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Relationship between soil texture and soil organic matter content on mined-out lands in Berau, East Kalimantan, Indonesia

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Abstract. *Hartati, Sudarmadji T. 2016. Relationship between soil texture and soil organic matter content on mined-out lands in Berau, East Kalimantan, Indonesia. Nusantara Bioscience 8: 83-88.* Post open pit mining may in most cases leave unarable and degraded lands due to heavy soil disturbances and therefore reclamation efforts of such area should be addressed on the revitalization of the soil functions for plant growth. The capability of tropical humid soils, including post open pit mining soils, to support plant growth is largely determined by their organic matter content-nutrient pool, soil aggregation, microbial activity, etc. However, soil organic matter content is, to large extent, governed by the soil clay content which is most likely permanent. This may imply that the soil texture couple with soil organic matter content could be a sound measurement to assess the recovery stages of the mined-out lands in term of soil functions for plant growth. This research was conducted in three sites of reclamation area in Berau, East Kalimantan. Soil texture varied from moderately fine (35-40% clay) to fine (40-50% clay) and very fine (>50% clay) for the BMO, SMO and LMO sites respectively. Soil clay eluviations were found in both of SMO (8 years old revegetation) and BMO (>12 years old revegetation) sites but not in LMO site. Soil organic matter content ranged from very low (<1%) to low (1-2%) and gradually increases in line with the increase of soil clay contents. For the soils with 35-50% clay contents (SMO and BMO sites), the top 30 cm depth soil organic matter content is to some extent controlled by the soil clay contents. Clay eluviations might be used as indicators of soil pedogenic were found in moderately fine to fine soil texture. Each process occurs at >12 and 8 years old revegetation when the organic matter content reaching its maximum. The very fine soil texture does not show clay eluviations process until > 12 years old revegetation even containing the highest organic C content and reaches its maximum at 8-10 years old revegetation.

Keywords: mined-out lands, soil texture, soil organic matter, clay content

INTRODUCTION

Post open pit mining may in most cases leave unarable lands due to heavy soil disturbances (Kainthola et al. 2011; Wang et al 2014) and therefore rehabilitation efforts of such area should be addressed on the revitalization of the soil functions for plant growth (Singh et al. 2002; Fan and Wang 2009; Zhang et al. 2015). In the mining activities open systems, soil damage begins with the destruction of the soil structure. As a result, the soil is no longer able to be the ideal medium for plant growth in terms of required air and water circulation. Soil organic matter is one of the most important adhesives in the formation of soil aggregates. The soil organic matter is also a source of some macro- and micro-nutrients of the soil, affecting soil improvement for nutrients adsorption and water as well as improving the biological life of the soil. Therefore, the recovery of mined-out land must be initiated with the revitalization of soil function, especially soil structure followed by other land components such as vegetation cover, microclimate and incoming wild lives (Bronick and Lal 2005; Peng et al. 2004).

Soil organic matter content is too large extent, governed by the soil texture which is most likely permanent. This may imply that couple of clay content and its soil organic matter content could be a sound measurement to assess the stage of the recovery of the mined-out land in term of soil functions for plant growth. The optimum content of soil organic matters that can support plant growth are ideally is about 2%. Another fact is known that the soil texture itself is a unique permanent soil property (Sopher and Baird 1998). Moreover, soil diversity expresses organic matter content and therefore at same time also indicates the potential mined-out lands recovery.

The main objective of this study was to determine the relationship between soil texture in term of clay content and soil organic C content in mined-out lands to assess the mined-out lands recovery stages of in term of soil functions for plant growth.

MATERIALS AND METHODS

Study area

The study of mined-out lands rehabilitation is conducted at coal mining concession of PT Berau Coal, Berau District, East Kalimantan, Indonesia (01°58'17,976"-02°8'45,974" South; 117°19'59,996"-117°29'0,994" East) as shown in Figure 1. Observations are carried out at 3 (three) different sites i.e. Sambarata (SMO), Binungan (BMO), and Lati (LMO) mining operation, by considering Mined-out Land (MoL) revegetation of <2, 2-4, 4-6, 6-8, 8-10, 10-12, >12 years old and Original Land (OL) (Hartati et al. 2013).

