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Analysis of land cover change due to mining and its potential economic loss: A case study in the Bukit Soeharto Forest Park, East Kalimantan, Indonesia

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Abstract. *Sunarto, Aipassa MI, Rujehan, Suhardiman A, Kristiningrum R, Ruslim Y, Sari WI. 2023. Analysis of land cover change due to mining and its potential economic loss: A case study in the Bukit Soeharto Forest Park, East Kalimantan, Indonesia. Biodiversitas 24: 1206-1214.* The Bukit Soeharto Forest Park in East Kalimantan, Indonesia, was once a conservation area but experienced annual land cover changes due to natural causes and human activities such as land clearing and mining. These changes can have economic, social, and environmental impacts. Therefore, this research aimed to analyze changes in land cover and potential economic losses from forest degradation due to mining in Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University. It was conducted from April to October 2022, and the land cover analysis was performed using a series of maps from 2016 to 2022, which were classified based on an overlay technique with the aid of a GIS computer program. The economic valuation of environmental damage was calculated using guidelines from the Regulation of the Minister of Environment No. 7/2014, with a modified method based on the full cost principle. The results showed that the BSREF land, which covers 20,271 ha, experienced changes in the function of the area, with 702.86 ha being converted, resulting in a total economic valuation of environmental damage of approximately 29.6 trillion rupiah due to mining. Therefore, firm action from the local government is necessary to half further conversion and ensure the proper functioning of BSREF as a conservation area.

Keywords: Bukit Soeharto, economic loss, economic valuation, land cover, mining

INTRODUCTION

Key indicators of global environmental change, such as changes in land use and land cover, have significant impacts on several important areas, including biodiversity, climate, urban planning, food security, economic opportunities, water resources, population growth, and the environment (Zhu and Woodcock 2014; Ehrlich et al. 2018; Atasoy 2020; Arowolo and Deng 2018). The Bukit Soeharto Forest Park (BSFP) in East Kalimantan, Indonesia, is a 64,815 hectares conservation area with the potential for rich and diverse natural resources. According to the BKSDA (2021), the BSFP has been classified into 12 distinct land cover types, including; secondary dryland forests, shrubs, secondary mangrove forests, swamp shrubs, mixed dryland agriculture, plantation forests, plantations, open land, settlements, mines, ponds, and water bodies. However, the actual land cover does not align with the designated classification, leading to the area's degradation (Toma et al. 2017). The changes in land cover have implications for the function of Bukit Soeharto. A significant challenge in this region is rampant mining, particularly in the Bukit Soeharto Research and Education Forest (BSREF) (Rujehan and Matius 2018). Despite ongoing efforts to enforce environmental laws against this illegal activity (Mujiono 2021), the most recent conditions indicate that the land use in this forest area has been severely disturbed, degraded, and threatened due to both internal and external factors. Therefore, more immediate action is necessary to address these issues. Bukit Soeharto is a conservation area for various natural and non-natural plants, animals, and native and non-native species. It is a protected region that provides benefits for research and development, science, education, cultivation support activities, nature tourism and recreation, and cultural preservation.

Environmental damage from open-pit mining can disrupt various ecological functions, such as hydrological functions, carbon absorption, oxygen supply, environmental temperature regulation, and landscape morphology and function. This form of mining also raises soil acidity through ferrite compounds (FeS_2) oxidation. Furthermore, other documented impacts include reduced river water discharge, damage to the landscape as a recharge area, high sedimentation, decreased river water quality, and infiltration (Sudirman et al. 2013; Rahmatillah and Husen 2018; Yanti et al. 2019). To fully understand the extent of the damage to natural resources, a detailed

assessment should be conducted, and the cost of this environmental damage should be quantified using economic valuation methods (Woodruff and Bendor 2016; Suparmoko et al. 2014; Parmawati 2019; Kristiningrum et al. 2020).

Several studies have been conducted in Bukit Soeharto Forest Park (BSFP) to examine land use. According to Suryadi et al. (2017), the BSFP and its buffer zones comprise mining, plantation, settlements, or built-up, and farming with areas of 956 ha, 52 ha, 173 ha, and 16,915 ha, respectively (Forest Park Management Block). Approximately 79% of the BSFP area conforms to its original function, which consists of swamps, water, and shrubs/forests. Meanwhile, 21% of the area is utilized for non-conforming purposes, such as mining, mixed dryland agriculture, dryland agriculture, open land, settlements, ponds/fisheries, and plantations. Ariyani et al. (2020) reported that 2.2 ha is a buffer zone.

The BSFP in East Kalimantan Province has an estimated total economic value of approximately 141 trillion rupiahs (Yulian et al. 2011). The valuation was calculated using contingency methods, substitute values, and productivity approaches, including estimates of medicinal plants, trees, firewood, non-timber forest products, coal, carbon sinks, rocks, and other environmental services. The significant economic value of these natural resources highlights the far-reaching consequences of their degradation for humans and the environment. Degradation of these resources is predicted to disrupt the area's functioning and conservation efforts, leading to ecological imbalances and substantial losses for the state. This has negatively impacted the environment, as demonstrated in studies by (Wasis et al. 2018; Saharjo and Wasis 2019; Duan and Yan 2019; Lee et al. 2020).

