

Research Article

Ex-coal mine lands and their land suitability for agricultural commodities in South Kalimantan

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Abstract: Coal mining is carried out with an open system that is dredging topsoil, and then taken the coal material. In 2016, the Indonesian Center for Agricultural Land Resources Research and Development conducted a survey, mapping and characterization of ex-coal mine areas in Tapin, Tabalong, Balangan, and Hulu Sungai Selatan regencies. This paper aimed to provide information based on the soil biophysical characteristics on ex-coal mine lands and to assess the land suitability for agricultural crops. The land characteristics obtained were then matched with the criteria of quality/suitability land for agricultural crops. The ex-coal mine lands in the four regencies cover an area of 17,141 ha. The landform characteristics have changed, namely voids and piles of excavated products in the form of small piles to hilly called anthropogenic landforms. According to Soil Taxonomy, the soil is classified as anthropic soil that was formed from material transported by humans, as Endoaquents Anthroptic, Epiaquents Anthroptic, and Udothents Anthroptic. The heavy metals found were Pb, Hg, and Cd that varied from low to high uneven both vertically and horizontally. The land suitability class of Suitable (S) for dryland food crops, vegetable crops and forage crops covered 12,606 ha, while for annual crops covered 14,158 ha. The land suitability class is classified as Marginally suitable (S3), and the remaining as Not suitable (N). Based on the biophysical conditions, the ex-coal mine area requires considerable land reclamation and rehabilitation efforts, both for the restoration of soil chemical and physical properties.

Keywords: *coal mining, ex-mine land, land suitability, soil classification, South Kalimantan*

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Introduction

Utilization of abandoned ex-coal mined land for the expansion of agricultural areas is an opportunity to solve the availability of food land and environment land problems. Bian et al. (2010) reported that most European countries reclaimed ex-mining land to be turned into forests or grasslands, while in China it was more used as agricultural land. The use of ex-coal mining land for agricultural is an opportunity to solve this problem. Identification data and up to date information about the extent of spatial distributions and characteristics of ex-coal mine lands are required. According to Wu et al. (2020), many

studies have identified the impact of surface mining through landscape changes, but data and information the spatial distribution related to the extent of the impact to characterized ex-coal mining lands are still limited. Rachman et al. (2017) stated that the limited information regarding the dynamics of changes in physical, chemical, and biological properties of soils on ex-mining land is a challenge in the framework of efforts to reclaim the ex-mining land to be used as productive and sustainable agricultural land. The activities of rehabilitation, reclamation and development of ex-mining land involve various development sectors as well as technical and socio-economic aspects and policies that require the involvement of various

scientific disciplines. Therefore, research on ex-mining land related to land reclamation and agricultural development on ex-coal mine lands are required.

Utilization of multi-spectral and multitemporal satellite imagery is considered to be more cost-effective and quite effective in detecting and delineating ex-coal mining land between new and old mining areas, although the resulting accuracy is different. In this case, the accuracy of sightings for the new coal mining land is better than the old mining land (Gunawan et al., 2010). Utilization of remote sensing data was emphasized on spectral characteristics (Haryani et al., 2019).

In 2016, the Indonesia Center for Agricultural Land Resources Research and Development (ICALRD) was conducted a survey, mapping and characterization of ex-coal mining lands in Tapin, Tabalong, Balangan and Hulu Sungai Selatan regencies, South Kalimantan Province. It is expected that with this activity land maps with a scale of 1:25,000 or higher will obtain information about the spatial distribution and land characteristics such as physical and chemical soil characteristics as well as the suitability of agricultural land and its management implications.

Conventional open-pit mining has dramatically changed the landscape balance of the land surface, reducing the quality and productivity of the soil and the environment quality (Subowo, 2011). Munawar (1999) says the topsoil of open coal mining was very heterogeneous and had a high fill weight, low total pore, low N and P content, and high Ca and Mg reserves and low soil microbial population compared to forest land surrounding. According to Tala'ohu (1995), in coal mines, excavated land is generally arranged upside down from its initial arrangement. Topsoil is under the subsoil. Generally, these materials are stacked on productive soil so that it can inhibit plant growth and reduce soil productivity. The remaining coal mining excavation consists of young coal and claystone, siltstone, sandstone or volcanic tuff. Land reclamation efforts in mining companies included in the Forestry Cultivation Zone (KBK) refer to regulations issued by the Ministry of Forestry that require planting of local plant species (Permenhut. No. P.4/Menhut-II/2011, Permenhut. No. P 60/menhut-II/2009). Meanwhile, those not included in the KBK can be planted with other crops such as food crops.

