RECLAMATION OF FORMER COAL MINING LAND AT THE NORTHERN PIT OF CV. SEMOGA SURYA SENTOSA, SELUANG RIVER, SAMBOJA, EAST KALIMANTAN

REKLAMASI LAHAN BEKAS PERTAMBANGAN BATUBARA DI LUBANG UTARA CV. SEMOGA SURYA SENTOSA, SUNGAI SELUANG, SAMBOJA, KALIMANTAN TIMUR

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Abstract

The rehabilitation of post-mining land with low nutrient content is carried out using chemical and organic materials. To improve soil fertility, the application of fertilizers is required. Soil fertility is crucial as a medium for plant growth to enable replanting. Once the planting medium is available, it is then cultivated with plants suitable for the land conditions. The methodology of this study involved observing land conditions by examining soil structure, texture, and pH in the research area. The results showed that the soil texture belongs to the sandy clay loam or clay loam class, with a soil pH of 3.72. Soil improvement was carried out by applying dolomite lime at 100 grams per planting hole, requiring a total of 66.7 kilograms. Goat manure was applied at 2 kilograms per planting hole, with a total requirement of 133.4 kilograms for 667 trees. The tree species planted were Sengon (Paraserianthes falcataria) and Trembesi (Samanea saman).

Keywords : Post-Mining Land, Revegetation, Soil, Dolomite Lime, Manure Fertilizer.

Abstrak

Rehabilitasi lahan pascatambang dengan kandungan nutrisi rendah dilakukan menggunakan bahan kimia dan organik. Untuk meningkatkan kesuburan tanah, diperlukan penggunaan pupuk. Kesuburan tanah sangat penting sebagai media pertumbuhan tanaman untuk memungkinkan penanaman kembali. Setelah media tanam tersedia, kemudian dibudidayakan dengan tanaman yang sesuai dengan kondisi lahan. Metodologi penelitian ini melibatkan pengamatan kondisi lahan dengan memeriksa struktur, tekstur, dan pH tanah di area penelitian. Hasil penelitian menunjukkan bahwa tekstur tanah termasuk kelas lempung berpasir atau lempung, dengan pH tanah 3,72. Peningkatan kualitas tanah dilakukan dengan mengaplikasikan kapur dolomit sebanyak 100 gram per lubang tanam, membutuhkan total 66,7 kilogram. Pupuk kandang kambing diaplikasikan sebanyak 2 kilogram per lubang tanam, dengan total kebutuhan 133,4 kilogram untuk 667 pohon. Jenis pohon yang ditanam adalah Sengon (Paraserianthes falcataria) dan Trembesi (Samanea saman).

Kata Kunci : Lahan Pasca Tambang, Revegetasi, Tanah, Kapur Dolomit, Pupuk Kandang.

1. INTRODUCTION

Mining activities have significant impacts that can be observed through environmental degradation, such as the decline in land quality, which reflects the deterioration of the physical, chemical, and biological properties of the soil. Open-pit mining systems disrupt soil structure due to compaction caused by heavy equipment operations. Efforts to improve soil fertility through fertilization are carried out to restore acidic and nutrient-poor soils into fertile media suitable for plant growth. Soil particles consist of a mixture of sand, silt, and clay.

Conducting laboratory tests and soil analysis is one of the methods to determine soil fertility levels. The high soil acidity resulting from the oxidation of sulfide compounds is caused by chemical elements in the soil that can be toxic to plant growth. Soils containing sulfide minerals can be identified through pH measurement to determine their acidity level. The management and improvement of soil conditions in post-mining land need to be studied to provide fertile media for plants. The objective of this research is to identify the types and dosages of fertilizers applied to coal post-mining land, as well as the plant species suitable for the soil conditions at the study site.

On coal post-mining land, soil recovery is usually initiated by applying lime as the first step to support plant growth. The type of lime commonly used is dolomite lime. The application of dolomite lime can increase soil pH, reduce aluminum saturation, enhance calcium and magnesium levels, and improve the physical and biological properties of the soil (Hardjowigeno, 1986). Dolomite lime application raised the soil pH from an acidic level of 4.47 to 5.3–6.2 (Lawing, Y.H., 2021). Post-mining land generally has acidic conditions with soil pH below 5. This condition is related to incomplete land management and the soil's low water-holding capacity. Acidic soils can be ameliorated by improving soil conditions through lime application or by adding organic matter (Mansur, 2010).

Soil fertility, low pH, and limited nutrient availability, along with high concentrations of heavy metals, occur due to sulfide solutions. The low levels of essential nutrients such as sulfur (S), nitrogen (N), and phosphorus (P) also contribute to soil acidification. Soil acidity increases the presence of iron (Fe) or Fe-related compounds, which originate from soil degradation caused by rainfall, leading to the formation of sulfuric acid (Mansur, 2010).

2. RESEARCH METHOD
a. Tools and Materials

The tools and materials used include soil laboratory test results, Trembesi (Samanea saman) plants, a soil acidity classification table, and criteria for the range of soil chemical fertility classes, which serve as a comparison with the soil pH conditions in the study area.

b. Research Location

The research was conducted at CV. Semoga Surya Sentosa, Sungai Seluang, Samboja, Kutai Kartanegara, East Kalimantan. The mining business permit (IUP) area of CV. Semoga

