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Case Study

Impact of Expanding Coal Industry on the Regional Environment in an Indian Coal-Belt - A Case Study from Jharkhand, India

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Abstract: Environmental sustainability of coal industry is a major concern considering the trends of its exponential effect on the region and towards climate change. The study examines the land use/land cover changes using spatio-temporal datasets of the years 2000 and 2020 in Dhanbad district which comes under the major coal-belt of India. The study shows the impact of expanding industries on the environment depicting a remarkable decrease in vegetation (18.89%), increase in built-up land (14.32%) and coalfields (0.9%) exhibiting massive deforestation activities. The study focuses on the increase in emissions from coal mining activities including GHGs, SOx, PMs, etc. over the years and their harmful impacts on the region. The sustainability evaluation of the coalfields of the study area is done through 15 predetermined indicators, suggesting the urgency and need of actions for sustainable functioning of coal mining industry in order to limit global warming to below 2 °C as suggested in the Paris Agreement-2016. The study also lays stress on the changing economic pattern of the region as an effect of increasing industrialization and changes in the land use.

***Keywords*:** land use/land cover, environmental sustainability, GHG emissions, Jharia coalfield

JEL Codes: Q01, Q24, Q32, Q53, Q54, R14, Z21

1. Introduction

Coal is one of the most abundantly available and the most used fossil fuel in the world, there are 1,074,108 million tonnes of proven coal reserves on the earth (Statistical Review of World Energy, 2021). While coal makes an important contribution to worldwide energy generation, its environmental impact has always been a challenge (Cheng et al., 2011; Giam et al., 2018; Goswami, 2015; Kolker et al., 2006; Mishra, 2004; Singh, 1988; Szczepanska, 1999; Tiwary, 2001; Zhengfu, 2010), due to which there has been a declining trend in the global primary demands for coal. The global coal demand declined 4% in the year 2020, but, in the case of India, a continuous growth in the demands has been observed which is also the highest as compared to any other country in the world. This accounts for over 14% of global demand by 2030, up from around 11% in 2019 (IEA, 2020). The coal demand was 300 Mtoe (around 33% of the national demand) in the year 2000 which was 40% in the year 2010, increased to 44% in the year 2019 and remained consistent (around 425 Mtoe) in the year 2020 (IEA, 2021b). Coal accounts for half of the energy produced in India today, and coal supply and end use attract a third of total annual energy investment (IEA, 2021a).

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India is the second-biggest coal producer and consumer in the world (IEA, 2020; Ministry of Coal, 2020). In the year 2018, the country produced 771 Mt of coal which is 7.9% of the global production (IEA, 2018). India also accounts for 12% of the global coal consumption and 240 Mt of coal was imported by India which made it the world's second-biggest coal importer (IEA, 2018). Around 75% of India's major production of electricity is achieved through coal-based thermal power plants (Ministry of Coal, 2021). India's coal share in primary energy consumption is expected to decline from 56% in 2017 to 48% in 2040 which is still nearly half of the total energy mix and way ahead of any other source of energy (Statistical Review of World Energy, 2018). India's coal production is increasing and produced a record high 729 Mt of coal in 2020 (Ministry of Coal, 2020). In a move to create a commercial coal sector in India, 40 new coalfields in some of India's most ecologically-sensitive ancient forests are to be opened up for coal mining (Petersen, 2020). This planned increase is not in sync with pledges, targets and goals of India including Paris Agreement under which India aims to reduce the emissions intensity of GDP by 33%-35% by 2030 below 2005 levels. The continuous and uncontrolled exploitation of coal over the decades has caused significant damage to the local environment (Castleden, 2011; Corbett, 1983; Deonarine et al., 2013; Kalia et al., 2017; Searle, 2006; Wang et al., 2008; Yun-jia, 2009; Zhang et al., 2016). Toxic gases are released from coal-fired plants like oxides of sulphur, nitrogen, carbon and other particulate matters and heavy metals which increase air pollution and result in smog, acid rain, and toxins in the environment (Baig, 2017; Liu et al., 2008; Pandey et al., 2018; Schreiber, 2009; Thitakamol, 2007). The coal used for power generation results into almost 75% of total carbon dioxide and 63% of sulphur oxide emissions in the atmosphere (Garg et al., 2002). The production of coal itself has a severe detrimental impacts on the surrounding region, there are numerous damaging environmental impacts of coal that occur through its mining, preparation, combustion, waste storage, and transport (Chen et al., 2015; Guo et al., 2018; Marquez et al., 2018; Tao et al., 2012). The coal mines lead to land subsidence, destruction of local water resources, soil erosion, air pollution, decreasing biodiversity, vulnerability to the local livelihood, impact on health, threat to infrastructure and life (Dutta et al., 2017; Ghose & Majee, 2000; Goswami, 2015; Hossain et al., 2015; Junker & Witthaus, 2013; Mishra, 2009; Niu et al., 2020). It is fundamental to perceive that coal mining is a significant emitter of GHGs (Black & Aziz, 2009; Garg et al., 2001; McGrath, 2008; Satterthwaite, 2008) and is the focus of increasing attention from green groups and regulators of the entire world to meet the climate related agreements and ensure low-carbon based policy development (Sun et al., 2020). In coal-mining industries, the majority of the emissions are attributed to fugitive emissions, mine fires, land-use change, etc. (Karacan et al., 2011; Sovacool, 2014; Tambo et al., 2016). Apart from adding harmful GHGs in the environment and inducing deforestation, they are also a major source of various other harmful elements which intrudes the local environment through soil, water, air etc (Duruibe et al., 2007; Pandey et al., 2018; Saha et al., 2017; Zhengfu et al., 2010).

On the other hand, the establishment of huge mines in the coal-belts has been major source of economic generation for those region (Anderson, 1995; Manowska et al., 2017; Szpor & Ziółkowska, 2018). It has over the years provided employment to various local groups but at the same time, it has increased the risk of weaker long-term economic growth of the region. The companies who operate the mines usually abandon the land after mining or shift to other places with higher potential of extraction, this leads to people losing their jobs. Thus, there is a low probability of coal mining to provide long-term employment. Also, the technological shift has led to less labor demand over the years. The number of coal mining jobs has been observed to be declining in India, the number of employees of the largest coal company of the country i.e., Coal India Limited have decreased from 510,671 in the year 2003 to 272,445 in the year 2020 (Statista, 2022).

