

Soil Physical Properties Development in Post-Coal Mining Rehabilitation Area in East Kutai District, East Kalimantan Indonesia

Veronika Murtinah^{1,*} Liris Lis Komara¹

¹ Forestry, East Kutai School of Agriculture, Jalan Soekarno Hatta, No. 1, Sangatta, East Kutai, East Kalimantan, Indonesia

*Corresponding author. Email: veronikamurtinah@gmail.com

ABSTRACT

The open-pit mining process has an impact on soil properties, including the soil physical properties. The physical properties of soil in the rehabilitation area will develop over time. This study aimed to determine the soil physical properties development in the 20 years old rehabilitation area and compare it with the natural forest area. Soil samples test was carried out in the laboratory, and data analysis refers to the criteria for assessing the soil's physical properties. Based on the soil profile observations, it is known that the rehabilitation site has 72 cm root depth; soil consistency and soil structure varies, soil texture is the silty clay loam. The natural site has 117 cm roots depth; soil consistency is predominantly firm (moist conditions) and sticky to very sticky (wet conditions); soil structures are sub-angular blocky and angular blocky, soil texture is sandy loam. The value of soil permeability, soil porosity, and bulk density is in the same class, namely a rather slow permeability, a low bulk density, and a very high porosity.

Keywords: Soil conditions, Coal mining, Rehabilitation

1. INTRODUCTION

Open mining techniques can cause ecological damage, and land degradation includes physical, chemical, and biological conditions of the soil in mining areas [1-3]. The Soil physical problems in mining areas include soil texture, soil structure, bulk density, porosity, and permeability [4,5]; besides that, the normal soil profile is disturbed [6,7]. The physical properties of soil in the rehabilitation area (reclamation-revegetation) will develop over time. If the post-mining land is not arranged and revegetated, the land can be degraded and un-productive [8].

The main obstacle in conducting revegetation activities on post-mining open land is the condition of the land that is not supportive (marginal) for plant growth [9,10]. In post-coal mining areas, topsoil generally has been mixed with the below subsoil [11].

The rehabilitation success in post-mining land is determined by many things, including aspects of landscape management, planting media fertility, planting, and maintenance. Media fertility is largely determined by the soil's physical, chemical, and

biological properties [12]. The important thing to know is soil properties information, including soil physicality, to support the post-mining land rehabilitation success. The soil has two main functions, and there are as a matrix where anchor plant roots and groundwater are stored and (2) as a plant's nutrients source [13]. The post-mining area can be used for productive purposes as well as biodiversity conservation [14].

To determine the effect of rehabilitation on the development of soil physical properties in the post-coal mining area, it is necessary to research soil properties in the area. Were there any significant changes in the rehabilitation area, especially the soil physical aspects?

2. METHOD

2.1. Study area

The study was conducted in the natural site (before mining) and in the 20-year post-coal mining rehabilitation site at PT Kaltim Prima Coal (PT. KPC), Sangatta, East Kutai Regency, East Kalimantan, Indonesia (Figure 1).