Despite numerous studies conducted on the Bukit Soeharto Forest Park (BSFP), it is important to continually monitor changes in land cover as they are prone to evolve. Furthermore, land cover at BSREF and the potential economic impact of environmental damage have never been assessed and evaluated. Therefore, calculating the financial cost of the damage caused to natural resources by the changes in land cover factors is necessary for effective BSFP management (Wasis et al. 2018; Saharjo and Wasis 2019). This is particularly relevant given that the BSFP will serve as a buffer zone for East Kalimantan's new national capital city. Consequently, it is essential to analyze changes in land cover and the economic potential of BSREF for environmental damage resulting from land use inconsistent with its designated function.

MATERIALS AND METHODS

Study area

Field research was conducted in the Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University East Kalimantan Province, Indonesia, which is included in or directly intersects with the new National Capital City, as shown in Figure 1. The research focuses on the changing land cover conditions at BSREF over the last six years, from 2016 to 2022. The environmental damage due to mining is calculated based on land cover data in 2022. Furthermore, the research was conducted from April to October 2022, and the total extent of BSREF was estimated at 20,271 ha based on the Decree of the Minister of Forestry number: 160/Menhut-II/2004. The minimum and maximum temperatures for the area were 21.4ºC and 29.9ºC, with an average annual rainfall of approximately 2,000 mm (Toma et al. 2017).

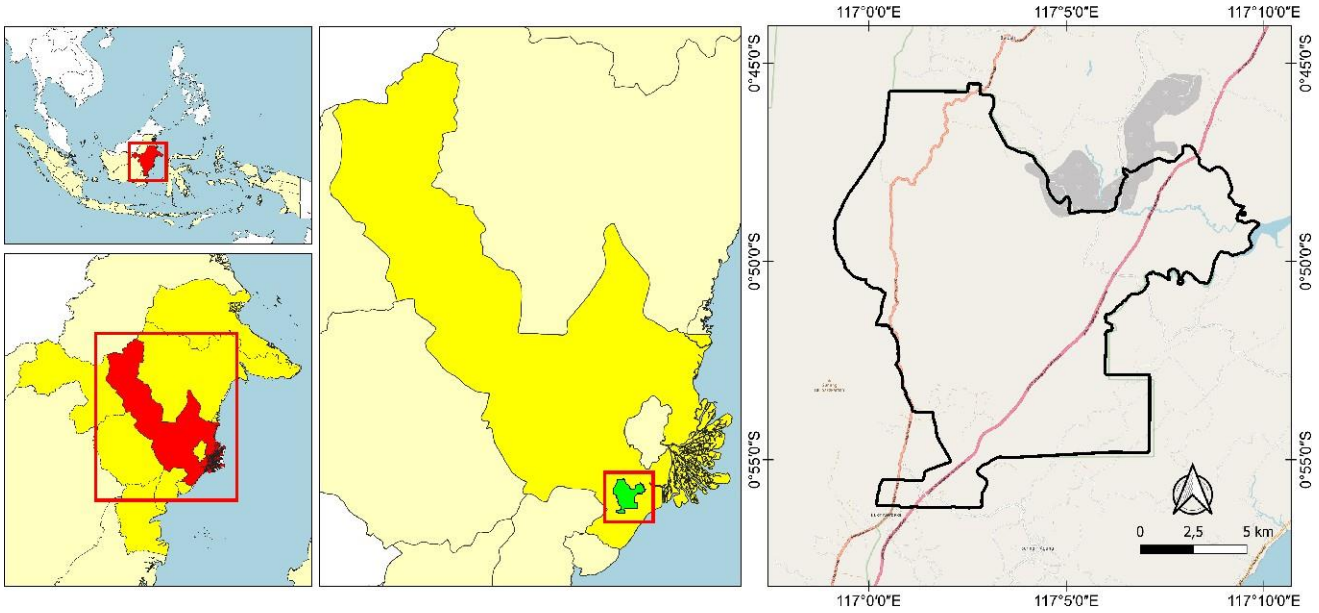

Figure 1. Map of location and work area of Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University, East Kalimantan, Indonesia

MATERIALS AND METHODS

The materials used in this research were (i) a map of the boundaries of BSREF within the Mulawarman University area, (ii) time series maps of land cover between 2016-2021 obtained from the Ministry of Environment and Forestry under the Forest Carbon Partnership Facility (FCPF) Data, ER Monitoring Report (ER-MR), Monitoring Measurement and Reporting (MMR) for East Kalimantan Province in 2022; and (iii) Landsat Image Map 8 Coverage from January-October 2022.