Coal undoubtedly is still core to the economic growth of India (utilized for electricity production, steel making, etc.), but even after considering its impact on the economy, many countries have started to decrease coal burning because of its harmful impacts (Carvalho, 2017). The present scenario demands urgent reduction and managing the negative impacts that occur due to the continued expansion of coal mining industry in the regions of India and increase social and environmental sustainability along with stabilizing the economy of the coal mining sector. The objective of this study is to detect the land use/land cover change of the study area over two decades (i.e., from year 2000 to 2020), the impact of coal mines over the region due to relentlessly expanding coal industry and assess the functioning of the coal mining sector in order to check if the operating companies are working ethically and as per the guidelines provided by the local or national authorities of India.

2. Materials and methods

In India, coal is mined basically along Damodar Valley, Sone-Mahanadi Valley, Pench-Kanhan Valley and Wardha-Godavari Valley. The areas with the bulk of coal reserves are confined to parts of Jharkhand, West Bengal, Odisha, Chattisgarh and Madhya Pradesh. Among all, the most crucial region for coal production in India is the district of Dhanbad in the Damodar Valley with many important coalfields and the mining activities have been exponentially expanding in Dhanbad over decades (Saini et al., 2016). This study was carried out at the Dhanbad district of Jharkhand which supports various important coalfields in India like Jharia, Raniganj (Bhowmik & Dutta, 2013), etc. The study area lies between 23° 37' 3" N to 24° 4' N latitude and 86° 50' E to 86° 59' E longitude (Figure 1). The region produces bituminous coal suitable for coke and in the most dominant activity of this region. It also supports many industries like steel plants, coal plants which are usually intimately attached with consumption of coal and allied materials which are fed mainly by the metallurgical coal produced in the Jharia Coalfield of Dhanbad.

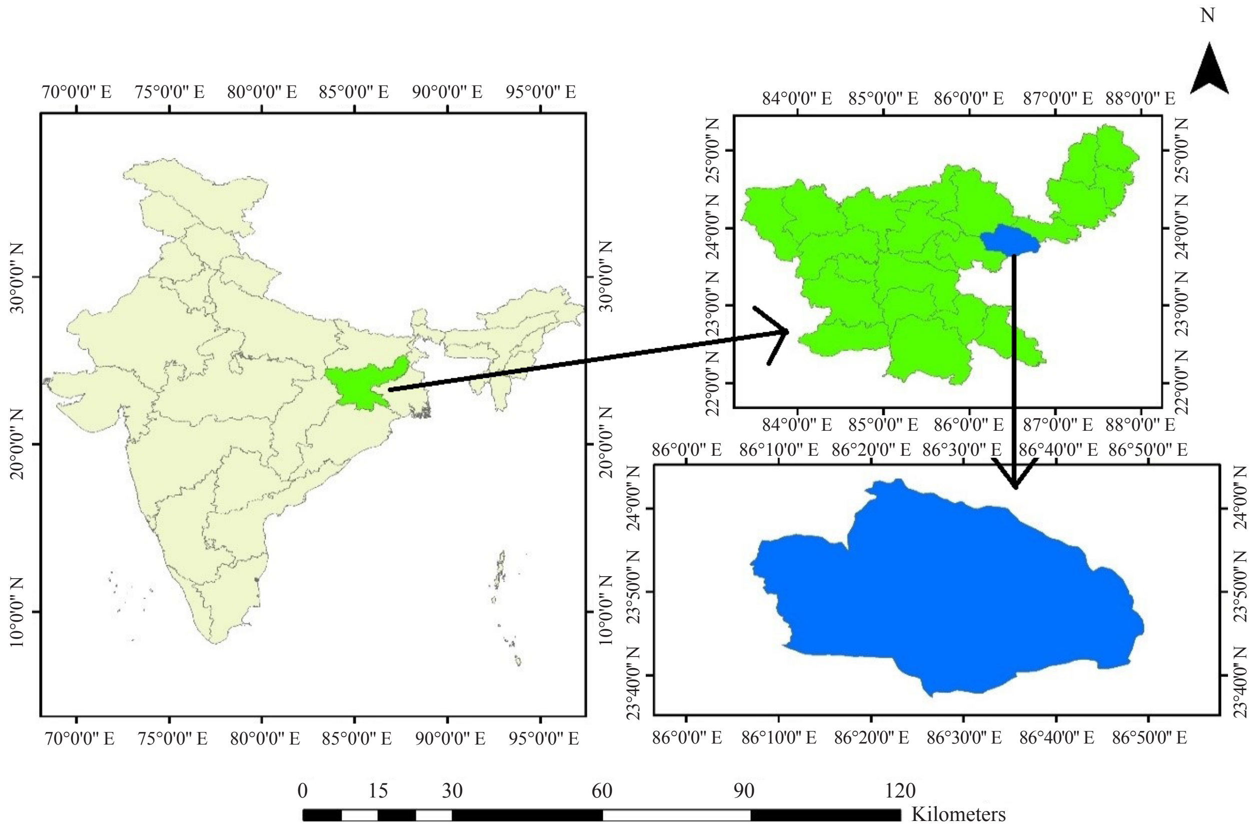


Figure 1. Location map of study area

To evaluate the Land Use Land Cover (LULC) pattern and its change, LANDSAT-8, 2020 and LANDSAT-5 TM, 2000 satellite imageries were used (Table 1). All the data analysis and thematic map were prepared using ArcGIS 10.6 software. The LANDSAT satellite images were downloaded from the USGS website (http://earthexplorer.usgs.gov) for the year 2000 (MSS) and 2020 (OLI). These satellite images were geometrically corrected and acquired in the standard projection system (UTM 45N, WGS84 datum). The satellite images for both the years (i.e., 2000 and 2020) were acquired in the month of November, as it experiences least rainfall and thus less cloud cover in India, due to which the impact of seasonal variations was very insignificant. The Maximum Likelihood Classification is performed and the changed area in different year is calculated for various features including non-forest vegetation, built-up land, mining area, river and water body etc and further the LULC change map was finalized.

