land is vital to preserving the productivity of land. However, the diversion of topsoil for brick-making has a damaging impact on land reclamation efforts.

Changes in the area of water bodies and river

Table 2 shows that the area of water bodies which also includes the rivers have increased by 5.45 percent from 2011 to 2019 (5.32 km^2 in 2011 to 5.61 km^2 in 2019). Although this expansion may not be related with opencast mining, it can be attributed to the shifting of the Ajoy River towards the Pandabeswar block. Consequently, the area of water bodies has increased from 2011 to 2019 (Fig. 2).

Conclusion

Opencast mining operations have brought about profound changes in the LULC of the mining sites of the Pandabeswar block. These changes extend beyond the mining areas, impacting the LULC of adjacent regions as well. Backfilling and restoring the topography is necessary in the block in order to make the land productive again. In the Pandabeswar block abandoned opencast mines are left without restoring the topography, which results in degradation of land and its productivity. Vast stretches of agricultural land, forest land, and productive land have been transformed into unproductive wastelands. The use of topsoil by the brick kiln industry has destroyed the valuable topsoil and affected land reclamation after mining. The mining has resulted in the conversion of vast stretches of land into fallow land. Instead of reclamation, mine pits have been used as a place for dumping of the overburden materials leading to the conversion of the abandoned mine pits into mine dumps. The major change in LULC classes includes a decrease in the area of vegetation and agricultural land with a corresponding rise in the area occupied by abandoned mine dumps, fallow land, and brick kiln industries.

Competing interest

The authors declare that they have no conflict of interest.

References

Bian, Z. & Lu, Q. (2013). Ecological Effects Analysis of Land Use Change in Coal Mining Area Based on Ecosystem Service Valuing: A Case Study in Jiawang. *Environmental Earth Sciences*- 68, 1619–1630.

Chitade A. Z. & Katyar, S. K. (2010). Impact Analysis of Open Cast

Coal Mines on Land Use/ Land Cover Using Remote Sensing and GIS Technique: A Case Study. *International Journal of Engineering Science and Technology*. 2 (12), 7171-7176.

District Census Handbook: Barddhaman. (2011). Village and Town Directory. Directorate of Census Operations, West Bengal. Ministry of Home Affairs, Salt Lake City, Kolkata-700106.

Eastern Coalfields Limited (A Subsidiary of Coal India Limited). Annual Report & Accounts (FY 2008-09 to 2016-17). PO: Dishergarh, Dist: West Burdwan, PIN: 713333, West Bengal.

Government of India Ministry of Power. (2021). Power Sector at a Glance All India. https://powermin.gov.in/en/content/power-sector-glance-all-india.

Lahiri-Dutt, K. (2001). *Mining and Urbanization in the Raniganj Coalbelt*. The World Press Private Limmited, Kolkata 7000073.

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