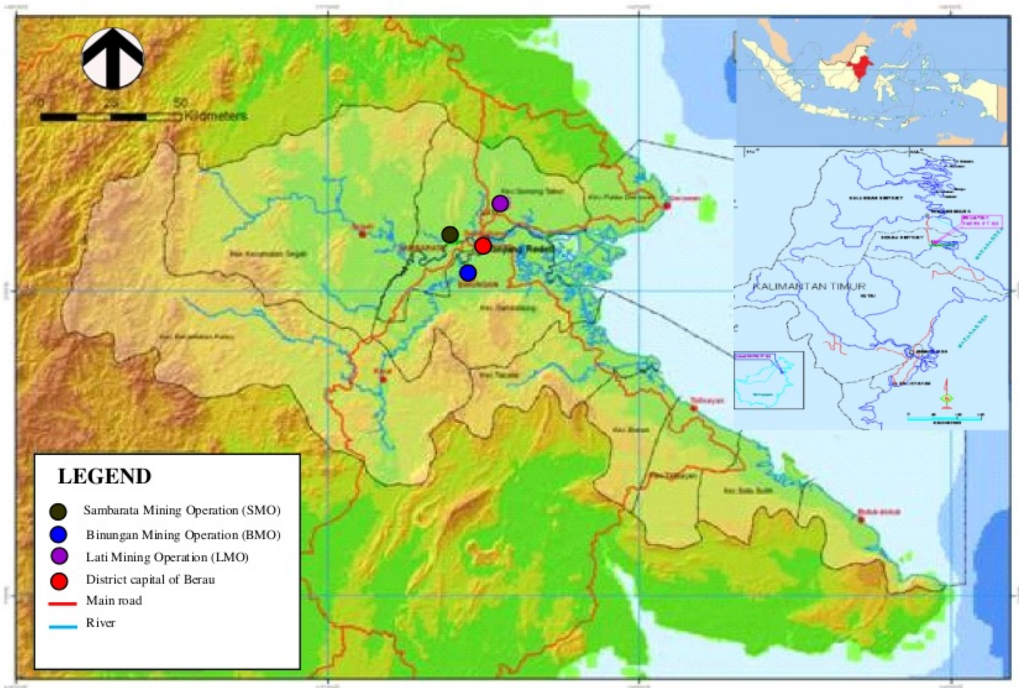


Figure 1. The study area at coal mining concession of PT Berau Coal, Berau, East Kalimantan, Indonesia

The climate of the region is classified as A-type (SMO and LMO), and B type (BMO) referred to Schmidt-Ferguson's classification system or Af in Koppen's classification system (Sudarmadji 2013). The geology of the areas is characterized by sedimentary rocks of tertiary and quarterly sediment, sandstone, aquiclude consisting of clay layers, claystone, shale, and siltstone. Geomorphologically, the coal concession of PT Berau Coal as syncline area belongs to lowland, river land until rugged hills characterized by steep slope in the river land and undulating to moderately steep in the rugged hills. Physiographically, the lowland consists of flood plain and back swamp.

Soils used and analytical method

This research was conducted at three sites of mined-out lands after revegetation works of PT Berau Coal East Kalimantan. Four hundred and thirty-two (432) disturbed soil samples were collected from MoL by considering MoL revegetation of <2, 2-4, 4-6, 6-8, 8-10, 10-12, >12 years old and OL, each 18 soil samples at three sites.

In each site, a series of different revegetation ages were taken to clarify the influence of revegetation on soil organic matter content. Simultaneously, the soils were selected to represent a possible wide range of soil texture for examining the influence of soil texture upon soil organic matter contents.

Mechanical composition was determined by the standard sedimentation method using natrium pyrophosphate as dispersing agent after H_2O_2 treatment. For this purpose, the international system of particle size limits was adopted. Organic C content was determined by modified Walkley-Black dichromate method (Walkley and Black 1934).

