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Research Article

A comparison of soil characteristics from four land covers around a coal mining concession area in South Kalimantan

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Abstract

Understanding soil characteristics is important to determine the alternative strategies of land management, particularly those related to the scheme of soil and water conservation. This study investigated soil characteristics from four land covers around the coal mining concession area located in South Kalimantan. A soil survey was conducted using a purposive sampling method with three replicates in each land cover. Soil samples that were taken at depths of 0-10 cm, 11-20 cm, and 21-30 cm, were composited before being brought to the laboratory to quantify their characteristics, such as texture and organic carbon content. Data analysis was processed using a non-parametric test with a significant level of 5%. Comparison average of soil characteristics between land covers was evaluated using the Kruskal-Wallis test and followed by Nemenyi-test. Results found that soil characteristics from four land covers significantly differed in texture and organic carbon content. The highest sand fraction was noted in shrubs (67.23±0.86%), while the greatest silt fraction was recorded in plantation forests (29.71±2.84%). Compared to other land covers, the clay content in plantation forests and reclamation area was relatively equal by around 53-54%. On another side, The highest soil organic carbon was found in plantation forests with ranging of (4.44±0.14%) followed by natural forests (4.24±0.62%), shrubs (3.38±0.09%), and reclamation area (1.14±0.09%). These findings indicated there were high variations of soil characteristics from different land covers around the coal mining concession area. Therefore, it is recommended for managers to apply adaptive strategies in supporting soil conservation efforts based on the soil characteristics in each site.

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Introduction

Soil is a component of natural resources that plays an important role in maintaining environmental stability. Besides supplying water and nutrients for plants (Sadono et al., 2021), soil also has fundamental contributions to supporting biogeochemical cycles and energy flow in the ecosystems (Smith et al., 2015). Numerous studies also report that soil characteristics directly correlates to the vulnerability to natural disasters like flood and landslide (Djukem et al., 2020). Considering to these strategic positions, it is important to apply soil conservation efforts to minimize the risk of degradation. This challenge has become the most essential issue in many commercial sectors, one of them is the coal mining industry.

During the last periods, the existence of the coal mining business has provided a high contribution to increasing gross domestic product. This industry also gives a lot of work opportunities for people who live around its concession. In fact, some literature explains the presence of coal mining industries can accelerate the effort of rural development, particularly from corporate social responsibility programs. However, the activity of coal mining exploration also has negative impacts on the environment, mainly related to soil degradation (Ma et al., 2019). For example, the coal mining industry commonly uses open-pit systems, wherein it is conducted by removing vegetation cover (Kuzevic et al., 2022). Consequently, the rate of run-off and erosion will occur more rapidly. This circumstance can reduce soil fertility because the number of topsoil layers has been leached (Lulu et al., 2022). Moreover, the use of chemical compounds can also cause soil contamination (Mourinha et al., 2022). Thus, the effort of reclamation will be more difficult to implement because soil contamination can stimulate plant stress (Li et al., 2018). It will make plants die or demonstrate detrimental growth (Chibuike and Obiora, 2014). Therefore, integrated soil management is necessary to minimize the impacts of coal mining activity on soil degradation. This scheme can only be formulated if there is comprehensive information about soil characteristics around the coal mining concession area.

As one of the mining enterprises, PT Borneo Indobara has received a permit to manage a coal mining concession area located in South Kalimantan. This site comprises various land covers like natural forests, plantations, shrubs, etc. Even though this company has been operating for more than 10 years, the information about soil characteristics from each land cover is still limited. It is caused by the work priority that focuses on coal extraction. Unfortunately, the challenge of soil management is not only on a small scale but also occurs in the landscape. The connectivity of each land cover becomes an important aspect that should be considered to find the optimum solution. Therefore, this study aimed to identify the variation of soil characteristics from different land cover around the coal mining concession area managed by PT Borneo Indobara. The outcome will provide sufficient information for managers to formulate adaptative strategies for soil conservation in every land cover.

Materials and Methods

Study area

This study was conducted in a coal mining concession area managed by PT Borneo Indobara, which is located in Tanah Bumbu District, South Kalimantan Province (Figure 1). The geographical coordinates of this site are E115˚54'38” 115˚39'00” and S3˚35'30” 3˚36'30”. Topography is predominantly by hilly areas with a slope level of 8−26%. Altitude ranges from 20 to 52 m above sea level (asl). Annual rainfall reaches 2,291.7 mm year$^{-1,}$ with the highest rainfall occurring in January by approximately 352.3 mm month^{-1}. The mean daily temperature is 27.7˚C with a minimum of 22.7 ˚C and a maximum of 35.2 ˚C. Dry periods are relatively longer than 4 months, from July to November. PT Borneo Indobara had a total coal mining concession of around 24,100 ha. This area is divided into 4 blocks to facilitate exploration activities, namely Batulaki, Bunati, Kusan, and Girimulya.