Table 1. Details of data used

LANDSAT sensor	Spatial resolution	Temporal resolution	Date of acquisition	Path and row	Cloud cover
MSS	30 meters	16 days	19th November 2000	149-43	0%
OLI	15 meters	16 days	26th November 2020	149-43	0%

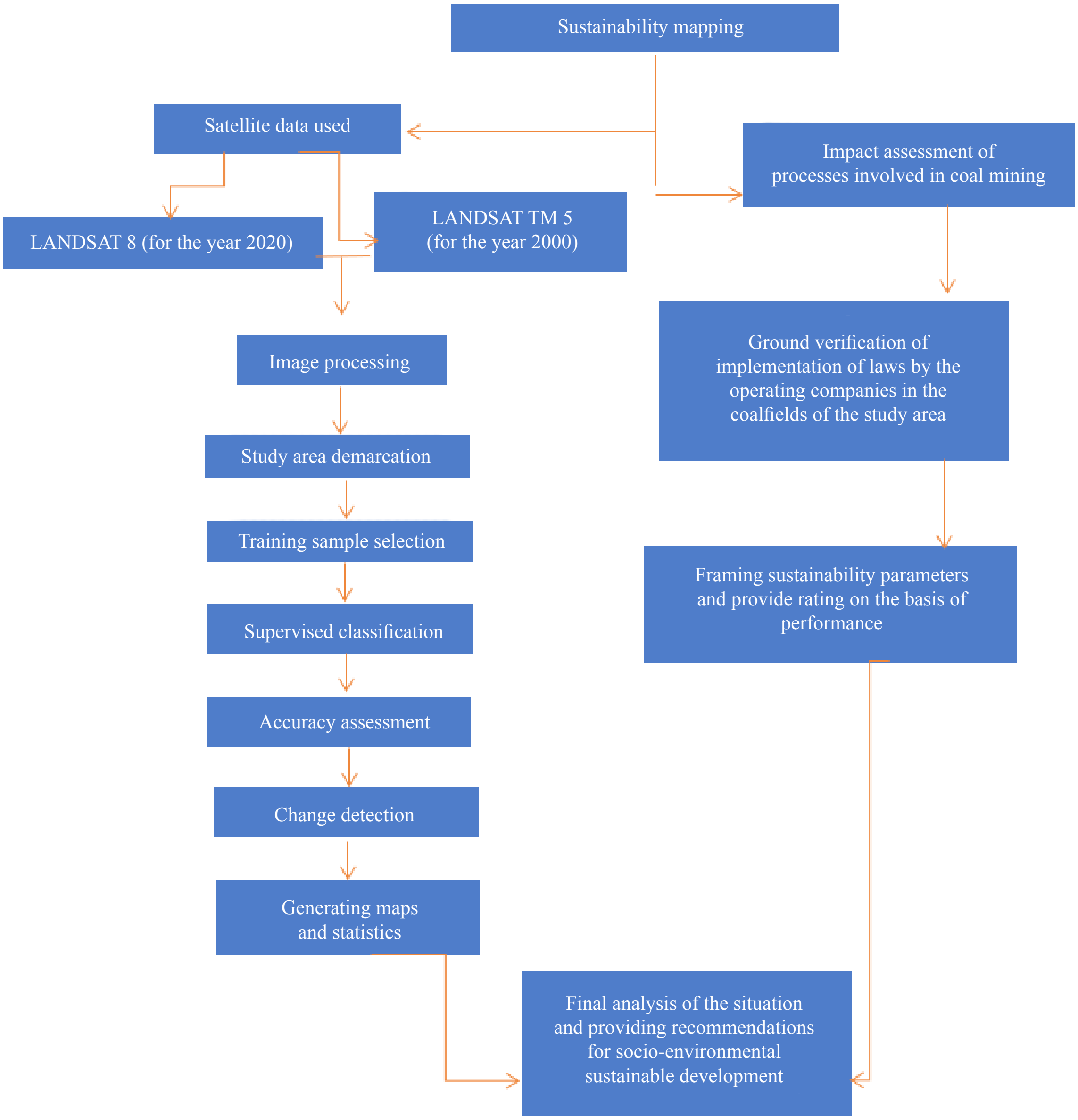


Figure 2. Methodology flow chart

For analysing the effect of the tremendous change in the land use/land cover pattern, the authors elaborately discussed the processes (Figure 2) performed by the operating in coal mining and the impact it makes on the environment and the society.

To assess the impact of coal industries on the environment and society extensive literature survey was carried out from the year 1992 onwards (section 3).

For monitoring and measuring the progress of a Company towards sustainability and corporate responsibility, a hybrid methodology has been used, for which 11 main approaches were identified (Bhattacharya, 2015), namely: 1. Surveys, 2. Award schemes, 3. Investor's criteria, 4. Benchmarking, 5. Sustainability indexes, 6. External communication tools, 7. Accreditation processes, 8. standards and codes, 9. Sustainability indicators, 10. Metrics for sustainability performance and 11. Non quantifiable sustainability initiatives. The data has been collected through questionnaire surveys, interview and field to study their operational impacts, related offset and initiatives. Additionally, CSR reports, sustainability reports and/or annual reports have been collected from the operating companies' website which was thoroughly analysed. Based on the information collected, the authors have finalized fifteen major indicators for assessment of the companies' initiatives and activities towards socio-environment sustainability. The indicators were also derived after a thorough assessment and converging all the prevalent issues that was raised during the survey and discussion with the local people including officials from the operating companies. The indicators are as follows: 1. Environmental Clearance and Compliance, 2. Ecological Restoration, 3. Satellite Mapping and 4. Environmental Awareness, 5. New Initiatives, 6. Action Plans, 7. Health Services, 8. Employment and Education, 9. Land Use and Territorial Aspect, 10. Infrastructural Development, 12. Land Reclamation, 13. Medical Facilities, 14. Action Plans for Resettlement and Rehabilitation, 15. Safety in mines. Under each indicator the coalfields are assessed based on their level of sustainability which is levelled as needs improvement, average or efficient. Selection of level is determined based on certain predetermined conditions. This content analysis-based assessment is to evaluate the socio-environmental sustainability condition and the level of sustainable development by the operating companies in the mining area.

3. Literature review

The study was conducted based on extensive literature review about the environmental, social, economic, health effect of coal mining in and around the mining region (Table 2). Apart from the literatures mentioned in the table below, various other literatures have been consulted in the study which are been cited in other section of the article.

4. Results and discussions

4.1 *Land use/land cover change analysis*

The results of LULC status of study periods 2000 and 2020 depicts land use land cover change in different categories forest vegetation, non-forest vegetation, water bodies, build up land, barren land. The maps (Figure 3 and Figure 4) exhibit significant changes in built-up land followed by land under coal mining activity. The study indicates that the total vegetation (forest and non-forest) was 1,655.53 km^2, covering 79.53% of land within the study area in 2000, which decreased significantly 1,263.33 km^2 (60.64%) in 2020 (Table 3, Figure 3 and Figure 4). A reverse trend is noticed with built-up land which witnessed rapid changes from 78.79 km^2 (3.78%) in 2000 (dominantly in southern and south-western parts) to 376.81 km^2 (around 18.104%) in 2020, (spreading central, south-western, north-eastern parts). A similar trend in LULC was observed with respect to coal mining areas, which increased from 39.56 km^2 (1.90%) in 2000 to 56.35 km^2 (2.707%) in 2020. The study reveals that there is a negative change of dense forest vegetation over the study period i.e.-16.82 from 2000 to 2020 (Table 3).