The tools used in this research were (i) a set of computers equipped with ArcGIS and Global Mapper software, with minimum specifications of 16 GB RAM, 1 TB Hard Disk, and Plotter (ii) Garmin GPS to determine research plot points; (iii) aerial photos captured using the DJI Phantom 3 Professional drone on 24 March 2022, to observe new mine openings in the KHDTK HPPBS UNMUL area, (iv) camera/cellphone for research documentation, (v) stationery as a tool for recording, and (vi) field vehicles for mobilization during research.

Data analysis

The spatial conditions were analyzed through an overlay of land cover using the GIS computer program. The results of the overlap process provided insight into the changes in land cover classes over time, allowing for an evaluation of the extent to which the recorded land cover classes were consistent with the designated function of the BSREF of the Mulawarman University area in 2022. The reduction or addition of land cover areas and their respective functions were calculated and presented in tables and graphs.

The land cover in 2022 was obtained from the interpretation of Landsat 8 imagery. The interpretation followed the Technical Instructions for Interpreting Medium Resolution Satellite Imagery for Updating National Land Cover Data with number; Juknis 1/PSDH/PLA.1/7/2020. That was issued by the Directorate of Inventory and Monitoring of Forest Resources under the Directorate General of Forestry Planning and Environmental Management of the Ministry of Environment and Forestry in 2020. Finally, the process employed remote sensing techniques and spatial metrics, as described by (Fenta et al. 2017).

The economic value of environmental damage caused by mining was calculated by determining the losses based on the Regulation of the Minister of Environment Kalimantan number; 7/2014. Given the various approaches that could be used for this purpose (Suparmoko et al. 2019), selecting an appropriate and accountable method is crucial. In this regard, the economic assessment impact of environmental damage due to mining was based on the Regulation of the Minister of Environment of the Republic Number 7 of 2014 on Environmental Losses resulting from Pollution and Environmental Damage. The regulations provide clear, precise language and legal rules (Wasis 2019; Fauzi 2014). Therefore, an approach based on a modified Full Cost Principle was employed in the economic valuation of damage at BSREF resulting from mining in protected areas. The compensation includes ecological loss, economic loss, and ecological recovery costs. The valuation figures from the database were then adjusted to the conditions in 2022, assuming a discount rate of 3.5% per year. Therefore, to estimate the current value as of 2022, the basic data was compounded with an annual interest rate of 3.5% (based on deposit rates).

RESULTS AND DISCUSSION

Bukit Soeharto Forest Park and its potential ecosystem

The Bukit Soeharto Grand Forest Park (BSFP) was established based on the Decree of the Minister of Environment and Forestry Number SK.1231/MenLHK-PKTL/KUH/PLA-2/3/2017 dated 16 March 2017, the Amendment to Kalimantan Menhut No. SK. 577/Menhut-II/2009 dated 29 September 2009, and Designation of the Bukit Soeharto Forest Park located in Kutai Kartanegara Regency and North Penajam Paser RKalimantanst in Kalimantan Province. The Bukit Soeharto area covers 64,814.98 ha, with a Geographical-Location of 000 41' 00" - 010 00' 00" South Latitude and 1160 55' 00" - 1170 03' 00" East Longitude. Its topography varies from flat, through light to heavy Undulations, with swampy land surrounding, the slope between 0% and 25%, and a height of 0 to 100 masl. In general, the condition of Bukit Soeharto varies from mildly undulating to steep hills with a slope of 3% to -25%. Based on the classification of Schmidt and Ferguson, Bukit Soeharto is included in the climate classification type A, with rainfall ranging from 2,000 mm to 2,500 mm year^{-1}. Finally, the temperature ranges from 20°C to 30°C, with an average humidity of 67-95% (BKSDA 2021).

There are three Forest Areas with Special Purposes: (a). Research and Development Forest covering an area of 3,504 ha, managed by the Samboja Natural Resources Conservation Technology Research and Development Center through the Regulation of the Minister of Forestry No. 290/Kpts-II/1991 dated 5 June 1991, and 201/Kpts-II/2004 dated 10 June 2004, (b). The Education and Training Forest, with an area of 4,320 Ha, managed by the Samarinda Forestry Education and Training Center through the Regulation of the Minister of Forestry No. 8815/Kpts-II/2002 dated 24 September 2002, in the Loa Haur Sub-DAS, and (c). Bukit Soeharto Research and Education (BSREF) of Mulawarman University covers an area of 20,271 ha, which is about 30% of the total area of the Bukit Soeharto Forest Park, managed by The Center for Reforestation Studies through the Regulation of the Minister of Forestry No. 160/Menhut-II/2004 dated 4 June 2004.

Based on biodiversity inventory activities and verification of the potential and problems of the BSFP, which were performed in 2021, the BSFP has ecosystems consisting of heath, mangrove, dryland, and pine forests covering areas of 2,936.2 ha, 538.3 ha, 61,316.5 ha, and 14.8 ha, respectively. The forest cover is 37,376.09 ha or 57.7% of the total area of Bukit Soeharto. There are also instances of illegal land use activities such as plantations,

mining, buildings, and rice fields. The park is known to harbor more than 600 species of plants, 42 mammals, 149 birds, and 27 amphibians and reptiles (BKSDA 2021).