RESULTS AND DISCUSSION

Soil texture variation at MoL

Soil texture is the relative ratio between percentage of sand, silt, and clay in a soil mass. Generally, soil textures are classified into 12 classes but then simplified into 5 types, i.e. very fine, fine, moderate, coarse and very coarse (Hardjowigeno 2003). Based on these, soils of MoL were studied by dividing into four different texture types; very fine, fine, moderate and coarse. Furthermore, soils of OL were divided into two different texture types; very fine and fine. Compared with the OL, soil texture of MoL was found to be more various (Table 1).

Soil textures of MoL were more coarse than the OL at the top 30 cm depth because of the amount of clay content were accidentally lost due to land clearing activities and/or during transportation from mining pit to the top of soils stockpiles.

Distribution of soil mineral particles of MoL

In general, soil mineral particles classified into different soil particle sizes, because of its different properties. Considering the particle size differences, finer soil particle has the largest surfaces compared with larger particles. The surface area of the particles in soil is quite important in determining the soil water holding capacity. This is due to much of water in soil is held as films on surfaces of the individual soil particles. Finer-textured soils will have larger amount of surface area and will hold larger amounts of water (Sopher and Baird 1998).

The highest average of sand content is found at BMO followed by SMO and the smallest is LMO. Furthermore, sand content sharply increases in the MoL than OL of LMO (Table 2). The highest silt content of MoL is found at SMO followed by LMO and the lowest is at BMO. In general, the more clayey soil, the higher silt content throughout the soil profile (Ohta et al. 1992). However, in the MoL the relationship could not be judged clearly. Silt content in the MoL of LMO is lower than in OL and reverse in LMO. Silt content at BMO is similar between MoL and OL. In the MoL, silt content decreased following the deeper soil profile.

The highest clay content on MoL is at LMO followed by SMO and the lowest is at BMO. Based on clay content, soil texture at study areas are classified into moderately fine (35-40% clay) to fine (40-50% clay) and very fine (>50% clay) for BMO, SMO, and LMO sites, respectively. Clay particle in the soil has specific properties that are different from other soil mineral particles. Small size particle allows a greater soil water holding capacity. Specifically, in the form of colloidal soil particles will be negatively charged so that it can adsorb nutrients which are generally in the form of cations (Sopher and Baird 1998). Similarly, in observing the process of pedogenic differences of clay contents between topsoil and subsoil can be used as an indicator of the improvement of soil structure and/or the initial pedogenic process. Soil clay eluviations were found in both of SMO (8 years old) and BMO (>12 years old) revegetation but not at LMO (Figure 2). The improved soil structure tends to be responsible element for the larger clay translocation vertically or clay eluviation in the upper soil of the moderately fine soil (SMO).

Potential content of soil organic matter in MoL

Soil organic matter is expressed by the content of soil organic C. Soil organic C contents itself ranged from very low (<1%) to low (1-2%) in the MoL and this situation is not much different from its OL. Table 3 shows that increasing age of the plant revegetation in MoL is not always followed by an increase in organic C content.

The ranging of fine (SMO) up to very fine (LMO) of soil textures of MoL showed the similar pattern, ie at each layer of soil examined levels of organic C content reaches a maximum when the plant revegetation 8-10 years old. The very fine soil texture decreased organic C content >10 years old revegetation, reverse by the fine soil texture. Furthermore, in the moderately fine soil texture (BMO) organic C content reaches a maximum magnitude when the plant revegetation >12 years old (Figure 3).

Most plant species used for mined-out land revegetation is *Paraserianthes falcataria* (L) Nielsen which is a kind of fast-growing species. The growth of *P falcataria* follows a sigmoid curve with age. At the first stage (<1 year), the height growth is slow as young plant, small trees are not able to accumulate energy for rapid terminal growth, but as the size and foliage of the tree increases, more energy becomes available for the terminal shoot to grow. This increase in energy accumulation potential results in accelerated height growth (1-5 years) that continues until the tree reaches its highest growth rate (6 years). After this peak (6-8 years), the growth rate slows down as the stress created by extreme height, exposure or crown size limit the expansion of the terminal growth (Oliver and Larson 1996; Riyanto and Pamungkas 2010).