This study aimed to characterize the soil on the ex-coal mining lands, determine the land suitability class and efforts to deal with land reclamation, especially the recovery of soil fertility on land after coal mining. Open mining activities such as coal mining cause loss of biodiversity, degradation of watersheds, changes in landforms

and the release of heavy metals that can enter the aquatic environment, for this reason, land reclamation efforts are needed. Reclaimed coal mining land can have a positive influence on reducing soil erosion and soil runoff (Patiung et al., 2011).

Materials and Methods

The materials used in this study were digital base map of Rupa Bumi Indonesia/RBI scale 1:50,000 published by the Geospatial Information Agency (BIG); Digital Elevation Model (DEM) maps of 30 m resolution from Shuttle Radar Topographic Mission (SRTM), topographic digital contour maps, 1:250,000 scale digital geological map published by the Center for Geological Research; Landsat 7, Landsat 8, SPOT 5 and SPOT 6 imagery, and Google Earth. The tools used in this study include: Belgian type ground drill (length 1.2 m); Munsell Soil Color Chart Book; the 2016 National Soil Classification revised edition; the 2014 edition of Keys to Soil Taxonomy; GPS; pH Truog to measure soil pH in the field; Abney level to measure slope; soil profile digging tool (hoe, shovel, crowbar); personal computer for data entry and spatial analysis, which is equipped with ArcGIS, ArcView, SAGA-GIS, Global Mapper programs. The activity began with the identification and characterization of the biophysical conditions of ex-coal mine land resources. The identification and characterization were carried out in four selected regencies in South Kalimantan Province, namely Tapin, Tabalong, Balangan, and Hulu Sungai Selatan. The study was conducted on ex-coal mining area for 2 (two) weeks in July 2016. The stages of activities carried out consisted of preparation, main survey, data processing/analysis of soil and water.

Preparation

The stages in this study included the interpretation of the distribution of ex-mining from satellite imagery, and verification data of land, land use, forest area status, climate, geological information and soil source rock.

Analysis of area mining spread

Before analyzing the distribution of ex-coal mines from satellite imagery, it is necessary to crop the data layer (DEM, sensory imagery, soil map view) in accordance with the administrative boundaries of the regencies to be mapped. The purpose of this analysis was to delineate the ex-mining area from satellite imagery of Landsat 7, SPOT 6 and Google Earth based on differences in colour, hue, shape and texture.

Landform analysis

Landform analysis or interpretation of satellite imagery and DEM was intended to delineate landform units on ex-mine land that have been restricted to the previous stage. The Soil Survey Staff (2014) and Schoeneberger et al. (2012) in the National Soil Survey Handbook, have classified landforms as a result of man-made into two broad categories, namely: (1) Anthropogenic Landforms and (2) Displays of Anthropogenic Micro Landform.

Area/slope analysis

Analysis of the shape of the slope and elevation was done from DEM data. The automatically analysis process was made with the software (ArcGIS, SAGA GIS) or directly (on-screen digitizing). Automatic analysis results usually produce many polygons, it needs for filtering or merging polygons. For 1:50,000 scale mapping, the area of polygons <10 ha was combined into the next broad polygon. The naming and coding of terrain forms and slope classes referred to the Technical Guidelines for Landform Classification for Land Mapping in Indonesia (Suparto et al., 2016).

Field research activities

Field research activities aimed to: (1) verify the results of delineation of ex-coal mining land through satellite imagery, (2) observe biophysical of ex-coal mine land, (3) sample soil, and (4) collecting of secondary data.

Soil characteristics and soil classification

Soil observation was carried out using drilling, mini-digging and soil profiles. Making mini pit of 40-50 cm followed by drilling as deep as 120 cm, and making a soil profile made as deep as 150 cm or up to the parent material when the soil depth was less than 150 cm. Drilling, mini pit, and profile soil observations were carried out at 35 sites. Ways of observing the morphological characteristics of the soil and the physical environment in the field referred to the Guidelines for Soil Observation in the Field (Sukarman et al., 2017). Soil samples were taken from the representative profile which is representing the soil units from each map unit, then given a symbol/code for subsequent analysis in the laboratory. Soil classification was determined in the field and then corrected with laboratory analysis data. Soil classification was based on the National Soil Classification to the category of soil types (Subardja et al., 2016) and the Soil Taxonomy Classification system to subgroup categories (Soil Survey Staff, 2014). In this classification, particular classification was used for

human-amended lands and human-transported lands.

Soil analysis

Analysis of soil samples was carried out in the Soil Research Institute laboratory, Bogor, including determination of organic matter content (C, N, and C/N), soil reaction (pH), potential P₂O₅ and K₂O levels (25% HCl extraction), P₂O₅ available (extract Bray 1), exchangeable bases (Ca, Mg, K, and Na), cation/CEC exchange capacity (NH₄OAc pH 7), Al, H and some heavy metal elements (Pb, Cd, and Hg). The analysis procedure followed the method stated in Soil Survey Investigation Report No. 1 (Soil Survey Staff, 2011) and Technical Guidelines for Chemical, Water, Plant and Fertilizer Analysis (Eviati and Sulaeman, 2012).