Table 2. List of major studies referred for social, environmental, economic and health impact of mining

Authors	Description
Haigh et al., 1992	The research article discusses about the deteriorating conditions of reclaimed land. It talks about the reason for poor condition of so-called reclaimed land. The study also suggests ways to correct these problems and discusses about the benefits of plantation, etc to make soils self-sustaining.
Allan, 1995	The study detailed local and regional level impacts of mining, waste generated from mining, tailings etc on land and aquatic ecosystems. The results show that areas of wasteland are under risk of getting contaminated by heavy metals etc which ultimately is leading to pollution in land, water bodies and other coastal regions.
Deegan & Gordan, 1996	The article discusses environmental disclosure practices through analysis of annual reports etc of few corporate companies of Australia. The article shows that most of the companies present their positive work in respect to environment in more over-emphasized manner and totally ignore the negative impacts that they are creating on the environment. The study also shows that over the selected time period there is an increase in the degree of disclosures made by the companies.
Dudka & Adriano, 1997	The study talks about the deleterious effect of mining on the environment. The study describes various case studies Various case studies to throw light on the negative impact on the inhabitants of the region. Under this study, a risk assessment has also been performed to study the food chain contamination.
Deegan et al., 2000	This study describes the condition of the mining-based companies in association with their disclosure reports. The study considers few social incidents and assessed the indication of those events in the annual disclosure reports of the selected companies. It was analyzed that higher degree of information was shared in the disclosure report post these incidents and compared to earlier condition. Based on the results, it has been described that the companies use their annual report as a tool of sway views of society about their operations.
Bell et al., 2001	The article examines the environmental impacts in association with abandoned coal mines. The research article has detailed the primary and secondary environmental impact. Some of the identified primary impacts are land subsidence, etc. and the secondary impacts are decreased ground water quality due to acid seepage etc.
Hilson, 2002	The study analyses conflicts among the operating mining firms and the local communities of land use conflicts between large-scale mines and community groups, and identifies a series of (land use) conflict resolution strategies for mine management. The article contends, however, that most of the unavoidable environmental problems that occur at sites-namely erosion, sedimentation and vegetation removal-are largely dismissed by locals, but that poor communications and highly preventable environmental accidents have been, and continue to be, the chief causes of intense land use disputes between mines and surrounding communities.
Albrecht et al., 2007	The study examines the issues arising due to disturbances in the environment using the term 'Solastalgia'. The 'Solastalgia' has been described as the affliction arising in people due to the environmental change. The study focusses on two aspects where solastalgia was found evident. One of the incidents of the study focussed on the impact of large-scale open-cut coal mining on the local individuals. The study identifies that this exposure of people to negative effect due to coal mining in the region has left them to a sense of powerlessness or lack of control over the unfolding change process.
Higginbotham et al., 2010	The research paper analyses the negligence of administration towards the deleterious health impact on the local people due to coal production. The study outlines the possible reasons for this negligence, which included interdependence of government authorities and private firms in gaining economic incentives through production of coal; lack and study framework related issues. The study also throws light on how the pollution generating due to coal mining is an important socio-political sphere, where all the sections of local people including residents, civil society, local government etc every now and then scuffle with the operating firms and state government over the increasing health risks.
Zhang et al., 2012	The review article focusses on environmental and human health consequences of lead/zinc mineral exploitation in China from the year 2000-2009. The study states that Lead (Pb) and cadmium (Cd) are the main pollutants and are associated with human health effects such as high lead blood levels in children, arthralgia, osteomalacia, and excessive cadmium in urine.
Morrice & Colagiuri, 2013	This paper combines the theoretical base for defining these injustices with reports in the international health literature about the impact of coal mining on local communities. It explores and analyses mechanisms of coal mining related injustice, conflicting priorities and power asymmetries between political and industry interests versus inhabitants of mining communities, and asks what would be required for considerations of health to take precedence over wealth.
Pascaud et al., 2014	The research article focusses on the issues arising due to mining waste. It throws light on the health issues arising due to exposure to metal based and other pollutants due to extract of Zinc, Lead and Silver. The research article focussed on movement and presence of metal(oid)s, assessment of threats on people etc.
Dutta et al., 2017	The research article investigates the environmental problems arising due to coal mining at NCL, Coal India high sulphur mining sites. The article discusses about the chemical aspects of coal, excessive stacking and exploitation of resources, Overburden (OB), mine drainage etc. to understand the overall environmental impact from high sulphur coal mining at north-eastern coalfield (India). The study finds that the total sulphur content of the coal is noticeably high compared to the Overburden (OB) and soil. The study examines the samples of soil, OB, water etc.
Agboola et al., 2020	This review article analyses pollution due to mine dumping, stockpiling, radioactivity in mine etc. It suggests ways for monitoring and managing pollution due to the same. The study also analyses the Acts, rules and regulations in relation to mining in few countries laying more emphasis on the enforcement of environmental laws, regulations, and standards. Further, of mine dump, stockpiles and tailing on the environment were discussed.
Sun et al., 2021	The study talks about the influence of government institutions in enhancing domestic energy efficiency. The research article through econometric model studies the spatial effect of institutional quality on energy efficiency over various countries from the years 1995 to 2016. The study identifies the importance of long-term planning to resolve global energy issue.