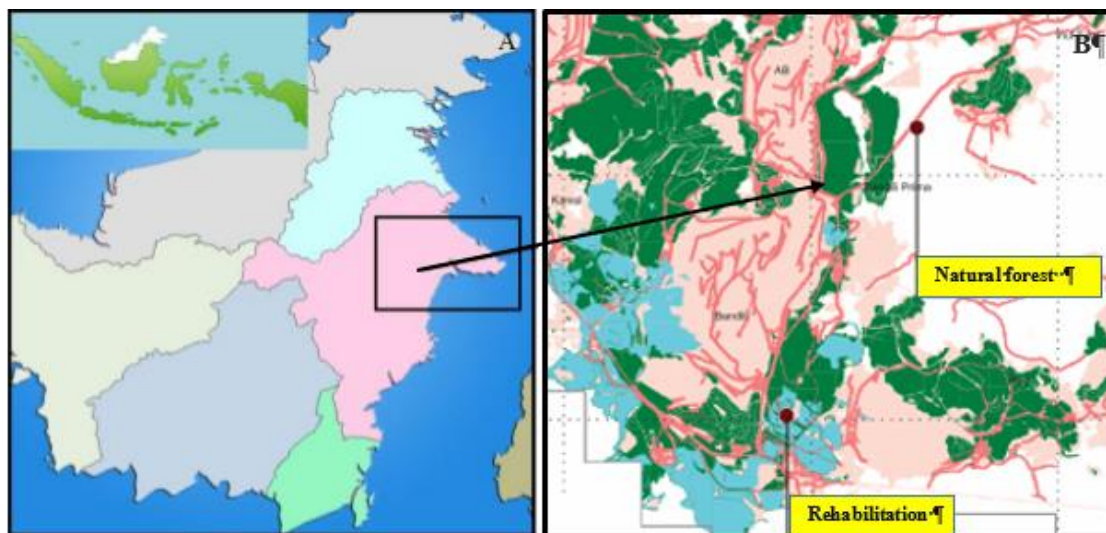


Figure 1 A. Location of the study area in East Kalimantan [15]. B. The red circle is the study area (natural and rehabilitation site).

Location of the study area in East Kalimantan at $00^{\circ}33'23''$ - $00^{\circ}38'17''$ N and $117^{\circ}23'55''$ - $117^{\circ}23'20''$ E, which has a tropical climate, average rainfall ranges from 1543 mm per year, air temperatures minimum is 26.68°C and maximum is 30.50°C . The average relative humidity per month between 80% - 90%, with a range of 70% in the afternoon and 90% in the morning [1].

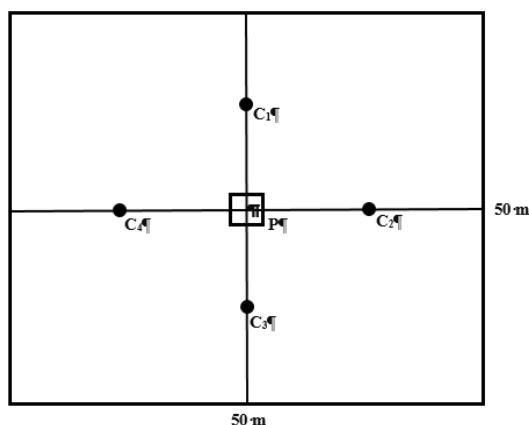


Figure 2 Research Plots in natural and rehabilitation sites, each a plot measuring $50 \times 50 \text{ m}^2$, a soil profile created in the center of the plot (P). 4 composite soil sample points are 12.5 m from the soil profile (C1-4).

The rehabilitation site has a 20% slope, and the natural site is a logged-over forest with a 14% slope. The vegetation that dominates the rehabilitation of the site is *Paraseriathes falcata* and *Cassia siamea*. Whereas natural sites (before mining) have varied vegetation and are dominated by *Nephelium eriopetalum* and *Macaranga hypoleuca* [15].

2.2. Research Procedure

This research was conducted for three months (April - June 2018), including field research and soil analysis

in the laboratory. Field research was carried out by making one soil profile in each research plot and observing its soil profile. Composite soil samples were taken in soil depth classes 0-10, 10-30, 30-60, and 60-100 cm using a soil drill. A sampling of soil for soil physical analysis was taken on the soil profile using a sample ring to determine soil permeability, bulk density, and soil porosity.

Soil texture was analyzed by hydrometer method, bulk density with weighing and drying at 105°C for 24 hours. Soil porosity was done by the volumetric method. Determination of soil physical properties criteria and soil profile description refers to soil criteria [16].

2.3. Data Analysis

Data analysis used descriptive quantitative analysis. The data obtained is processed and presented in table form.

3. RESULT AND DISCUSSION

3.1. Soil Profile Characteristic

The soil physical properties observed directly on the soil profile include effective soil depth, soil color, rooting, soil consistency, and structure. Soil texture was analyzed in the laboratory (Table 1).

3.2. Soil Permeability, Bulk Density, and Soil Porosity

The soil's physical properties were analyzed in the laboratory, including soil texture, bulk density (BD), soil permeability, and soil porosity (Table 2).