The ecosystem areas comprised of good, bad, and moderate conditions are 7,516 ha (11.6%), 20,160 ha (31.1%), and 37,114 ha (57.3%), respectively. According to data from Bukit Soeharto, the proportion of heath forest ecosystem types in good, moderate, and bad conditions are 13%, 36%, and 51%. Meanwhile, only 11%, 30%, and 59% of dryland forest ecosystems are in good, bad, and moderate conditions. The proportions of good and bad situations in the mangrove forest ecosystem are 92% and 8%. Inventory results have recorded over 600 species of flora and numerous species of fauna, including 149 species of birds, 42 species of mammals, 19 species of amphibians, and 9 species of reptiles. Some of the important species of mammals, birds, amphibians, and reptiles are Clouded Leopards (*Neofelis diardi*), Sun Bears (*Helarctos malayanus*), Proboscis Monkeys (*Nasalis larvatus*), Gibbons (*Hylobates muelleri*), Red Langurs (*Presbytis rubicunda*), Silvery Lutungs (*Trachypithecus cristatus*), Slow Lorises (*Nycticebus coucang*), Tarsiers (*Tarsius bancanus*), several types of eagles, hornbills, water birds, several types of frogs, snakes, and crocodiles (BKSDA 2021).

Land cover types and changes in Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University

Land use classes in conservation areas are subject to alteration due to human activities or natural causes (Fuller et al. 2019; Kuswanda and Sunandar 2019; Milanova and Telnova 2007), with potentially negative implications for biodiversity (Renwick et al. 2015; Bode et al. 2015). For example, the BSREF of Mulawarman University has ten types of land cover. These include secondary dryland forests, secondary mangrove forests, shrubs, water bodies, mining, dryland farming, mixed shrub farming, plantations, open land, and settlements, as shown in Table 1 and Figure 2.

Table 1 shows significant changes in the land cover within the BSREF of Mulawarman University from 2016 to 2022. Four of the ten land cover types have experienced a decline in the area: shrubs, dryland farming, dryland mixed shrub farming, and plantations. Meanwhile, three areas have increased: secondary mangrove forest, mining, and open land. The remaining three land cover types have remained stable, with no change in areas, including secondary dryland forests, water bodies, and settlements.

During the last seven years, Open Land and Mining have experienced the greatest increase in the area among the land cover categories in BSREF of Mulawarman University. This substantial rise could cause degradation, affecting the function of BSREF as a conservation area. The ability to serve its purpose will be decreased by a land cover that does not meet the appropriate conditions. The decline in shrubs and dryland mixed shrub farming is also significant. Figure 2 below shows the land cover images from 2016-2021.

Figure 2 shows that between 2016 to 2019, there was a lack of secondary dryland forest land cover until 2020 and 2021. However, it did not change in the area (fixed), while secondary mangrove forests tended to experience an increase in land cover area. Shrubs had a yearly reduction in land cover, and water bodies and settlements remained unchanged. The size of dryland farming and dryland mixed shrub farming decreased, while mining and open land tended to increase in land cover.

Land cover changes in the BSREF are dynamic, with suspected causes of both natural and human factors. These have a significant impact on the function of the area. Some land covers do not function properly, disrupting the main function of BSREF as a protected and conservation area. The alterations could also disturb biodiversity (Yadav et al. 2012; Surni et al. 2015; Yi et al. 2017; Bryan et al. 2018; Najmuddin et al. 2022), bearing in mind that protected areas are not developed for human land use rather than top priority to biodiversity conservation (Venter et al. 2018; Fuller et al. 2019). The visualization of land cover forms in BSREF is shown in Figure 3.

Areas not following their designation are predicted to disrupt the functions and interests of conservation, and degrade the ecosystem in the Bukit Soeharto area, particularly BSREF of Mulawarman University. Furthermore, land cover changes, especially in forest areas, are the main cause of ecological system degradation, soil degradation, loss of biodiversity, and reduction in goods and services provided by nature (Quintas-Soriano et al. 2016; Halimi et al. 2018; Fenta et al. 2017; Gomes et al. 2020).