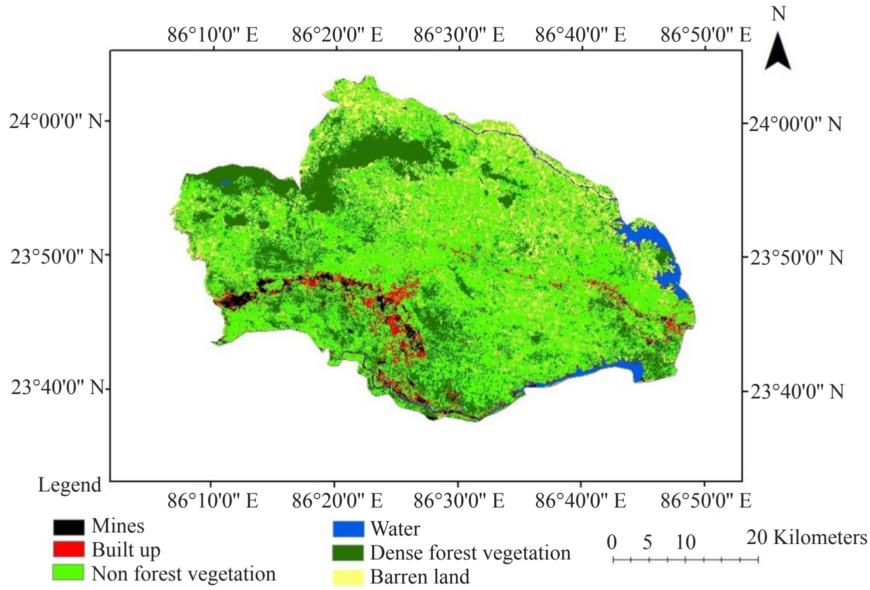


Figure 3. Land use/land cover change detection for the year 2000

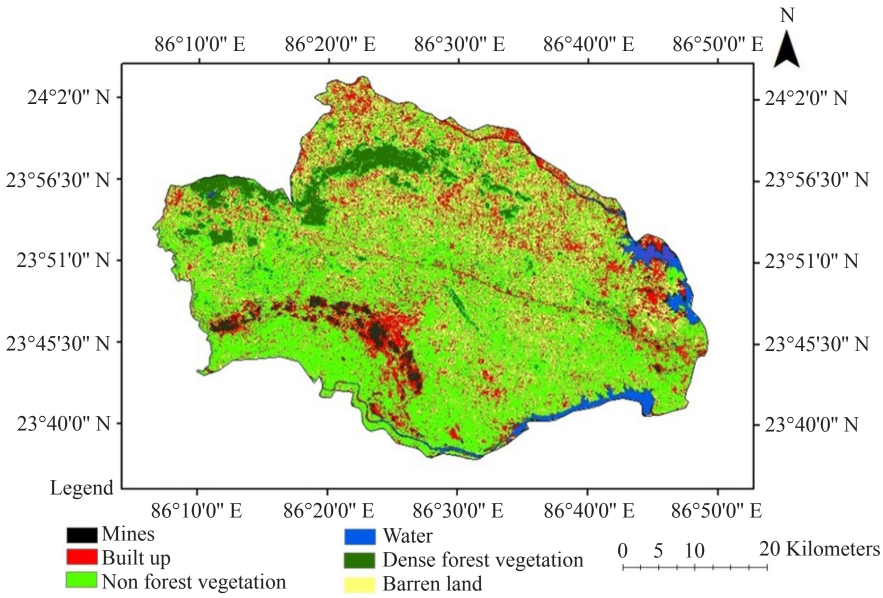


Figure 4. Land use/land cover map for the year 2020

The analysis further indicates that the built-up land (urban, rural and industrial settlements) has enormously increased, 14.32% of increase in built up land is seen from 2000-2020. The growing population has become a major cause of destruction of vegetation (Chakravarty et al., 2012; Pedlowski, 1997). Due to increasing industrialization large forest and non-forest vegetation plots have been converted into buildings, commercials, etc. which is the indirect effect of increasing population and decreasing forests (Ahmad & Goparaju, 2017). The mining area increased from 1.9% of total land in 2000 to 2.707% in 2020. Also, barren land and others increased at a very drastic rate over the years with 12.43% in 2000 to 16.46% in two decades. The study indicates that there has been a rapid increase in the settlement area around the coalfields which led to heavy deforestation over the years. The increase in the barren land might clearly be due to the increase in mined out wasteland areas and expanding mine fired area changing the non-forest vegetation into the barren area (Singh et al., 2018). The decrease in the area of water body in 2000 to the year 2020 is -0.259%.

Table 3. The LULC statistics of Dhanbad in the years 2000 and 2020

	Change detection				
Features	Area in the year 2020 (sq. km.)	Area in 2020 (%)	Area in 2000 (sq. km.)	Area in 2000 (%)	2000-2020 (%)
Forest vegetation	141.16	6.78	491.29	23.60	-16.82
Non-forest vegetation	1,121.17	53.86	1,164.24	55.93	-2.07
Build-up land	376.81	18.104	78.79	3.78	14.32
Coalfields	56.35	2.707	39.56	1.900	0.9
River and water body	43.12	2.071	48.66	2.33	-0.259
Others (barren land, sand, etc)	342.72	16.46	258.79	12.43	-4.03
Total	2,081.33	100	2,081.33	100	

The area change that occurred in land use/land cover classes in the period 2000-2020 has been shown in Figure 5. The reason is very obvious and clear, the economy of Dhanbad depends mostly on coal mining, meeting the respective demands through open cast mining and underground mining (Ahmad & Dey, 2017). Built-up land has also been increased to great extent. Construction of buildings and other residential units are going on to accommodate the exponentially increasing population of the area. For making buildings, commercials, industrial plans trees are uprooted, forests are destructed; which leads to the decrease in vegetation covers as in very dominant (Figure 3, Figure 4, Figure 5 and Table 3).

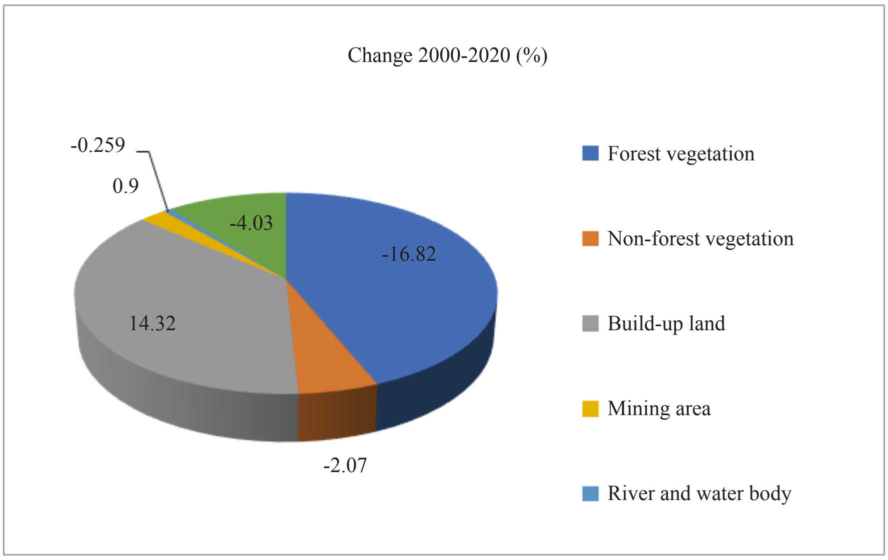


Figure 5. Pie-chart representing percentage of area change from the year 2000 to 2020