Land suitability evaluation

The land evaluation was carried out by means of matching and was guided by the Technical Evaluation of Land Guidelines for Agricultural Commodities (Ritung et al., 2011). The assessment was carried out up to the subgroup category, which shows the land suitability class and its limiting factors for each commodity assessed, for example, the land suitability class for chilli plants is S3-oa-na, which means that the land is classified as suitable marginal land (S3) with a limiting factor for poor soil drainage (oa) and low nutrient availability (na).

Results and Discussion

Biophysical characteristics

Coal mining is carried out with an open system that is dredging topsoil, then coal material is taken. Biophysical damage sightings on ex-coal mine land in four districts in South Kalimantan Province as a result of coal mining land clearing activities are shown in Figure 1. This change caused the contamination, degradation of land quality as well as biophysical damage and landforms in the form of mixing of top and bottom layers of soil as well as the disclosure of subsoil layers containing heavy metals that are toxic to the surrounding environment. Ex-dug holes filled with turbid water that is brown, grey called under or voids.

Topographic forms

The ex-coal mining area in the four regencies covers an area of 17,141 ha (Table 1). This area is divided into 16,656 ha of open coal mine area and 485 ha of the voids area. Tabalong Regency is the largest with an area of 7,721 ha, consisting of 7,655 ha of open land and 66 ha in the form of voids. The topography at the location of the ex-coal mine in

Tapin Regency is divided into nearly flat (slope 1-3%) covering 81 ha, undulating (slope 3-8%) covering 1,668 ha, rolling (slope 8-15%) covering 572 ha, hillocky (slope 15-25%) covering 857 ha and hilly (25-40%) covering 913 ha. The rest is in the form of a pit which is an ex-mine pit filled with water (voids) covering an area of 169 ha. The area in Balangan Regency consists of undulating (slopes 3-8%) covering an area of 3,913 ha with the

voids covering an area of 194 ha. The area in Tabalong Regency is divided into undulating (slope 3-8%) covering an area of 7,633 ha, and hillocky (slope 15-25%) covering an area of 22 ha with the voids covering an area of 66 ha. The area in Hulu Sungai Selatan Regency consists of undulating (3-8% slopes) covering 241 ha, and hillocky (slopes 15-25%) covering 271 ha with the voids covering an area of 56 ha.



Figure 1. The land before mining (left) and ex-coal mining land with voids (right) in South Kalimantan.

Table 1. Forms of areas of ex-coal mine lands in four regencies of South Kalimantan.

No.	Topography and slopes	Tapin	Balangan	Tabalong Area (ha)	Hulu Sungai Selatan
1	Flat (0-1%)	-	-	-	-
2	Nearly flat (1-3%)	81.00	-	-	-
3	Undulating (3-8%)	1668.00	3913.00	7633.00	241.00
4	Rolling (8-15%)	572.00	-	-	-
5	Hillocky (15-25%)	857.00	-	22.00	271.00
6	Hilly (25-40%)	913.00	-	-	-
7	Voids	169.00	194.00	66.00	56.00
Total		4260.00	4107.00	7721.00	568.00

Landform

In the Technical Guidelines for Landform Classification Guidelines for Soil Mapping in Indonesia (Suparto et al., 2016), landforms as natural formations on the surface of the earth, especially land on land formed by specific geomorphic processes and through a series of certain evolutionary processes. At the study area, the appearance of the landform was found to have changed as a result of the process of excavation and landfill mining. In the 12th edition of the Soil Taxonomy Keys (Soil Survey Staff, 2014), it describes landforms explicitly for human transformed and human-transported soils called Anthropogenic Landforms. Referring to the Soil Taxonomy Keys, the landform at the study site is

included in the constructional anthropogenic landform, namely reclaimed land, there is also a dug-out dune land and destructive anthropogenic landform, namely open-pit mining areas and also ex-mining basin areas.

Ex-coal mining lands physical and morphological properties

The field observations in the four study locations showed that the topsoil morphologically tended to be better than those in the subsoil. The soil colour is brownish grey to bright red; the soil texture is nearly fine, fine to moderate, the structure of the soil is solid and massive, the consistency of moisture is nearly sticky to sticky and firm, the soil pH is 4.0 - 6.0 with the depth of the soil is

moderate, deep to very deep. While the bottom part of the soil generally has a greyish-brown to dark grey soil colour, the soil texture is nearly fine, very fine, moderate to nearly rough, the consistency of moisture is nearly sticky to very sticky and firm, the soil pH is 4.5 - 5.5 with deep soil (> 100 cm). Soil compacting occurs in the subsoils so that the soil structure is solid and massive with fast or poor drainage. The morphological and physical

characteristics are presented in Table 2. Data presented in Table 2 show that ex-coal mining soils in the Southern Province are dominated by very fine and fine soil textures, clay loam to clay textures at the top of the pile of excavated material. Whereas in the subsoil of the texture is clay loam to silty clay. These lands have poor soil drainage as a result of soil compaction that occurs due to the accumulation of minerals.