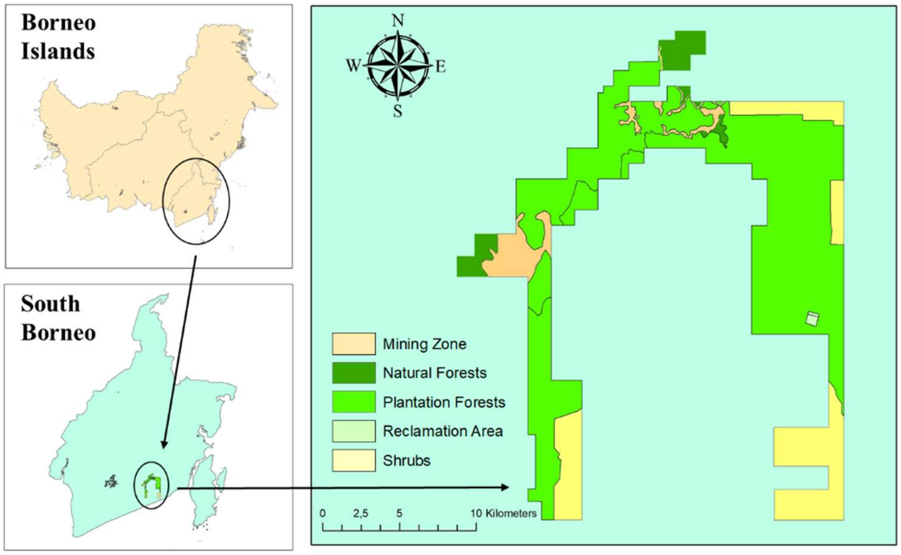


Figure 1. Sketch of the study area in coal mining concession managed by PT Borneo Indobara.

Before becoming the coal mining area, this area had various land cover, such as oil palm plantations, natural forests, plantation forests, etc. However, several land covers have been removed due to the impact of mining exploration. Among those sites, Girimulya still had land cover variation since it is the last block to mine the coal deposit based on company planning.

Data collection

Data were collected around 3 months from August to October 2020. This study consisted of three important phases, namely site stratification, soil survey, and laboratory analysis. The objective of site stratification was to identify the land cover variation around the coal mining concession area. This step was required to design the location for soil sampling. The spatial approach was applied to facilitate site stratification using the most updating image from Google Earth. There were four land covers found in the study area, including natural forests, plantation forests, shrubs, and reclamation areas. Then, sampling points were distributed randomly in every land cover with three replicates. The coordinate of every point was saved to GPS to facilitate the tracking process in the field.

In every sampling location, the soil samples were taken at depths of 0-10 cm, 0-20 cm, and 0-30 cm (Wirabuana et al., 2021a). Then, these samples were composited for each sampling position before being brought to the laboratory for quantifying their characteristics. There were two parameters used to identify soil variation among land cover, i.e. texture and organic carbon content. Soil texture was determined using the Pipette method (Alam et al., 2020), while soil organic carbon was quantified using Walkley and Black method (Estefan et al., 2013).

Statistical analysis

Data analysis was processed using R software version 4.1.2 with a significant level of 5%. The *dplyr* and *agricolae* packages were used to support the data processing (De Mendiburu and Simon, 2015). The first stage started with descriptive analysis to identify the range of data distribution, including mean, standard deviation, and standard error (Wirabuana et al., 2021b). This step was also carried out to assess the coefficient of variation and the coefficient of precision (Table 1). Both parameters were generally used to assess the accuracy and precision of data obtained by the sampling method (Santos and Dias, 2021). Then, the second stage was focused on assumption tests. There were two assumption tests that were applied for data evaluation, namely normality tests and homogeneity variance tests (Ghasemi and Zahediasl, 2012; Beyene, 2016). These tests were executed twice, wherein the first round was conducted using actual data, and the second round was undertaken using natural logarithmic transformation from data. However, the second round was only processed if the actual data did not follow normal distribution nor had heterogeneous variance. Based on the preliminary test, it has been confirmed that the data did not fulfil both assumptions. Therefore, this study used a non-parametric test to get a conclusion from the data. In this context, the comparison means of soil characteristics among land covers was examined using Kruskall-Walis test and followed by the Nemenyi test (Alam et al., 2020).