The forest and non-forest vegetation have been encroached and converted into coalfields and built-up land (Table 4). A total of 220.60 sq. km. of non-forest area and 32.40 sq. km. of forest vegetation have been converted into built-up. Though there has an increase in built up in and around the coalfields but most of the forest encroachment has taken place in the north eastern part of the study area (Figure 3 and Figure 4) which suggests that people have started to shift away from the mining region realizing the detrimental effects of coal mining on their health and lifestyle. The constant decrease in the forest and non-forest vegetation has become a matter of concern as the disruption created by the coal mining and the associated activities demand increased green covers in order to sequestrate carbon (Lal, 2008; Lorenz & Lal, 2009). But the increasing built up and mining areas in the region is completely opposite. Thus, the study brings forth the need to manage the rapid land use land cover changes, mainly through urbanization and deforestation, and limit the environmental and social impact to some extent.

Table 4. Change matrix of LU/LC from 2000-2020

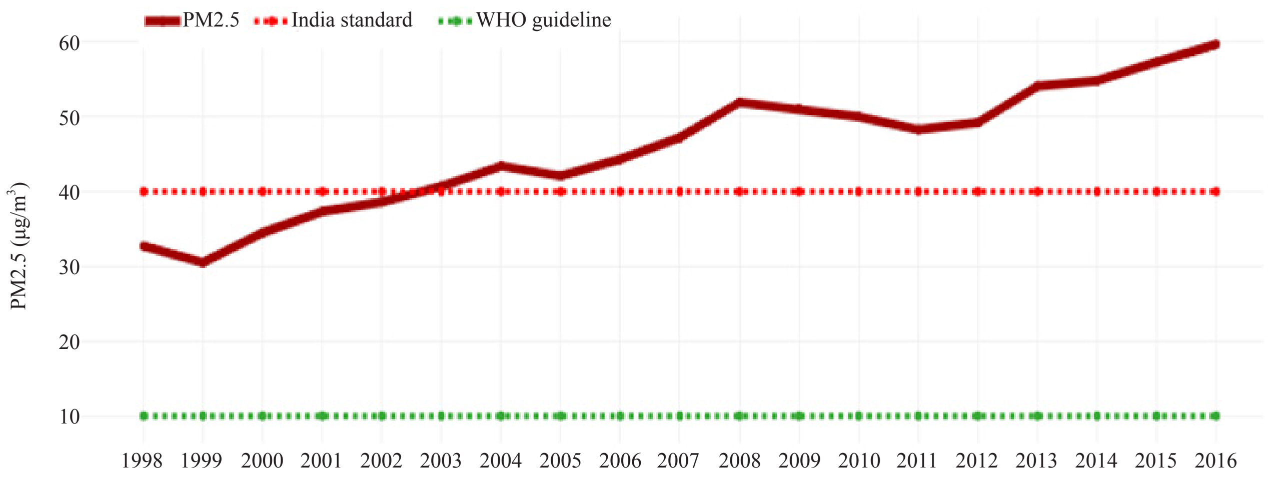
		Land use/land cover 2020 (sq. km.)						
		Barren land	Built-up	Forest vegetation	Coalfields	Non-forest vegetation	Water	Grand total
LU/LC 2000 (sq. km.)	Barren land	54.56	70.63	2.31	1.88	128.29	1.12	258.79
	Built-up	1.71	34.81	1.08	9.98	28.01	3.21	78.79
	Forest vegetation	34.59	32.40	123.40	6.11	293.76	1.04	491.29
	Coalfields	0.31	13.70	0.38	15.91	6.08	3.18	39.56
	Non-forest	251.17	220.60	13.45	12.74	663.24	3.04	1,164.24
	Water	0.38	4.68	0.55	9.74	1.78	31.53	48.66
	Grand total	342.72	376.81	141.16	56.35	1,121.17	43.12	2,081.33

4.2 *Impacts on the environment, society and economy*

The results show that there has been vast change in the study area over the years. Apart from forest and non-forest vegetation encroachment leading to increased CO_2 levels in the local environment, the expansion of coal mining activities has created other harmful impact on people directly or indirectly (Mishra, 2004; Nomani et al., 2021). Extremely deleterious consequences have been experienced by the residents and the negative impacts caused is increasing proportionally with the expansion of the coal mining industry in this region (Chadwick et al., 2013; Dutt, 2017; Grech et al., 2016; Jha et al., 2021; Oskarsson & Bedi, 2018; Roy & Schaffartzik, 2021). Presently, many of these effects have been investigated by research community but various indirect impacts have not yet been elaborately touched upon (Upgupta & Singh, 2017), these includes effects on the land, air, ecosystems, human health, biological diversity, ethnic groups, socio-economic conditions etc include some of the effects. Every process involved in coal mining operations has the potentiality to demolish the environment and contaminate soil, air, and water in the surrounding areas. This has direct impact on the local environment (Zhengfu et al., 2010; Katoria et al., 2013) but at the same time all of them summed together has various far-reaching impacts on the region (Franks et al., 2010; Cardoso, 2015).

Air pollution is one of the major concerns of the people (Chaulya, 2004; Pandey et al., 2014; Nayak & Chowdhary, 2018) living in and around the coal mining region. A large number of people prefer not to stay and tend to flee from the mining region because of the excessive dust and air pollution (Cao et al., 2017), this restricts various other small industries to grow in these regions, consequently restricting the possible economy generating activity. According to Central Pollution Control Board Ministry of Environment & Forests (2007), the annual average of SO_2 in Dhanbad in the year 2007 was 20 $\mu g/m^3$ and NO_2 was 52 $\mu g/m^3$. A severe increase has been found in the year 2019 with 102 $\mu g/m^3$

annual SO_2 concentration, 102 µg/m^3 annual NO_2 concentrations. The concentration of Particulate Matter (PM) in the atmosphere of the study area has doubled over the years (i.e., 30 µg/m^3 in 2000 to 60 µg/m^3 in the year 2020). Also, the PM2.5 levels of the study area have been consistently reported extremely high with respect to India's annual emissions (Figure 6) (Urban Emissions.info, 2021). The high level of PM2.5 can be linked with the unsustainable coal mining practices (Gautam et al., 2016) in the study area and are very dangerous for the environment and health of the people living in the nearby region (Sandstrom & Forsberg, 2008). According to United States Environmental Protection Agency (USEPA) (2021), particles smaller than 10 micrometres in diameter pose the greatest problems, because they can get accumulated into the lungs, and some may even get into the bloodstream. When these particles are breathed in, they penetrate into the lungs resulting in numerous impacts on health and problems including coughing, wheezing, asthma attacks, bronchitis, high blood pressure, heart attack, strokes and premature death (Gandhi et al., 2021; Ganguly et al., 2019; Medina et al., 2004; Maji et al., 2017).