Table 2. The soil physical and morphological properties soil on ex-coal mine lands.

Regency Symbol	Morphological and physical properties	Topsoil	Subsoil
1	Soil colours (moist)	dark brown-yellowish, brown greyish	brown greyish, grey, brown-yellowish, yellow-reddish
2		brown, grey, strong grey	dark grey, grey, brown
3		grey, dark red, brown-yellowish	yellow-reddish, dark brown greyish
4		brown, grey, dark brown greyish	brown greyish, grey, brown-yellowish
1	Soil texture (field)	slight fine, fine, medium	slight fine, fine, very fine
2		slight fine	medium
3		slight fine, fine	slight coarse, slight fine
4		slight fine	medium
1	Structure	massive	massive
2			
3			
4			
1	Consistency (wet and moist)	sticky, slightly sticky, firm	sticky, very sticky, firm
2			
3			
4			
1	pH (field)	4.0-5.0	4.5-5.5
2		4.5-5.0	4.5-5.0
3		4.5-6.0	5.0-5.5
4		4.5-5.5	4.5-5.0
1	Depth	moderate, deep, very deep	deep
2			
3			
4			
1	Sand (%)	42.30 (28.00-61.00)	35.73 (12.00-58.00)
2		26.33 (1.00-43.00)	35.16 (23.00-80.00)
3		31.50 (24.00-44.00)	54.33 (29.00-83.00)
4		13.50 (13.00-14.00)	25.33 (17.00-34.00)
1	Silt (%)	30.20 (22.00-36.00)	31.93 (18.00-39.00)
2		33.66 (29.00-42.00)	26.5 (8.00-42.00)
3		33.75 (30.00-40.00)	21.16 (7.00-36.00)
4		40.00 (36.00-44.00)	37.00 (30.00-47.00)
1	Clay (%)	27.50 (13.00-39.00)	32.33 (14.00-51.00)
2		40.00 (28.00-57.00)	38.33 (11.00-63.00)
3		34.75 (26.00-43.00)	24.50 (10.00-45.00)
4		46.50 (42.00-51.00)	37.66 (32.00-46.00)
1	USDA texture class	Clay loam	Clay loam
2			Silty loam
3		Clay	Silty loam
4			Clay loam

Notes: 1= Tapin; 2=Tabalong; 3=Balangan; and 4=Hulu Sungai Selatan.

These conditions indicate that the morphological and physical properties of the local soil have been damaged. This condition is certainly a limitation for the continuity of optimal plant growth. Sukarman and Gani (2017) in their research said that to be able to improve these lands requires land reclamation and rehabilitation efforts, including improving the physical properties of the soil through the provision of organic material and planting cover crops to avoid the danger of erosion and landslides. Junaedi et al. (2017) in their review stated that reclamation and revegetation is the best way to improve and restore the function of the ex-coal mining land.

Soil characteristics and soil classifications

The identification of the ex-coal mines in Tapin, Balangan, Tabalong, and Hulu Sungai Selatan, were produced spatially in the form Semi Detail Atlas of ex-mine land of South Kalimantan Province. As an example of a soil map of an ex-coal mine land and its legend in a regency in South Kalimantan Province is shown in Figure 2, Table 3, and Table 4. These soils are formed from piles of excavated mining material that has been mixed up and formed topsoil. The soil has mostly undergone physical and chemical changes. Coarse soil texture, soil structure has been damaged and soil compaction occurs at the bottom due to solid

and massive, soil drainage is very fast or very slow and washing of nutrients and minerals. The identification result from the soil maps and field verification show that the soils are classified based on the classification of land changed by humans and human-transported land including ex-mine lands (Soil Survey Staff, 2014), and its equivalent based on the National Soil Classification (Subardja et al., 2016) presented in Table 5.

The soil on ex-coal mine land in Balangan Regency is classified into the soil order and subgroup as Entisols and the Anthroportic Epiaquents (Aluvial Eutrik) and Anthroportic Udorthents (Regosol Eutrik). Soils on ex-coal mining areas in Tabalong Regency and Hulu Sungai Selatan Regency are classified into the soil order and subgroup as Entisols and the Anthroportic Udorthents (Regosol District) and Anthroportic Udorthents (Regosol Eutrik). These soils are also classified as voids or holes from the ex-coal mining area. According to the National Soil Classification (Subardja et al., 2016), Regosol is soil with coarse-textured of albic material, does not have a horizon characteristic, or any horizon (except if buried 50 cm or more new material) other than the A-ochric horizon, histic-horizon or sulfuric-horizon and 60 percent or more sand content at depths between 25-100 cm from surface.