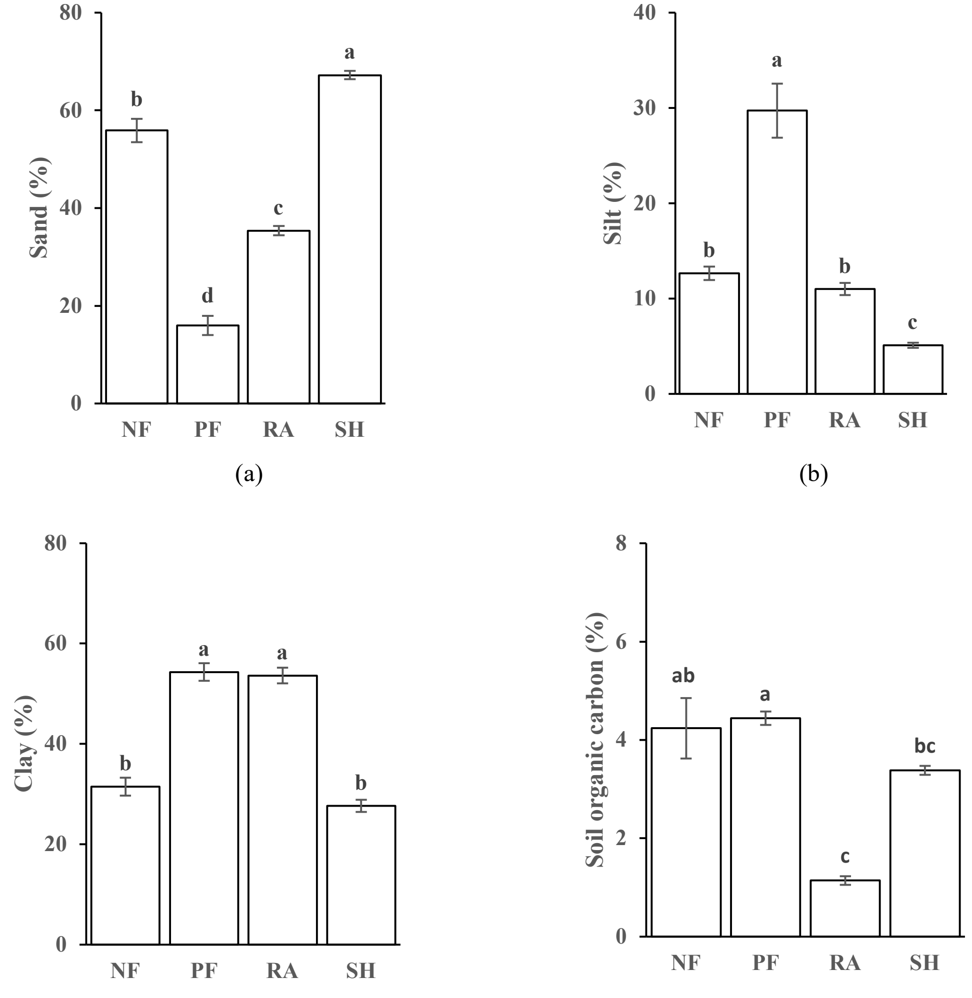
Table 1. Summary statistics of soil variation from four land cover types.

Land covers	**Parameters**	**Unit**	**Summary of Statistics**			
			Mean	**SE**	**CV (%)**	**P (%)**
NF	Sa	%	55.86	2.40	7.43	4.29
	Si	%	12.65	0.71	9.70	5.60
	Cl	%	31.48	1.78	9.80	5.66
	Organic C	%	4.24	0.62	25.21	14.55
PF	Sa	%	15.97	1.95	21.16	12.22
	Si	%	29.71	2.84	16.53	9.54
	Cl	%	54.33	1.75	5.59	3.23
	Organic C	%	4.44	0.14	5.30	3.06
RA	Sa	%	35.39	0.93	4.55	2.63
	Si	%	11.00	0.64	10.07	5.81
	Cl	%	53.61	1.56	5.05	2.91
	Organic C	%	1.14	0.09	13.27	7.66
SH	Sa	%	67.23	0.86	2.21	1.28
	Si	%	5.11	0.27	14.76	5.25
	Cl	%	27.66	1.21	7.56	4.36
	Organic C	%	3.38	0.09	4.55	2.63

Note: NF (natural forests), PF (plantation forests), RA (reclamation area), SH (shrubs), Sa (sand), Si (silt), Cl (clay), Organic C (soil organic carbon), SE (standard error), CV (coefficient of variation), P (coefficient of precision).