Table 1. Land cover types and changes in Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University (2016-2022)

Land use classifications	Year (ha)							Changes	Remarks
	2016	2017	2018	2019	2020	2021	2022	(2016-2022)	
Secondary dryland forest					3877	3877	3877	0.00	Stable
Secondary mangrove forest	560.82	560.82	556.12	556.12	554.34	554.34	561.81	-0.99	Increased
Shrubs	9765.06	14867.35	12876.31	12726.94	8696.51	8561.53	8494.43	1270.63	Reduced
Water bodies	12.45	12.45	12.45	12.45	12.45	12.45	12.45	0.00	Stable
Mining	306.46	306.46	444.75	444.57	446.43	450.02	702.86	-396.40	Increased
Dryland farming	3597.52	3597.52	3524.33	3515.95	3515.87	3515.87	3495.03	102.49	Reduced
Dryland mixed shrub farming	5860.46	758.17	2580.21	2556.29	2492.36	2492.36	2425.18	3435.27	Reduced
Plantation	140.45	140.45	24.84	24.84	24.84	24.84	24.84	115.61	Reduced
Open land	27.72	27.72	251.93	433.79	651.29	782.68	677.47	-649.75	Increased
Settlement	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00	Stable
Total	20271	20271	20271	20271	20271	20271	20271		

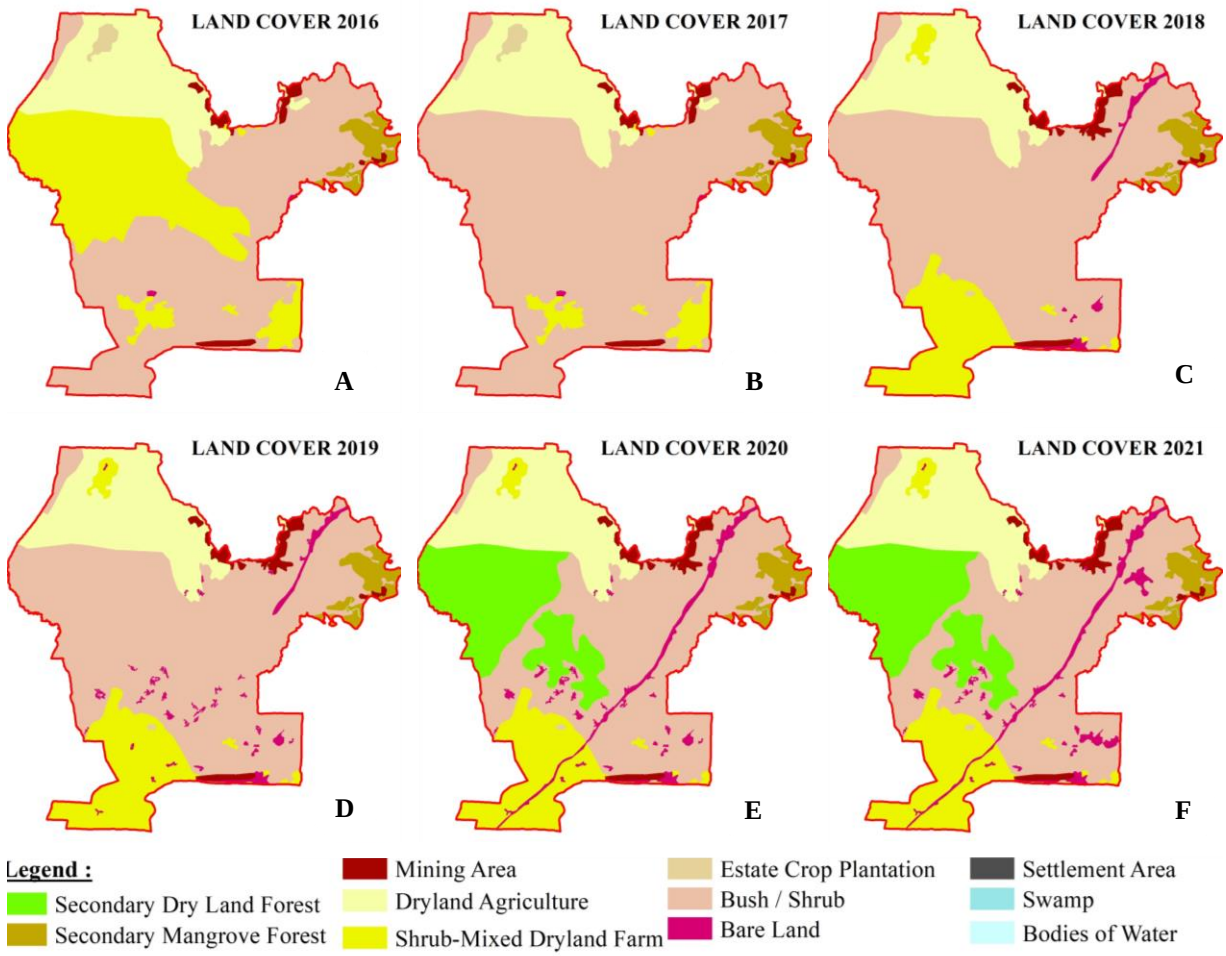

Figure 2. Land cover time series maps for Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University between 2016 and 2022. A. Land cover in 2016, B. Land cover in 2017, C. Land cover in 2018, C. Land cover in 2019, D. Land cover in 2020, and E. Land cover in 2021