In both of MoL and OL, the highest organic C content was found at LMO followed by SMO and the lowest at BMO. Finer-textured soils would enrich the surface with nutrients (Drees 1993). Vertically, organic C content decreased with increasing its soil depth. This fact shows that the accumulation of soil organic matter is largely originated from the vegetation litterfall. Each site shows a different time in the accumulation of organic matter, ie SMO was 4-6 years old, 2-4 years old vegetation at BMO and < 2 years old vegetation at SMO.

Table 1. Variation of soil texture in the MoL and OL

Site	Soil depth (cm)	Land type	Soil type			
			Very fine	Fine	Mode-rate	Coarse
SMO	0-10	MoL	c	cl, scl	sil	-
		OL	sc	scl	-	-
	10-30	MoL	c, sc	cl, sicl	sil	-
		OL	sc	-	-	-
	30-60	MoL	c, sc	cl, scl	sil	
		OL	c	cl	-	-
BMO	0-10	MoL	c, sc	cl, scl	l	ls
		OL	c, sc	cl	-	-
	10-30	MoL	c, sc	cl, scl	-	-
		OL	c, sc	cl	-	-
	30-60	MoL	c, sc	scl	sil	-
		OL	c, sc	-	-	-
LMO	0-10	MoL	c, sic	cl, sicl	-	-
		OL	-	cl	l	-
	10-30	MoL	c, sic	cl	-	-
		OL	-	cl	-	-
	30-60	MoL	c, sic	sicl	-	-
		OL	c	cl	-	-

Note: c: clay, cl: clay loam, scl: sandy clay loam, sil: silty loam, sc: sandy clay, l: loam, ls: loamy sand

Table 2. Distribution of soil particles on MoL and OL

Site	Soil depth (cm)	Sand (%)		Silt (%)		Clay (%)	
		MoL	OL	MoL	OL	MoL	OL
SMO	0-10	31.76	48.69	27.16	15.35	41.07	35.96
	10-30	30.82	48.60	25.66	10.52	43.51	40.89
	30-60	33.86	41.65	21.11	16.47	45.03	41.88
BMO	0-10	47.50	45.14	14.60	15.65	37.91	39.21
	10-30	46.81	45.88	13.17	13.40	40.02	40.71
	30-60	47.59	44.15	11.92	9.59	40.48	46.27
LMO	0-10	19.61	39.59	24.00	33.45	56.38	26.96
	10-30	21.39	39.44	19.64	26.74	58.97	33.82
	30-60	19.82	34.95	20.25	29.86	59.93	35.20

Table 3. C organic soil content (%) in MoL and OL

Site	Soil depth (cm)	Revegetation age of MoL (yr)								Original land
		<2	2-4	4-6	6-8	8-10	10-12	>12	Avg.	
SMO	0-10	0.38	0.60	0.43	0.75	1.66	0.79	1.43	0.86	1.65
	10-30	0.42	1.09	0.25	0.71	1.43	0.55	1.00	0.78	0.98
	30-60	0.34	1.29	0.43	0.44	1.30	0.46	0.96	0.74	0.56
BMO	0-10	0.51	0.15	0.36	0.31	0.95	0.43	1.19	0.56	1.57
	10-30	0.47	0.13	0.21	0.27	0.31	0.22	0.37	0.28	0.61
	30-60	0.63	0.07	0.24	0.24	0.32	0.13	0.30	0.28	0.43
LMO	0-10	0.74	0.67	0.78	1.06	2.27	1.75	1.19	1.21	1.50
	10-30	0.63	0.33	0.54	0.61	1.85	1.24	0.61	0.83	1.18
	30-60	0.57	0.43	0.31	0.47	1.54	1.09	0.79	0.74	0.61