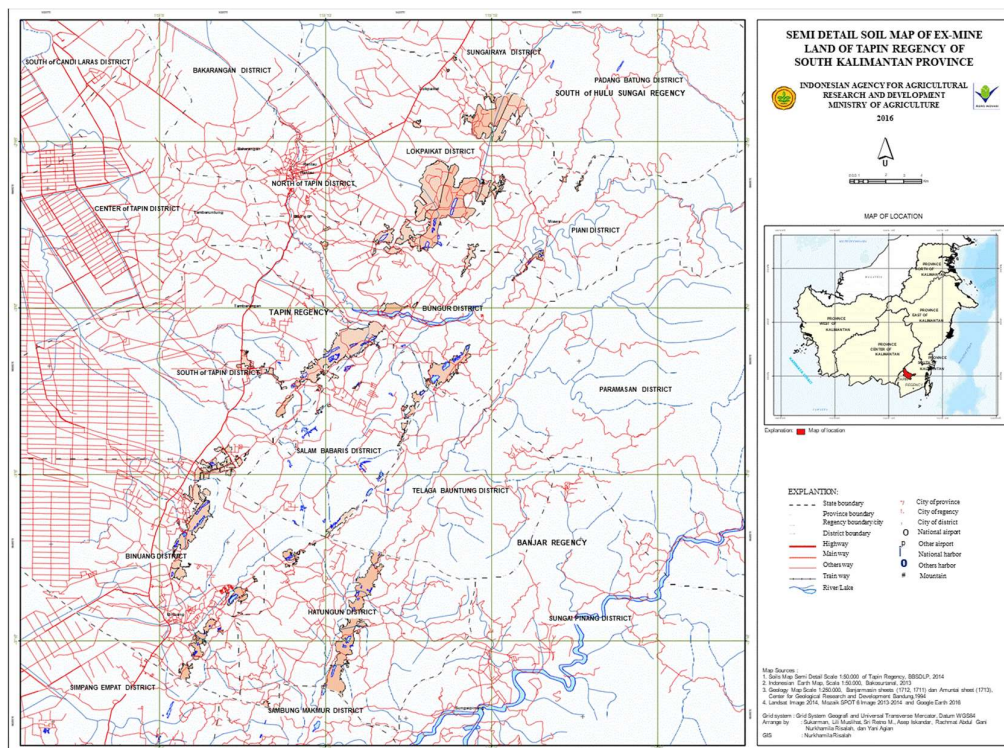


Figure 2. One of the soil maps of the ex-coal mine lands in the Tapin Regency, South Kalimantan.

Table 3. Legend map of one of the ex-coal mine soil maps in the Tapin Regency, South Kalimantan.

Soil Mapping Unit (SMU)	National Soil Classification, ICALRD 2016	Proportion	Landform	Parent Materials	Slope (%)	Area	
						Ha	%
1	Anthroportic Udorthents, very deep, nearly well drainage, medium texture on the top horizon and nearly fine texture on sub horizon, acid, low CEC and moderately base saturation (Regosol Distrik)	D	Open-pit mining on a tectonic plain with measly of small and large voids		Nearly flat (1-3)	81.25	1.91
	Anthroportic Epiaquents, medium, nearly poorly drainage, nearly fine texture on the top horizon and medium texture on sub horizon, acid, low CEC and high base saturation (Regosol Eutrik)	F					
	Voids	T					
2	Anthroportic Udorthents, deep, nearly well drainage, medium texture, acid, very low CEC and low base saturation (Regosol Distrik)	D	Open-pit mining on an undulating tectonic plain with a little and medium voids		Undulating (3-8)	1668.67	39.20
	Anthroportic Udorthents, very deep, nearly well drainage, fine texture on the top horizon and sub horizon, acid, low CEC and low base saturation (Regosol Distrik)	F					
	Voids	M					
3	Anthroportic Udorthents, deep, well drainage, nearly fine texture, acid, low CEC and moderately base saturation (Regosol Distrik)	D	Open-pit mining on rolling tectonic plain with a little of medium voids	Sandstones and claystones (pile of waste material)	Rolling (8-15)	571.67	13.43
	Anthroportic Udorthents, shallow, well drainage, fine texture on the top horizon and very fine texture on sub horizon, acid, low CEC and moderately base saturation (Regosol Distrik)	F					
	Voids	M					
4	Anthroportic Udorthents, deep, well drainage, nearly fine texture, acid, low CEC and moderately base saturation (Regosol Distrik)	D	Open-pit mining on hilly tectonic with a little and medium voids		Hillocky (15-25)	856.42	20.12
	Anthroportic Udorthents, shallow, well drainage, fine texture on the top horizon and very fine texture on sub horizon, acid, low CEC and moderately base saturation (Regosol Distrik)	F					
	Voids	T					
5	Anthroportic Udorthents, deep, well drainage, nearly fine texture, acid, low CEC and very high base saturation (Regosol Eutrik)	D	Open-pit mining on a hilly tectonic plain with a little of medium and large voids		Hilly (25-40)	910.66	21.39
	Anthroportic Udorthents, medium, well drainage, medium texture, acid, very low CEC and moderately base saturation (Regosol Distrik)	F					
	Voids	M					
X.3			Open soils			168.52	3.96
Total						4257.20	100.00

Table 4. The soil chemical properties on ex-coal mine lands in four regencies of South Kalimantan.