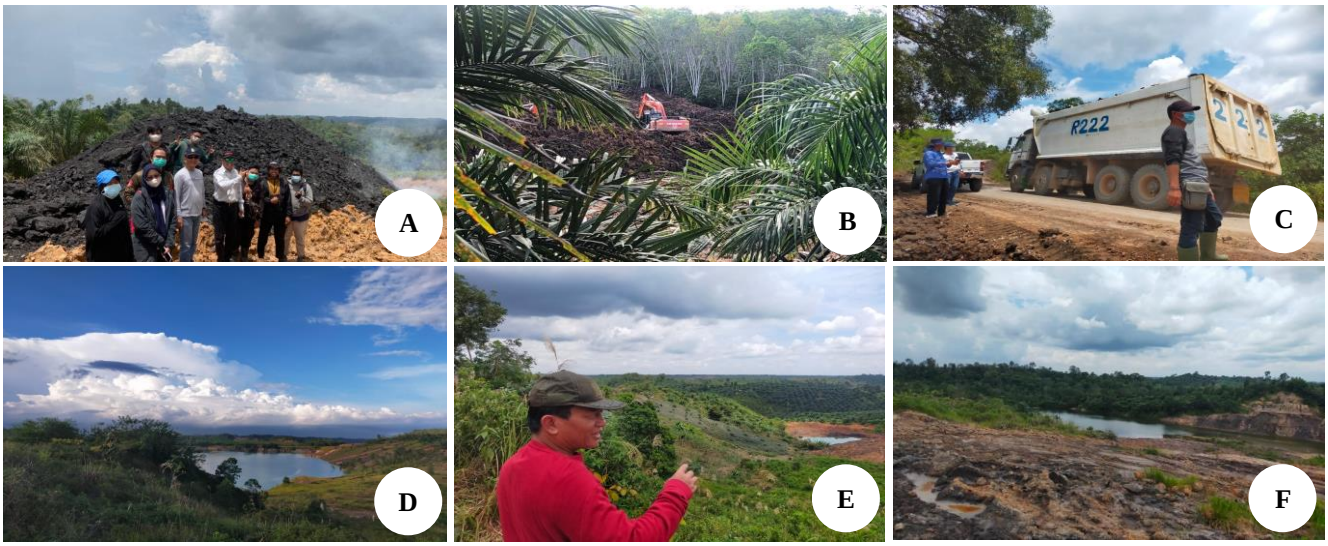

Figure 3. Land use conditions in Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University. A. Pile of coal, B. Mining land-clearing activities, C. Transporting coal through the BSREF road, D. Void at km 58, E. Pineapple plantations are one form of area utilization, F. Types of ecological damage due to mining

Sarminah et al. (2017) stated that open coal mining techniques have many negative environmental impacts. Changing environmental conditions include decreased soil productivity, erosion, sedimentation, and ground movements or landslides. In addition, land use is related to human activities, the existing resources, and their impacts, such as vegetation (natural or planted) or human construction that covers the ground surface (Li et al. 2022). This will lead to the loss of global biodiversity habitat (Choi et al. 2020). Furthermore, the relationship between land cover change and habitat loss is a consequence of natural processes that can harm human activities. Increasing populations support that, land use intensification, and loss of natural habitats (Wu et al. 2013; Jones et al. 2016; Arowolo et al. 2018; Chughtai et al. 2021). (Wu et al. 2013; Jones et al. 2016; Arowolo et al. 2018; Sapena and Ruiz 2019; Chungtai et al. 2021).

Observing the results above, it appears that the area of land clearing for coal mining mostly occurs around the border of Bukit Soeharto. Several coal mining companies with licenses are located in this area's outermost part. Their existence has resulted in the encroachment of coal mining activities into the Bukit Soeharto area. For instance, the perpetrators used the company's haul road to transport coal out of the region. Therefore, it is necessary to have maximum supervision of these locations to prevent land-clearing expansion.

The value economic losses BSREF due to mining

Mining is one form of damage resulting from changes in land cover that do not follow the intended function. The increasing area of land cover used for mining will have a negative impact on the environment as a whole and decrease biodiversity. The 2022 land cover map identified that the area used for mining in the BSREF of Mulawarman University is 702.86 ha. On 24 March 2022, data was collected through aerial photography utilizing drones, focusing on observation points at the X axis: 503245.30 and Y axis: 9896977.35. The aerial photography resulted in a total captured area of 7.47 ha.

Figure 4 shows environmental damage due to mining with an observation area of 7.47 ha. There are three categories of damaged land resulting from this activity, namely (1) degraded area with an estimated to be 24,954 m^2, (2) main coal excavation area estimated to be 11,466 m^2, and (3) bare open land, estimated at 33,912 m^2. The results of the aerial photography analysis, conducted using drones, show that the coal excavation area and the estimated height of the mine are 61.5 masl - 75 masl, with a depth of 13.5 m. It also indicated that the coal reserves are 5,000 MT, covering an area of 1.2 ha. Therefore, the estimated coal reserves per hectare are 4,167 MT ha^{-1}. Given that the land cover for mining is 702.86 ha, the total estimated coal reserves are 2,928,818 MT.