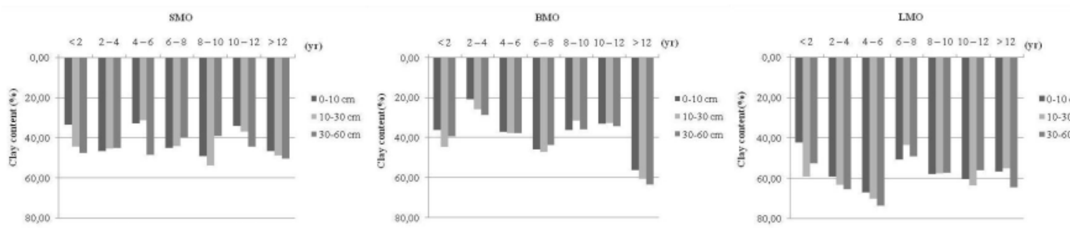


Figure 2. Clay eluviation process at MoL

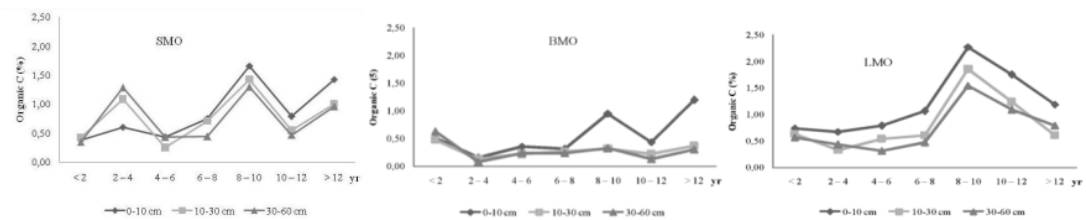


Figure 3. The dynamics of soil organic C content by increase of revegetation age

Relationship of soil texture and soil organic C content

Soil organic matter content gradually increases in line with the clay content increase of the moderately fine to fine soils (BMO and SMO) on the top of 30 cm depth of MoL (Kumar et al. 2013; Fontaine et al. 2007; Rumpel and Kögel-Knabner 2010). Conversely, the relationship is unclear for the > 30 cm soil depth. It is believed that it would be related to the source of organic matter that accumulates on the top layer of soil (Sanchez 1976; Ohta et al. 1992). The obtained results showed no clear consistent regularities of the soil organic C content on very fine soil (LMO). In the OL this tendency was the most obvious figure for the top 10 cm depth and unclear in the deeper layers (Figure 4).

Based on the average of clay content (> 40%) in MoL, the clay contents of diverse shows the control of different organic matter content. Correlation analysis between the clay content and the organic C content in MoL is shown in Figure 5. The organic C content in BMO and SMO primarily for the top 30 cm depth was correlated with clay content (r = 0.51 and r = 0.43). It means that for the soils with 35-50% clay contents (SMO and BMO), the top 30 cm depth soil organic matter content is to some extent controlled by the soil clay contents. For this reason, the application of soil amendment is required to increase soil organic matter content and eventually enhancing soil function recovery. For the soils at LMO with >50% clay contents is not closely related (r = 0.10) between the two parameters.

Clay eluviations as indicators of soil pedogenic were found in moderately fine to fine soil textures. These processes occur at >12 and 8 years old revegetation (Shan et al. 2013) when the organic matter content reaches its maximum. When the organic matter content reaches a maximum, the soil structure would be stabilized. Soil structure can be defined in terms of form and stability (Bronick and Lal 2005). Soil structure depends on the presence of stable aggregates. In fact, aggregate stability