Results and Discussion

Summarized results of the observation demonstrated that soil characteristics among land covers relatively varied (Table 1), wherein there was a significant difference in particle-size distribution and soil organic carbon (Figure 2). The highest sand fraction was recorded in shrubs (67.23±0.86%), while the greatest silt fraction was discovered in plantation forests (29.71±2.84%). Compared to others, the clay content was relatively equal in plantation forests and reclamation areas by around 53−54%. These were substantially higher, around 30%, than the proportion of clay fraction in natural forests and shrubs. On another side, this study noted the highest soil organic carbon was found in plantation forests (4.44±0.14%), followed by natural forests (4.24±0.62%), shrubs (3.38±0.09%), as well as reclamation areas (1.14±0.09%). The presence of soil variation from different land cover indicated there was an interaction between vegetation and soil around the coal mining concession area. This finding was also confirmed by previous studies that documented the influence of vegetation on soil properties (Silva et al., 2018; Toru and Kibret, 2019; Wei et al., 2019).



(a) (b)

(c) (d)

Figure 2. Comparison mean of soil characteristics among NF (natural forests), PF (planted forests), RA (reclamation area), and SH (shrubs). The different letters above the graph indicate a significant difference based on the results of the statistical analysis.

In this context, there were two processes that accommodated the relationship between vegetation and soil, including the nutrient cycle and erosion. For explanation, soil with dense vegetation would have better fertility than soil with low vegetation density since there was higher litterfall accumulation sourced from vegetation above it (Duan et al., 2019; Lei et al., 2019). Several kinds of literature explained that litterfall was classified as natural organic matter from plants that are composed of nutrients such as N, P, and K (Castellanos-Barliza et al., 2018; Tongkaemkaew et al., 2018; Wongprom et al., 2022). Other studies also recorded around 50% of litterfall was composed of carbon elements (Park et al., 2020; Sadono et al., 2020; Wirabuana et al., 2021b). When litterfall was decomposed, its nutrient content, especially its carbon, would release into the soil (Giweta, 2020). Therefore, it could be understood why the soil organic carbon in natural and plantation forests were considerably higher than in shrubs and reclamation area.

The vegetation above the soil can also minimize erosion because it reduces the direct contact between rainfall and soil through their canopy layer (Moisa et al., 2021). The occurrence of soil erosion can decline soil fertility because it leaches the top soil layer, which contains nutrients (Novara et al., 2018). This explanation also supports our finding wherein the soil fertility in shrubs and reclamation areas was relatively lower than in natural and plantation forests. However, soil erosion is a natural process that contributes to weathering process. Soils that have high weathering intensity are generally dominated by clay content and also have low fertility (Alam et al., 2020). Interestingly, this study found that soil fertility in plantation forests was equal statistically to natural forests even though the clay content was substantially higher (Figure 2). This condition could have happened because before converting into a mining concession area, this site was managed as a commercial plantation forest wherein there were intensive silvicultural treatments, mainly related to fertilization. The application of fertilization can significantly improve soil fertility even though nutrient availability is naturally limited (Purwanto and Alam, 2020). This effort is generally conducted in plantation forests, especially those that are located in mature soil (Halomoan et al., 2015; Amezquita et al., 2018; Wirabuana et al., 2020).

Overall, this study realized the different types of vegetation and their density become the main factor that caused the soil variation around coal mining concession areas. Despite the fact that this site would be excavated for coal exploration, it would be better for managers to formulate soil conservation strategies to minimize the impact of mining activities on the environmental condition. These efforts will reduce the risk of soil degradation after mine closure and also have the potential to accelerate the reclamation activities for ecosystem restoration.

Conclusion

This study concluded there were high variations of soil characteristics from different land covers around coal mining concession areas. Soil texture indicated greater variation than soil organic carbon, wherein the composition of sand, silt, and clay was significantly different between land covers. The highest soil organic carbon was recorded in the plantation forests, while the lowest was found in the reclamation area. It indicated the implementation of soil and water conservation strategies should be determined carefully based on the specific condition of every land cover.

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