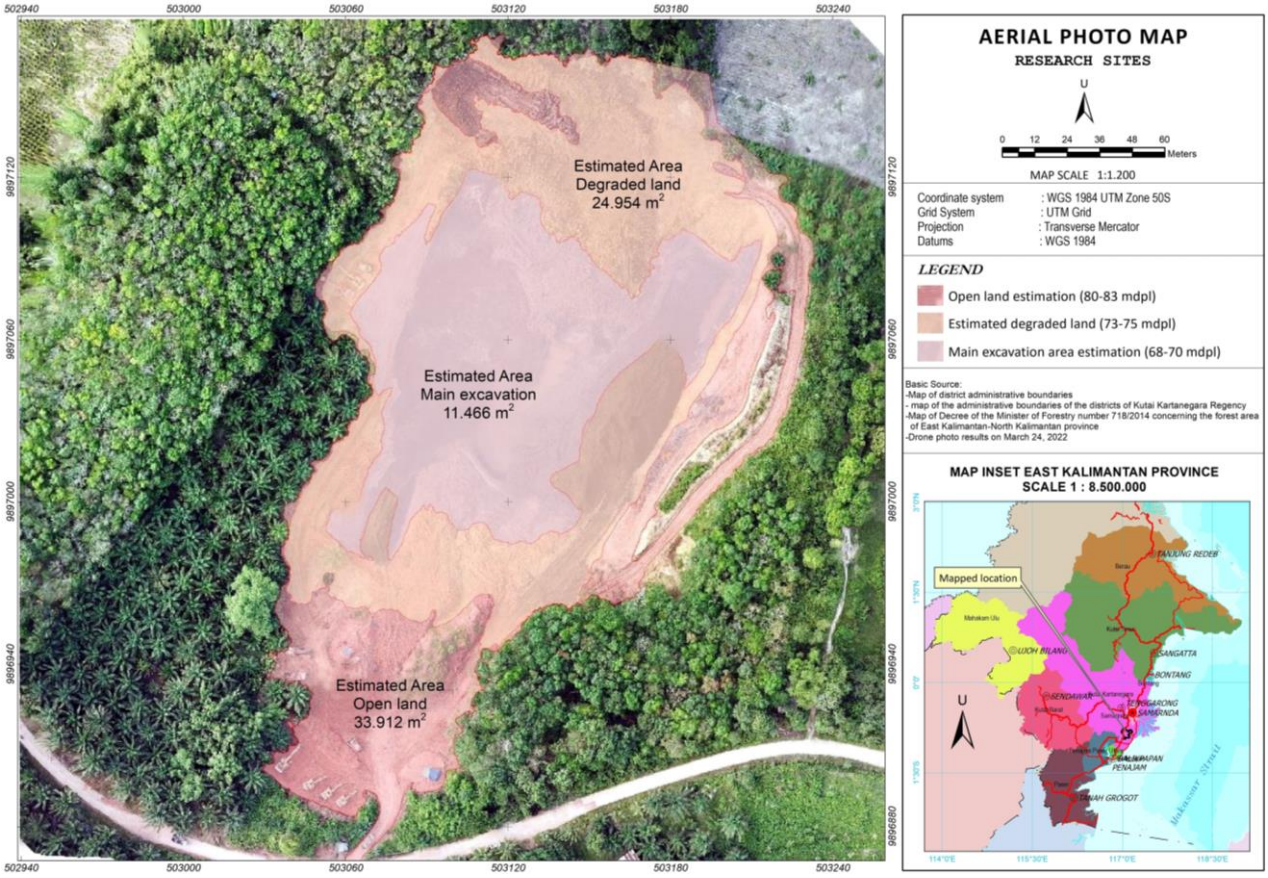

Figure 4. Aerial photo maps of environmental damage due to mining at Bukit Soeharto Research and Education Forest (BSREF) of Mulawarman University, East Kalimantan, Indonesia

The economic valuation of damage and losses caused by illegal mining in the BSREF area of 702.86 ha was calculated based on field research, laboratory analysis, and KLH Economic Valuation guidelines (2006). The calculations followed the land cover specified in the Minister of Environment Regulation Number 7 of 2014 and Wasis (2019). Furthermore, the raw data was adjusted to the current year (2022) by considering an interest rate of 3.5%.

The economic valuation of environmental damage includes three components: ecological losses, financial losses, and recovery costs. The calculation was performed following the Minister of Forestry Regulation number 7 of 2014, as reported by Saharjo and Wasis (2019), which focused on the damage caused by fires on peatlands. Similarly, the present research focuses on the damage and loss caused by mining, based on the Minister of Forestry Regulation number 7 of 2014. Therefore, the estimated cost to the state of the environmental damage caused by the mining encroachment within the BSREF area of Mulawarman University is divided among these three cost categories, as outlined in Table 2.

Table 2 shows that the total value of economic losses from mining in BSREF in 2022 is IDR 29,634,308,951,392 or approximately 29 trillion. This includes ecological losses of IDR 3,812,985,242,057 or about 3.8 trillion, financial loss of IDR 22,029,449,861,316 or 22 trillion, and recovery costs of IDR 3,791,873,848,019 or 3.8 trillion.