Table 1. Soil profile characteristic

Soil characteristic	Rehabilitation	Natural
Soil depth, effective soil depth	96 cm (deep), 72 cm (deep)	126 cm (very deep), 117 cm (very deep).
Soil colour	Horizon (1) 7,5 YR 3/2 (dark brown); (2) 7,5 YR 5/6 (strong brown); (3) 10 YR 4/3 (weak red)	Horizon (1) 10 YR 4/2 (dark greyish brown); (2) 10 YR 5/8 (yellowish brown); (3) 7,5 YR 6/6 (reddish yellow); (4) 5 YR 5/8 (yellowish red); (5) 10 YR 8/6 (yellow).
Rooting	Horizon (1) very fine and fine root: frequent, medium and coarse root: few; (2) very fine, fine and coarse root: few; (3) medium and fine root: very few.	Horizon (1) very fine and fine root: abundant, medium and coarse root: frequent; (2) very fine, fine, medium and coarse root: few; (3) very fine and coarse root: very few, fine and medium root: few; (4) very fine and coarse root: very few, fine and medium root: few; (5) very fine, fine, medium and coarse root: very few.
Soil structure	Horizon (1) granular, medium size, weak grade; (2) subangular blocky, medium size, medium-grade; (3) crumb, fine size, single grain grade.	Horizon (1) granular, medium size, weak grade; (2) subangular blocky, coarse size, medium grade; (3) angular blocky, medium size, medium-grade; (4) angular blocky, coarse size, medium grade; (5) angular blocky, coarse size, strong grade.
Soil texture	34.63% (clay); 45.94% (silt); 19.44% (sand): SiCL (Silty Clay Loam).	18.22% (clay); 24.90% (silt); 56.87% (sand): SL (Sandy Loam).

Table 2. Soil permeability, bulk density and soil porosity

Lokasi	Soil depth (cm)	Bulk density (BD) (g/cm ³)	Soil permeability (cm/hours)	Soil porosity (%)
Rehabilitation area	0-10	1.42 (M)	0.19 (S)	45.03 (VH)
	10-30	1.15 (L)	0.23 (S)	52.42 (VH)
	30-60	1.14 (L)	1.29 (RS)	47.33(VH)
	60-100	0.93 (VL)	0.22 (S)	56.15 (VH)
	Average	1.08 (L)	0.54 (RS)	51.65 (VH)
Natural forest area	0-10	0.70 (VL)	0.55 (RS)	64.44 (VH)
	10-30	1.21 (L)	0.94 (RS)	49.69 (VH)
	30-60	1.01 (L)	1.19 (RS)	57.12 (VH)
	60-100	1.11 (L)	0.99 (RS)	50.62 (VH)
	Average	1.06 (L)	0.99 (RS)	53.76 (VH)

S= slow; RS = rather slow; M = medium; L = Low; VL = very low; VH = very high

3.3. Discussion

The rehabilitation site has effective soil depth (soil depth that plant roots can reach) 72 cm (deep), while in natural site 117 cm (very deep). However, the soil can function well enough for the roots and trees to grow and

develop with this depth. Root development generally decreases with the soil depth increased. The topsoil in the rehabilitation site has been formed and distinguished based on the color of the soil. Rehabilitation and the natural site have the same tendency in the soil color that the topsoil color is darker than the below soil layer.

Organic matter content differences generally cause soil color differences. The higher the organic matter content, the darker the soil color [17,18].

The soil structure in the rehabilitation site varies (irregularly), influenced by (1) the organic matter, (2) the mixing of soil material, (3) the influence of the parent soil material layer. The topsoil structure in rehabilitation site is granular, medium-size, and weak stability, which is the result of the formation of soil which is strongly influenced by organic matter, while the bottom layer of Sub Angular Blocky/SAB is medium size, medium stable, and crumbs, fine size, loose stability, mainly due to the soil material used reclamation has mixed with the soil parent material layer. Whereas in natural forest areas, topsoil structures were granular, the lower layers are Subangular blocky (horizon 2) and angular blocky (horizon 3, 4, 5).

The soil texture in the rehabilitation area is different from the natural forest area. The soil texture in the rehabilitation area is dominated by silt (45.94%), followed by clay (34.63%) and sand (19.44%), while in the forest, the area is dominated by sand (56.87%), followed by silt (24.90%) and clay (18.22%). The dust and clay content is greater at the rehabilitation site 80.57% and natural site at 43.12%. Soils that have dust and clay values above 70% will be problematic for plant growth. Soil that is dominated by clay and dust causes the soil to store water well, but it is difficult to absorb water; besides that, the soil with a high level of clay and dust causes the soil to become dense so that the root growth in the plant will be disturbed by disturbing plants [19], besides that's it is easily carried by erosion, especially if it has a high slope. An ideal soil has a balanced texture of clay, sand, and dust, called loam so that the soil is not too loose and not too tight [20]. The occurrence of soil mixing and overburden used for reclamation causes the soil texture of the rehabilitation area to be different from the original soil texture [21].