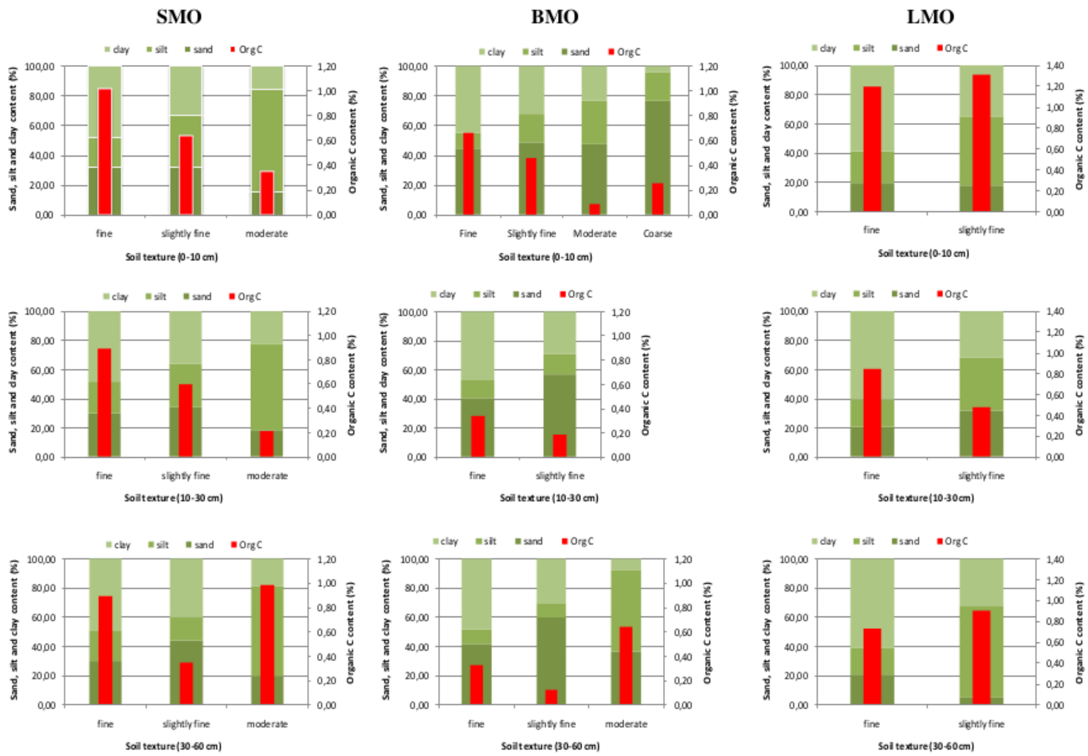
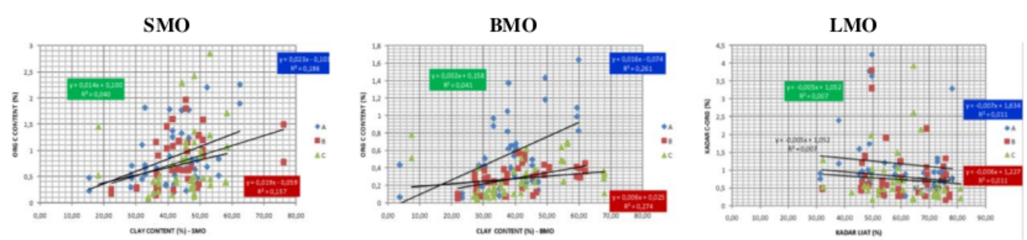


Figure 4. The dynamics of organic matter content at the various levels of fineness soil texture



Depth (cm)	Equation	R^2	Equation	R^2	Equation	R^2
0-10	Y = 0.023x-0.103	0.186	Y = 0.016x-0.074	0.261	Y = 0.007x + 1.634	0.011
10-30	Y = 0.019x-0.059	0.157	Y = 0.006x+ 0.025	0.274	Y = 0.006x + 1.227	0.011
30-60	Y = 0.014x + 0.1	0.040	Y = 0.002x + 0.158	0.041	Y = 0.005x + 1.052	0.007

Figure 5. A relationship between clay content (%) and soil organic C content (%) at MoL

influences several soil physical processes, such as water infiltration and soil erosion (Amézketa 1999; Le Bissonnais et al. 2007). Specifically, aggregate stability determines the movement and storage of water in soils, soil aeration, soil erosion, biological activity, and crop growth (Zhang and Miller 1996). The very fine soil texture does not show clay eluviation process until >12 years old revegetation even though having the highest organic C content and had reached its maximum content level at 8-10 years old revegetation.

In general, pedogenic process as of soil clay eluviations in MoL was found in both of SMO (8 years old vegetation) and BMO (>12 years old vegetation) sites with 35-50% clay but not in LMO site with >50% clay when organic matter content reaches its maximum. Soil organic matter content in MoL ranged from very low (<1%) to low (1-2%) and the content gradually increases in line with the increase of clay content of the soils. Maximum content of C-organic was found at the 8-10 years old vegetation site. In the MoL for the soils with 35-50% clay contents (SMO and BMO sites), the top 30 cm depth soil organic matter content is to some extent controlled by soil clay contents, and therefore the application of soil amendment is required to increase soil organic matter content and eventually enhancing soil function recovery.

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