Chemical properties	Regency	Ex-mining topsoil	Soil fertility criteria of CSR (1983)	Ex-mining subsoil	Soil fertility criteria of SR (1983)
pH soil (H ₂ O)	Tapin	4.79 (3.55-5.63)	very acid-low acid	4.66 (3.50-6.03)	very acid-low acid
	Tabalong	6.47 (5.58-7.36)	low acid-netral	5.37 (4.88-6.37)	acid-low acid
	Balangan	5.66 (4.39-8.01)	low acid-low alkali	6.48 (4.46-8.03)	acid-low alkali
	Hulu Sungai Selatan	4.90 (4.83-4.97)	acid	4.80 (4.50-5.00)	acid
C-organic (%)	Tapin	1.46 (0.14-3.70)	very low-medium	1.12 (0.09-1.66)	
	Tabalong	0.64 (0.09-0.93)	very low	0.77 (0.08-1.39)	very low-low
	Balangan	0.81 (0.59-1.35)	very low-low	1.03 (0.15-1.65)	
	Hulu Sungai Selatan	2.34 (1.39-3.08)	low-high	2.64 (0.70-4.17)	very low-high
P ₂ O ₅ total (mg/100 g)	Tapin	34.21 (1.60-184.57)	very low-very high	21.59 (1.29-61.61)	very low-very high
	Tabalong	18.95 (13.20-28.69)		9.05 (4.14-17.29)	very low-low
	Balangan	14.74 (2.35-31.34)	very low-medium	19.80 (6.17-32.67)	very low-medium
	Hulu Sungai Selatan	8.77 (8.35-9.19)	very low	8.52 (8.00-9.00)	very low
K ₂ O total (mg/100 g)	Tapin	8.85 (1.50-24.34)	very low-medium	10.88 (2.25-39.35)	very low-medium
	Tabalong	11.72 (3.92-17.45)		8.48 (2.42-17.66)	very low-low
	Balangan	6.79 (3.07-12.93)	very low-low	4.89 (2.81-7.35)	
	Hulu Sungai Selatan	4.68 (3.48-5.88)	very low	4.27 (3.00-5.00)	very low
P ₂ O ₅ Bray I (ppm)	Tapin	13.68 (2.41-103.66)	very low-very high	4.72 (2.70-9.55)	
	Tabalong	7.66 (5.15-11.69)	very low-low	4.18 (3.67-4.81)	
	Balangan	3.23 (1.72-5.00)		4.04 (2.98-4.89)	very low
	Hulu Sungai Selatan	4.79 (0.62-4.01)	very low	5.42 (2.20-8.60)	
CEC (cmol/100 g)	Tapin	8.27 (2.94-25.29)	very low-very high	9.98 (3.39-33.56)	very low-high
	Tabalong	7.30 (4.93-8.75)	very low-low	9.24 (2.38-14.38)	
	Balangan	9.20 (6.73-11.89)		6.84 (4.28-10.22)	very low-low
	Hulu Sungai Selatan	9.85 (8.78-10.91)	low	7.43 (6.20-9.47)	low
Base saturation (%)	Tapin	57.11 (15.07->100)	very low-very high	63.62 (8.45->100)	
	Tabalong	100 (>100)	very high	68.79 (12.03->100)	
	Balangan	54.91 (7.18->100)		70.38 (11.06->100)	very low-very high
	Hulu Sungai Selatan	45.78 (8.52-91.55)	very low-very high	51.00 (11.00-81.00)	
Al ³⁺ (cmol/kg)	Tapin	3.70 (0.20-9.47)	very low-medium	3.18 (0.26-10.43)	very low-medium
	Tabalong	td	td	1.99 (0.16-4.32)	very low
	Balangan	6.89 (6.35-7.42)	low	6.01 (5.24-6.77)	low
	Hulu Sungai Selatan	2.98 (0.43-5.53)	very low-low	1.91 (0.20-5.11)	very low-low

Note: td= not measured.

Table 5. Soil classification on ex-coal mine lands in four regencies of South Kalimantan.