Bulk density (BD) is an indication of soil density. The more soil dense, the higher the bulk density, the more difficult it is to continue the water or penetrate the roots [22]. A Dense soil will be difficult to infiltrate water and interfere with the development of plant roots, disturbing plant growth. BD in the rehabilitation area tends to decrease with increasing depth. On the contrary in the forest area increases with depth. BD is influenced by texture and soil organic matter. The soil texture in the natural site is dominated by sand, so it is more porous, while in the rehabilitation site dominated by dust and clay, it tends to be denser. In addition, more varied vegetation will produce organic materials and support the development of roots. This organic material supports soil organisms' activities, which will increase soil pores to decrease BD.

Soil permeability shows the ability of the soil to pass water. Soil structure and texture, as well as organic

elements, affect soil permeability [23]. The permeability of the land in the rehabilitation area is lower (0.54 cm/hour) than the natural forest area (0.99 cm/hour), but based on the permeability class, both are included in the permeability class rather slowly. This is influenced by the soil texture, especially the sand and clay fractions, to affect the soil structure. The more space between structures, the faster the permeability in the soil will be. These conditions will affect soil porosity. Pores are very decisive in soil permeability; the larger the pore in the soil, the faster the soil permeability.

The soil pores are the part that is not filled with solid material (filled with water and air). Soil with coarse pores that are difficult to hold water so that plants are prone to dryness [24]. The average porosity in the rehabilitation area was lower (51.65%) than the natural area (53.76%). Based on the porosity class, both are included in the very high soil porosity class. This is influenced by soil texture and vegetation (rooting conditions and organic matter content). The higher sand content indicates the soil's high porosity due to soil texture in the natural area. The influence of the content of organic matter in the soil also affects the pores of the soil. Soils that have greater porosity values indicate that the soil is increasingly porous. Porous soil has enough pore space for water and air movement so that it is easy to enter and enter the soil [24]. There is a mutually influential relationship between BD, soil permeability, and soil porosity. The value of BD is inversely proportional to the porosity and permeability of the soil. The higher the BD will reduce soil porosity and soil permeability.

5. CONCLUSION

The development of soil profiles differs between rehabilitation areas and forest areas, including effective soil depth, soil color. The soil consistency in the rehabilitation area varied, while the forest area is friable in the topsoil and firm in the subsoil. Soil structure in the rehabilitation area: granular, sub-angular blocky, and crumbs, while in the forest area: sub-angular blocky in the upper layer and angular blocky in the soil layer below it.

The soil texture in the rehabilitation area was dominated by silt (45.94%) and clay (34.63%), while the forest area was dominated by sand (56.87%). The dominance of dust and clay causes the soil to become denser and more easily carried away by surface erosion so that the reclamation area is formed more sloping or shortens the length of the slope.

Soil permeability and soil porosity in forest area is higher (0.99 cm/hour; 53.76%) than rehabilitation area (0.54 cm/hour; 51.65%), on the contrary for lower bulk density (1.06 g/cm³; 1.08 g/cm³). This value is in the

same class, namely a rather slow permeability, a low bulk density, and a very high porosity.

Post-coal mining Rehabilitation areas (reclamation – revegetation that is carried out seriously will result in good soil development (productive). The soil's physical development properties are mainly influenced by soil organic matter. Creating conditions that are good for the development of land and soil organisms will greatly support the soil's development at the rehabilitation site. For this reason, it is necessary to increase the diversity of plant species by planting longer-term local species so that the ecosystem succession process runs well.

ACKNOWLEDGMENTS

Many thanks to PT Kaltim Prima Coal for all the facilities during this study.