Source: Urban emisions.info

Figure 6. Annual PM2.5 concentration of Dhanbad from the year 1998 to the year 2016

Many heavy metals are also emitted through coal; Iron, Copper, Chromium, Zinc, Cadmium, Nickel, Arsenic etc being the major ones (Mishra et al., 2008; Rout et al., 2013). These are the main reasons for the increased water, soil and air pollution in the region. They get trapped in the land eventually contaminating the underground water and nearby surface water bodies resulting in sulphur poisoning (Aneja et al., 2012). Also, these are contained in the coal refuse and fly ash and enter the soil through coal industry activities, including production and accumulation of a large amount of gangue, discharge of sewage, and emissions from coal-fired power plants and coal transportation (Li et al., 2018). This leads to soil degradation (Feng et al., 2019; Ghose & Kundu, 2004; Haigh, 1992; Ma et al., 2019; Pandey et al., 2014; Rathore & Wright, 1993), hence, leads to deforestation, loss of flora and fauna, destruction of ecosystems of nearby area etc. The presence of arsenic and antimony in soils has led to diminution in total soil bacteria due to the lower pH, temperature changes and change in chemical concentrations due to the increase in level of unwanted content in the soil (Ayangbenro & Babalola, 2017). The consistently increasing levels of pollutants have created a havoc, the Comprehensive Environmental Pollution Index (CEPI) of Dhanbad has risen to an astounding 78.63 (Air-64.50, water-59.00 and land-65.50) and any industrial cluster with CEPI more than 70 is considered critically polluted (Sohail, 2021). All this has taken a toll on the health of residents, many health problems are faced by the locals like skin and health diseases, chronic bronchitis, asthma and pneumoconiosis etc (Finkelman, 1999; Roy & Singh, 2014; Shah et al., 2019). According to a study by Conservation Action Trust & Urban Emissions.info (2014), the estimated annual health impacts due to emissions from coal-fired thermal power plants in the study area was 4,120 in the year 2017 and is estimated to rise up to 7,190 in the year 2030, if the same trends continue.

The economy of the region is largely dependent on the coal mining sector and the allied industries (Bapat, 1999;

Lahiri-Dutt, 2017) which makes it a strenuous task to make rapid implementation of the transformation plans and policies on ground. Establishment of large-scale coal mines serve as a major source of employment for the local people, some of them are even employed in the illegal mines (Alexander, 2007; Lahiri-Dutt, 2007). This has been leading to local revenue enhancement and improvement of local infrastructure (Hazra & Sengupta, 2017). The mines operating companies play a significant role in the development of key socioeconomic infrastructure such as roads, hospitals, schools and housing (Murombo, 2013) under their corporate social responsibility (Pathak et al., 2014; Singh & Mishra, 2016). Coal mining has definitely has empowered the local communities by providing circumstances to avail income opportunities (Hazra, 2021) but at the same time has deeply impacted on the socio-economic condition of the region (Guha, 2014; Nikhil, 2005; Pandey et al., 2016) which includes declining dominion of the indigenous communities etc. Mining has disturbed the cultural ties, traditional knowledge, identity of the indigenous communities (Dubey, 2017). It has also taken away their sources of income generation since they are forced to vacate and migrate to new areas where there are chances of them to unknowingly encroach on forest lands and are then considered as illegal occupants (Nite, 2019; Singh, 2008). This type of displacement has led to far-reaching negative economic consequences, also, it gets more difficult for such displaced people to find jobs for themselves. A large number of people leave their agricultural lands which takes away their source of income, those left with their lands find it difficult to conduct agricultural activities on the land due to deteriorating quality of soil (Ghose & Kundu, 2004; Rai et al., 2010). Moreover, the expansion of the industry leads to increased economic activities which consequently leads to an increase in the cost of living by generating more money which adversely affects the other people, including tribal people and other local communities, who may not directly be associated with these activities (Singh, 2008).

It must also be considered that the labours were local residents of the region (Sen, 2010) and its employment has been decreasing because of rapid improvements in labour productivity, technical advancement and decreased productivity. The labour intensity of coal mining has been decreasing in India in the recent past, mining jobs per 1,000 ton of production used to be 3.1 in 1960 which has come down to 0.2 in 2016 (Spencer et al., 2018). Similar effect can be observed in the study area as well. Illegal mining and coal mafias are serious issue in this region (Bharti et al., 2016; Kumar, 2019; Roy, 2000; Singh, 2018) whose involvement have been the major reason for economy disruption of the study area (Lahiri-Dutt, 2017). Many workers are hired on contract in both the legal and illegal mines and are adversely affected (Mishra, 2020; Goyal, 2018; Gupta, 2019) as they receive salary lesser than the minimum wages, work overtime and are denied benefits available to their organised.

The operating companies in this region have been conducting extensive coal extraction in this region and exploited the land to a great extent over the years (Tiwary & Dhar, 1994; Singh et al., 2001; Singh, 2013). The production rates of the operating companies in this region have been declining which is another important reason of worry for local economy generation because this will also affect the allied industries in the near future. The unsustainable overexploitation of mines has led to coal fire (Pal et al., 2021) and huge areas which cannot be used for any other purposes in future. Since these lands have not been reclaimed properly (Paul, 2010; Stracher & Taylor, 2004; Tripathi et al., 2016) so it would be difficult to use those land for any other economy generation purpose in future due to coal fires and other such effects. This also has become a major reason for a lot of people to lose their jobs indicating the fact that coal mining does not assure long term employment.

4.3 *Assessment of sustainability of the coalfields of Dhanbad*

The previous section discusses the impact of expanding coal mining industry on the environment and people from the processes involved in mining coal. There is a need to answer a key question, namely: are the rules of sustainable development being applied to this kind of industrial activity? Only if the common people along with the operating companies consistently apply the rules, it can be ensured coal will beneficially serve, not only the present, but also many future generations.