Regency	Soil Classification		
	National (Subardja et al., 2016)	Soil Taxonomy (Soil Survey Staff, 2014)	
	Soil Type	Order	Subgroup
Tapin	Regosol Distrik	Entisols	Anthroportic Udorthents
	Regosol Eutrik		Anthroportic Endoquents
Balangan	Aluvial Eutrik		Anthroportic Epiaquents
	Regosol Eutrik		Anthroportic Udorthents
Tabalong	Regosol Distrik		Anthroportic Udorthents
	Regosol Eutrik		
Hulu Sungai Selatan	Regosol Distrik		Anthroportic Udorthents
	Regosol Eutrik		

Soil is formed from the parent material leftover from the results of coal mining or the result of the addition of mine excavated material. The soil characteristics as deep, rough texture, fast drainage, and has very low CEC and base saturation, in the soil category is classified as Regosol Eutrik and Regosol District, and its equivalent based on Soil Taxonomy Keys (Soil Survey Staff, 2014) in the subgroup category is classified as Anthroportic Endoquents and Anthroportic Udorthents. Alluvial is soils developed from young alluvium material (recent), have a stratified layer structure or irregular organic C content with soil depth, and do not have a characteristic horizon (except buried by > 50 cm new material) other than horizon A-ochric and H-histic, and has a finer texture than sandy clay at a depth of 25-100 cm from the surface of mineral soil. The soil was formed from the parent material leftover from the results of tin mining or the result of the addition of mine excavation material. The soil characteristics are as follows: deep, nearly fine texture, poor drainage, moderate CEC, and high base saturation. In the category of soil types, the soil is classified as Alluvial Eutrik, and their equivalents based on Soil Taxonomy Keys (Soil Survey Staff, 2014) in the subgroup category, the soil is classified as Anthroportic Epiaquents.

Soil chemical characteristics

Table 4 shows the pH value of the topsoil, which is part of the excavation of soil and the subsoil ranges from acid to slightly acidic (pH: 4.79 - 6.47). Organic C content varied in top and subsoils from low to high (0.09 - 4.17%) as well as other chemical characteristics. Organic C-values, P₂O₅ total, K₂O total, CEC, base saturation (BS), and Al³⁺ saturation tended to be low to very low and fluctuating. Based on the value of the chemical characteristics, indicating the soil has been mixed in a state of a landfill, and it is poor as a result of washing and reversing the original position that occurred during the dredging and landfiling

process. In line with the study of Ernawati (2008), the soils on ex-coal mining lands produce low values on the chemical properties. Based on the content of heavy metals (Table 6), soils in ex-coal mining lands have been polluted by heavy metals (Pb and Hg), both in the topsoil and subsoil. However, based on the criteria for the heavy metal content of the Ministry of State Population and Environment of Indonesia, and Dalhousie University, Canada (1992) and USEPA (1993), the heavy metal contents are still below the critical threshold that can be toxic. In the study of heavy metal mercury (Hg), Juhriah and Alam (2016) concluded that the phytoremediation technology of the soil with the *Celosia plumosa* (Voss) Burv plant is effective and able to reduce Hg content in the soil. The use of organic material can improve soil fertility of ex-coal mining land (Amelia and Suprayogo, 2018). Sopialena et al. (2017) reported that mixing topsoil and fertilizer on ex-coal mine land increased microbial diversity, soil fertility, and plant growth. Hermawan (2011) reported that all soil physical and chemical variables have risen to levels suitable for food crops after being reclaimed for 12 years.

Ex-coal mining lands suitability, limiting factors, and handling

The land suitability criteria used in this study referred to the Land Evaluation Technical Guidelines for Agricultural Commodities (Ritung et al., 2011), namely by matching and comparing plant growth requirements with land characteristics. The ex-coal mining land in four Regencies was classified as Marginal Suitable land (S3) and Not Suitable land for now (N). Land suitability assessment was carried out on dryland annual food crops (TPLK), namely on upland rice, corn, soybean, vegetable crops such as red chilli and onion, annual crops such as oil palm and cocoa, and elephant grass fodder plants. The extent of the results of the land suitability evaluation results on ex-coal mine land is presented in Table 7.

Table 6. Averages and ranges and critical limits of some characteristics of heavy metal in soils on ex-coal mining areas in four regencies of South Kalimantan.

Heavy metals	Regency	Ex-mining topsoil	Above the critical limit	Ex-mining subsoil	The critical limit	Limits in the soil
Pb (ppm)	Tapin	16.84 (6.22-24.29)	No	18.01	No	100**)
	Tabalong	17.76 (10.69-23.12)		14.12		
	Balangan	15.88 (14.76-18.42)		13.59		
	Hulu Sungai Selatan	22.22 (17.66-26.78)		19.46		
Cd (ppm)	Tapin	td	td	Td	td	0.5**)
	Tabalong			0.16 (0.12-0.21)	No	
	Balangan				td	
	Hulu Sungai Selatan			Td	td	
Hg (ppb)	Tapin	63.76 (12.91-108.94)	No	78.67 (7.26-222.80)	No	420*)
	Tabalong	83.69 (69.27-104.18)		58.01 (15.33-75.02)		
	Balangan	51.11 (32.31-69.91)		87.41 (29.86-168.42)		
	Hulu Sungai Selatan	67.66 (54.74-80.58)		60.44 (38.30-100.49)		

Notes: td = not measured, *) U.S. EPA (1993); **) Ministry of State Population and Environment of Indonesia, and Dalhousie University, Canada (1992).