REFERENCES

- [1] W. Wardana, Evaluation of soil potential and vegetation biomass in reclamation area of PT Kaltim Prima Coal. *Sengata. East Kutai*. Thesis. Universitas Mulawarman, Samarinda, Indonesia, 2008.
- [2] A.N. Putri, Evaluation of the Crops Revegetated Success in Post-Coal Mining Land Site Lati PT Berau Coal East Kalimantan. Skripsi. Siviculture Departemen. Forestry faculty. Bogor Agriculture Institute. Forestry on Silviculture Departement, 2012.
- [3] I. Mansur, Silviculture Technique for Post mining Reclamation Areas, SEAMEO BIOTROP, Bogor, 2011.
- [4] B. Hermawan, Improving the Quality of Post Mining area through Revegetation and Compliance as Food Crop Farming Land Proceedings of the National Seminar on Cultivation. Urgency and Strategy for Controlling the Transfer of Functions of Agricultural Agricultural Land. Bengkulu, 7 Juli 2011. ISBN 978-602-19247-0-9.
- [5] L.O. Asir, Alternative Technique of Degraded Land Rehabilitation in Former Industrial Excavation Land BPK Manado Info, 3(2), 2013, pp. 113-130.
- [6] D.V. Pattimahu, Critical Post-Mining Land Restoration in accordance with Ecological Rules, 2004.
http://www.rudycr.com/PPS702ipb/09145/debby_pattimahu.pdf. Accessed date: Juni 8th 2018.
- [7] R.K. Shrestha, R. Lal, Changes in physical and chemical properties of soil after surface mining and reclamation, *Geoderma*, 11, 2011, pp. 268-276.
- [8] I. Hamid, S. Priatna, A. Hermawan, Physical and Chemical Properties Characteristic in Post Tin Mining in Indonesia, *Science Research Journal*, 1(19), 2017, 19105-23.
- [9] Y. Setiadi, Post Mining Restoration. Notes: Post mining revolving, 2013. (unpublished)
- [10] C.Y. Kusmana, M.A.S. Latief, Study of Revegetation Plant Result in Post Coal mining of PT Arutmin Indonesia Site Batulicin South Kalimantan, *Tropical Silviculture Journal*, 04(3), 2013, 160-165.
- [11] L.L. Komara, Pengembangan Indikator Keberhasilan Reklamasi Pada Lahan Pasca Tambang Batubara Menggunakan Protozoa. Disertasi. Biologi Institut Teknologi Bandung, 2017.
- [12] D.T. Iskandar, Suwardi, Suryaningtyas, Reklamasi Lahan-lahan Bekas Tambang: beberapa Permasalahan Terkait Sifat-sifat Tanah dan Solusinya, 2012.
http://repository.ipb.ac.id/jspui/bitstream/.../62632/1/PRO20_12_ISK.pdf. Accessed date: 31 Januari 2017.
- [13] S. Arsyad, Soil and Water Conservation. IPB Press, Bogor, 2006.
- [14] Rahmawati, Post Mining Restoration Area Based on Ecology. Agriculture Faculty of North Sumatera University, 2002.
<http://library.usu.ac.id/download/fp/hutan-rahmawaty5.pdf>. Accessed date: 16 Februari 2010.
- [15] L.L. Komara, V. Murtinah, Evaluation of plant species composition after thirteen years post-coal mining rehabilitation in East Kutai District of East Kalimantan, Indonesia. IOP Publishing Conf. Series: Earth and Environmental Science, 2018;144(012057). DOI: 10.1088/1755-1315/144/1/012057.
- [16] Anonymous, Land Classification Reference Terms, Soil Research Institute, Bogor, Indonesia, 1983.
- [17] Hakim, Soil Science Basics. Universitas Lampung, 1996.
- [18] Sutanto, Rachman, Soil Science Basics concept and reality. Kanisius, Yogyakarta, 2005.
- [19] Y. Setiadi, Restoration Ecology Lectures Materials. Forestry Science Study Programme Post Graduates School of Bogor Agriculture Institute, 2012. (Unpublished).
- [20] Maidhal, Perbandingan sifat fisika tanah lapisan atas oxisol di dataran tinggi dan dataran rendah. Skripsi Universitas Andalas Fakultas Pertanian, Padang, 1993.

- [21] D. Murjanto, Soil characteristic and development on Post Coal Mining Reclamation Area, Thesis Post Graduates School of Bogor Agriculture Institute, 2011.
- [22] Hardjowigeno, Soil Claifikation and Pedogenesis. Akademika Pressindo, Jakarta, 2003.
- [23] Rohmat, Soil Science Basics. Erlangga, Jakarta, 2009.
- [24] K.A. Hanafiah, Soil Science Basics. PT. Raja Grafindo Persada, Jakarta, 2005.