The major coal mines of Dhanbad are visited for this study which includes both open cast coal mines and underground coal mines. A holistic check has been conducted to check the impact of the expansion of coal mines on the environment and society in the coalfields is being monitored constantly by the company and adequate measures are undertaken for control of air, water and noise pollution, land degradation, health hazard, safety, deforestation, human development, etc.

As per the survey, several plans for ecological restoration of hectares mined out degraded land are drawn up in the coalfields. Still, large areas of degraded land are left abandoned for which more efficient action plans are required. As per the main operating company in the study area (BCCL-a subsidiary of Coal India Limited), which operates most of the coal mines in this region, the earlier practice of plantation adopted by BCCL was single-tier and monoculture. As per open-end discussion with the officials of the company, it can out that a three-tier ecological restoration strategy has now been incorporated for plantation of native species consisting of lower-level grasses, middle level shrubs and bushes and top-level trees to establish a natural forest ecosystem and to bring back original normalcy of function, structure, potential, service and process of an ecosystem in the mined-out land. Though this strategy was found implemented in few of the coalfields, the frequency of the implementation is very low. On our survey on the coalfields owned by TATA Steel, it is found that the Biodiversity Management Plans have been implemented to fair. More lands need to be regenerated in order to bring down the high level of negative impact and hazards that are arising due to extensive mining activities in these coalfields. Use of the datasets collected through remote sensing satellites and GIS techniques are been made, though usage must be increased for future projections and impact management by the operating companies. Various master plans and action plans have been made by the operating companies for social welfare also including exercise of labour laws, education, resettlement, etc. For the rehabilitation of people living very near to coal mines and to ensure their safety, BCCL has constructed 5,576 houses for the employees' families, 9,424 houses are in progress. 2,612 families have been shifted to safer regions of Dhanbad. As per our survey, it was found that numerous dispensaries and hospitals are serving in Dhanbad, out of which most of them are government owned. The major operating companies (i.e., BCCL and TATA Steel) have more than 40 dispensaries, multispecialty hospitals in the mining regions as well as the non-mining regions.

Table 5. Status of coalfields based on certain criteria

Criteria	Condition
Environmental clearance and compliance	Average
Ecological restoration	Needs improvement
Satellite monitoring	Efficient
Environmental awareness	Efficient
New initiatives	Average
Action plans	Average
Health services	Average
Employment and education	Needs improvement
Land use and territorial aspect	Efficient
Infrastructural development	Efficient
Land reclamation	Average
Medical facilities	Average
Action plans for resettlement and rehabilitation	Needs improvement
Safety in mines	Average

The level of awareness has increased as compared to past situations, various new policies, action plans, new initiatives have been taken by the authority, operating companies and other regulatory agencies for land reclamation, health and safety, sustainable developmental activities, etc. Yet there is still a long way to go, for ensuring sustainability of the study area. After carefully examining all the conditions in the visited coalfields a summary of findings have been demonstrated in Table 5, based on few criteria, in order to rate the socio-environmental development of the coalfields of Dhanbad. The parameters were selected based on the concerns and relevance of the issues in the study area, which consequently became evident which our interactions and discussions with the local people, employees of the operating companies, administrators, etc.

5. Conclusion and recommendations

This study depicts the overall picture of change in the land use pattern and the influence of expanding coal mines in Dhanbad. The first part of the study reveals that there has been a tremendous change in the land cover pattern over the years with a striking decline in the forest land cover (from 23.60% of land within the study area in 2000 significantly to 6.78% in 2020). Also, there has been a drastic increase in the built-up land (from approximately 3.78% in the year 2000 and 18.10% in 2020), mining areas (1.9 % in 2000 and around 2.70% in 2020).

From Section 4 it can be observed that the expanding coal mining industry have laid severe impact on the people, environment and economy due to the increasing mining areas and built-up land, decreasing area of forest and non-forest vegetation. The PM levels of the atmosphere of Dhanbad have constantly been higher than Indian Standards which seem to be proportionally increasing with the expansion of coal mining industry (30 $\mu g/m^3$ in 2000 to 60 $\mu g/m^3$ in the year 2020). All this is resulting in increasing health related problem in the people living in this region. The study also shows that the expansion of mining industry in the study area was earlier a big support to the regional economy of the region but over the years scenario has drastically changed due to various aspects including technological development, displacement of local people, abandonment of mined out land, etc. The non-reclaimed mined out lands is severely affecting the regional economy and shows threat to future growth as well. The local and tribal communities living around that region also come under major threat due to their displacement and land acquisition.

Finally based on the conclusions and findings, authors propose the overall recommendations in the context of ensuring sustainable environmental, social and economic practices, not only in the study but the recommendations can also be replicated to other coal mining areas with similar geography in various developed and developing countries of the world. They are as follows:

• Enhancing transparency and knowledge on various issues by conducting research and development to generate innovative ideas for socio-environmental development. It is highly recommended to develop and implement technologies for carbon sequestration since the level of carbon emissions from the coal mines are very high. Hence, the operating industries must be well equipped for carbon capturing from mines and pipelines for transporting them to deep underground rocks.

• A master plan must be created including all the stakeholders of the region to stop illegal mining and ensure fair salary to the labours as the laws of the country so that the economy of the region can be correctly accounted.

• Plans for rehabilitation have to be implemented with more effectiveness to control health related and other hazards in the coalfields. Also, the plans must ensure the generation of job opportunities for these people.

• Vigilance departments must be very effective and must monitor that the funds are released and managed correctly and corruption can be controlled. A higher degree of accountability and responsiveness is required across all the responsible authorities and hierarchy.

• The responsible authorities must give spaces for sharing stake with entrepreneurs with start-up ideas, research institutions who can suggest innovative plans and programs for sustainability. This will ensure proper reclamation of mined out land, sustainable agricultural practices, inclusion of local communities, safeguard their traditional knowledge etc. The involvement of such organizations can be done through Corporate Social Responsibility funds of the operating companies.

• Conducting intensive surveys and studies to check the socio-economic status of the tribal communities surrounding the mining region to safeguard their traditional culture, knowledge and ensure long term employability to them.

• It is important to clearly designate respective functions and responsibilities to the total capacity for immediate and effective application of laws, rules, regulation and acts for the sustainable development in the coal mining. For example, it is highly suggested to bring a legislation to achieve the requisite GHG emission target in order to bring accountability which is lacking in the present scenario.

• Engaging the NGO and NPOs in partnership to implement more socio-environmental offset initiates. Effective utilization of CSR activities is essential in this context.

Conflict of interest

The authors declare that they have no conflict of interest to the publication of this article.

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