Table 6 shows that the suitability of ex-coal mining lands in the four regencies for TPLK, vegetable crops, and forage crops is 12,606 ha each and class N land area is 3,995 ha, while for annual crops is 14,158 ha and the total area of class N is 2,443 ha. The limiting factors found for TPLK, vegetable crops, annual crops, and animal food crops are slightly rough to coarse soil texture or blocked soil drainage, low to very low nutrient retention, very low nutrient availability and erosion hazard (S3-oa-nr-na-eh). Most of the ex-coal mining lands

have been severely damaged and degraded both physical and chemical. Physical properties, especially soil structure, was damaged (loose or massive), the soil texture became coarse. Almost all soil chemical properties and sources of plant nutrients are classified as very low, which means that they cannot support plant growth optimally. To handle and repair degraded land, it is necessary to reclaim land and rehabilitate land that is quite heavy, for the recovery of chemical and physical properties.

Table 7. Land suitability on ex-coal mine lands in four regencies of South Kalimantan Province.

Regency	Area (ha)			
	TPLK	Vegetables	Annual crops	Forage crops
Tapin	2,088	2,088	3,663	2,088
Tabalong	6,891	6,891	6,891	6,891
Balangan	3,416	3,416	3,149	3,416
Hulu Sungai Selatan	211	211	455	211
Total S3	12,606	12,606	14,158	12,606
Total N	3,995	3,995	2,443	3,995
Total	16,601	16,601	16,601	16,601

Notes: S3= marginally suitable; N = not suitable; TPLK = dry land food crops.

In an effort to develop food crops in the ex-coal mining lands, clear and well-planned and programs are needed, starting from the status of arable land, supporting facilities and good infrastructures. The sustainable development of human resources starting from on-farm, harvesting, post-harvesting to marketing the results. Therefore, the use of ex-coal mine land must be very selective, and the land must be recovered first, which can take quite a long time. Efforts to utilize ex-coal mining lands quickly and appropriately can be done by land loosening through restoration or construction of drainage channels, composting or manure as an effort to deal with limiting factors for coarse soil texture and poor soil drainage (oa). Liming and fertilizing and addition of soil organic matter as an effort to handle limiting factors for nutrient retention (nr) and nutrient deficit (na). Whereas limiting factors for soil erosion hazard (eh) can be overcome by making terraces and planting cover crops. Before this, it is necessary to first topsoil the ex-coal mining land to further enhance soil fertility. This effort certainly requires quite expensive input costs and proper planning. Amelia and Suprayogo (2018) in their research on organic material management for mine land reclamation concluded that the use of organic materials (topsoil, bokashi, and compost of oil palm empty fruit bunches) was able to improve soil fertility and be able to improve the development of plant roots in ex-coal mining piles. Susilawati and Maryati

(2012) reported that *Melastoma malabathricum* and *Mikania micrantha* H.B.K are pioneer plants that associate with microbes as bioremediatory on rooting and soil which can adapt well and are found in all depths of excavated land of former coal mines. Besides that, the need for further research in each growing season in the study of the composition of metals contained in lands contaminated with heavy metals (Agustine et al., 2018).

Conclusion

The soils at ex-coal mining lands are classified as Regosol Distrik (Anthroportic Udorthents), Regosol Eutrik (Anthroportic Udorthents and Anthroportic Endoaquents), and Aluvial Eutrik (Anthroportic Epiaquents). Soil fertility in these lands was low to very low and fluctuated as a topsoil and subsoil mixer. The land suitability class assessment was classified as Marginal Suitable lands (S3) and Not suitable lands for now (N). The area of S3 sub-land area for suitability of TPLK lands, vegetable crops and forage crops is 12,606 ha, and the area of class Not suitable lands (N) is 3,995 ha. For annual crops, the suitability lands with S3 class is 14,158 ha and N class is 2,443 ha. The biophysical condition in the ex-coal mining area requires a substantial effort to reclaim and rehabilitation the land, both for the recovery of chemical and physical properties. Efforts to use the

land of ex-coal mines quickly and appropriately can be done by loosening the land through the provision of compost or manure. Previously it was necessary to topsoil the ex-coal mining lands to further enhance soil fertility. This effort certainly requires quite expensive inputs with proper planning.

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