Table 2. The total value of economic losses due to mining in the BSREF of Mulawarman University

Description	Value (Rp.)
Cost of ecological losses	
The cost of turning on the water Management function	3,748,406,218,866
Water arrangement fee	21,111,394,038
Erosion and runoff control costs	5,553,194,398
Cost of land formation	462,766,200
Nutrient recycling cost	4,266,704,363
Waste decomposition function cost	402,606,594
The cost of losing biodiversity	2,498,937,479
The cost of losing genetic resources	379,468,284
Carbon release costs	29,903,951,835
Total ecological/environmental losses	**3,812,985,242,057**
Cost of economic losses	
Land value	13,882,985,995,802
Cost of lost lifespan of land	2,961,703,679,104
Coal value	5,184,760,186,410
Total economic losses	**22,029,449,861,316**
Environmental recovery costs	
Reservoir development costs	3,748,406,218,866
Erosion and runoff control recovery costs	5,553,194,398
Soil formation restoration costs	462,766,200
Nutrient recycler recovery cost	4,266,704,363
Waste decomposition function recovery cost	402,606,594
Biodiversity recovery costs	2,498,937,479
g. Cost of restoring genetic resources	379,468,284
h. Carbon release recovery costs	29,903,951,835
Total recovery cost	**3,791,873,848,019**
Total cost of environmental damage due to mining	**29,634,308,951,392**

This is much greater than the valuation of losses in the research by Fachlevi et al. (2015), who estimated the value of community losses due to environmental degradation by coal mining at IDR 1,972,833,514. Furthermore, in earlier research, Yulian et al. (2011) stated that the economic value of damage to natural resources in Bukit Soeharto was Rp. 6,827,810,650,719.90 covering an area of 64,814.98 ha. Therefore, the estimated cost of environmental damage in 2022 was almost 4.3 times the value in the BSREF as of 2010. That implies on the last 12 years, there has been significant land degradation, with the cost almost 4.3 times in 2010.

Coal mining significantly impacts the environment, causing a decline in soil fertility, threatening biodiversity, reducing water and air quality, and causing environmental pollution. It is challenging to mitigate the negative environmental impact of illegal coal mining. The degradation should be prioritized in restoration planning (Nicoleite et al. 2017). Implementing CSR projects in the coal mining sector requires a sustainable livelihood framework (Narula et al. 2017). While post-mining integrated landscapes are recommended for sustainable land use (Kodir et al. 2017), understanding responsible mining practices is limited, leading to uncontrolled environmental damage that negatively impacts the surrounding community.

Mining is crucial for national development but can also severely affect biodiversity directly through operations at extraction sites or indirectly through broader socio-economic development (Seki et al. 2022; Saputri and Harini 2018). There are also decreases in environmental quality due to the government's inability to implement consistent policies to protect and manage the environment, especially in mining areas. Despite this, the community positively perceives the presence of coal mining companies. However, mining activities increase the potential for conflict between communities regarding land tenure rights and job vacancies.

The indirect negative impacts of mining are often overlooked (Mancini and Sala 2018; Sonter et al. 2014). These effects are indirectly caused by population growth, disruption of biodiversity, and reduction of various ecosystem services, such as water quality, carbon sequestration, pollination, and soil regulation (Csillik and Asner 2020; Roy et al. 2018; Tollefson 2019). Mining can lead to water pollution, reduced water biota, changes in soil structure, and even contribute to landslides and flooding during heavy rains. Additionally, its activities result in environmental imbalances, such as reduced water biota in rivers, pollution, and the formation of holes due to dredging. Most coal mines are operated through an open pit system, which significantly impacts the environment (Agboola et al. 2020; Esbri et al. 2023). Continued operation is feared to result in even greater issues such as deforestation, loss of vegetation diversity, land degradation, pollution of specific rivers, and air and residue pollution (Fachlevi et al. 2015; Sudarmadji and Hartati 2016; Jimmy and Merang 2020). The waste from open pit coal mining includes solid waste from stripping and removing topsoil, excavating overburden, and washing

coal. The mining process is closely related to the dredging of natural resources and causes changes in land cover and soil morphology (Hartati and Sudarmadji 2022). As a result of these activities, there are changes in soil structure at the excavation site, affecting soil fertility. For this reason, soil excavation procedures need to be adjusted to minimize soil damage.

The Bukit Soeharto Forest Park is the largest area of Borneo's tropical forest habitat and is located within the delineated plan for the State Capital of the Republic of Indonesia. This research showed that several locations in the Bukit Soeharto area were damaged due to both human activities and natural factors. The damage to the forest ecosystem needs to be dealt with comprehensively. In addition to restoring the ecosystem, the state should enforce a law that apprehends individuals who deliberately commit illegal acts in Bukit Soeharto and upholds the state's authority in maintaining the integrity of legislated conservation areas.

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