Surya Sentosa can be reached by land using a four-wheeled vehicle from Samarinda toward Balikpapan at KM 41, with a travel time of approximately 1 hour and 50 minutes on paved roads. The distance from the Bukit Merdeka Village Office to the concession area of CV. Semoga Surya Sentosa requires about 60 minutes of travel on cemented village roads.
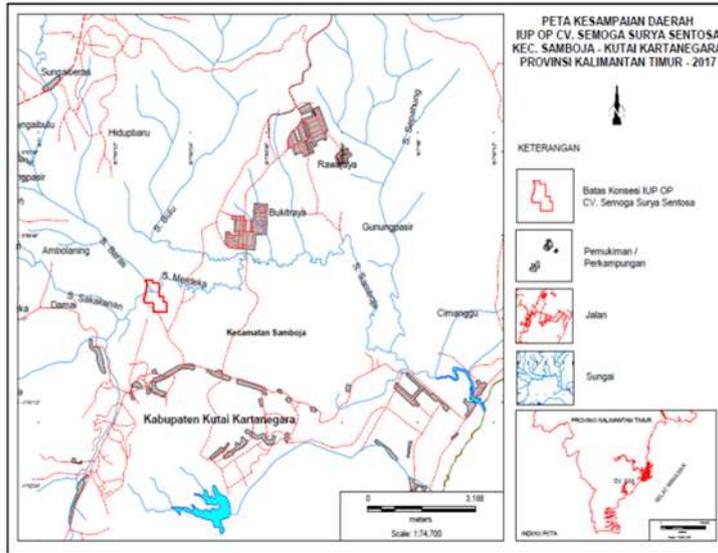

Figure 1. Research Location

The research area is located in the Northern Pit, covering approximately 1.2 hectares. The land was planted with leguminous cover crops (LCC) using the hydroseeding method, which involved a mixture of legumes, organic fertilizer, inorganic fertilizer, growth stimulants, and adhesives. Mining activities had previously been carried out in the Northern Pit over an area of 0.6 hectares. Overburden removal and topsoil storage were conducted in the designated out-pit area, which was prepared over 1.3 hectares.

Figure 2. Research Location of the Northern Pit

c. Methods

The method used in the rehabilitation of post-mining soils consists of three stages. The first stage is identifying the soil type. The second stage involves analyzing soil texture, structure, and acidity level. The third stage is adjusting the type of plants according to the soil pH. The research method applied is a descriptive-comparative approach, which compares the results of soil analysis with the soil acidity classification table and subsequently evaluates soil fertility status based on that table.

3. RESULT AND DISCUSSION

a. Soil Analysis

1) Soil pH

The soil in the study area has a pH of 3.7, which is classified as strongly acidic. A proper lime requirement analysis is necessary to adjust the soil pH to match the needs of the plant species to be cultivated. Low soil pH increases the solubility of Fe and Al, which in turn raises the risk of Fe and Al toxicity symptoms (Rosmarkam and Yuwono, 2002). For soils with acidity levels below pH 5, it is recommended to apply dolomite lime at a rate of 100 grams per planting hole to facilitate root absorption of soil nutrients (Sumarna, 2012).

Table 1. Results of Soil Chemical Analysis

Parameter	Nilai
pH	H_2O: 3.79, KCl: 3.72
Bahan Organik	C. Org: 0.66 %, N. Org: 0.06 %
Fosfor Tersedia (Bray 1)	P_2O_5: 0.67 ppm
Kalium Tersedia (Bray 1)	K_2O: 46.80 ppm
KTK (Kapasitas Tukar Kation)	10.00 meq/100 gr
Kation (NH$_4$O-Ac, pH 7)	Ca^{2+}: 0.48
	Mg^{2+}: 0.62
	K^+: 0.17
	Na^+: 0.06
	Al^{3+}: 7.33
	H^+: 1.33
Ekstraksi HCl 25%	K_2O: 6.61 ppm, P_2O_5: 0.51 ppm
Kejenuhan Basa	Basa: 13.31 %, Al: 73.35 %
Minyak & Lemak	1.99 %
Pyrite	FeS_2 0.80 %
Logam Berat	Pb 10.26 %
	Cd 0.30 %
	Cu 8.75 %
	Zn 9.75 %
Tekstur	Pasir (Sand) 41.10 %
	Debu (Silt) 22.70 %
	Liat (Clay) 36.20 %
Fisik Tanah	Bulk Density 1.47 gr/cm³
	Total Porositas 43.22 %
	Kadar Air 26.70 %
	Permeabilitas 3.36 cm/jam

The soil organic matter content, represented by organic carbon (C-organic), is 0.66%, indicating the carbon derived from soil organic matter. This value is considered low, which means the soil is biologically less fertile. Low organic carbon content may occur due to erosion, whereas higher organic matter levels improve soil quality. Organic carbon serves as an indicator of soil organic matter; the higher the total C-organic content, the better the soil quality (Sipahutar et al., 2014; Siregar, 2017).

The available phosphorus (P) content in the soil at the study site is approximately 0.67 ppm, which is categorized as very low. This condition is due to the soil being formed from parent material (rock/mineral) that is poor in P elements, resulting in only a small fraction of soil P being present in the soil solution (available P). The availability of P is strongly influenced by soil pH. Phosphorus is readily absorbed at near-neutral pH (6–7). In acidic soils, P is bound to Al and Fe elements, making it unavailable for plant growth. A deficiency of P leads to inhibited plant growth and stunted development (Hardjowigeno, 2007). One way to overcome this problem is by applying fertilizers containing P.

The organic nitrogen (N) content of the soil is 0.06%, which is considered low and indicates a potential nitrogen deficiency. Nitrogen sources in the soil originate from soil organic matter, fixation by microorganisms from atmospheric N, fertilizers, and rainfall (Hardjowigeno, 2007). Based on the soil analysis, the total nitrogen content in the study area is very low. This condition is caused by vegetation contributing organic matter to the soil being poor in nitrogen, as well as the limited supply of organic matter from vegetation growing on the soil, which has not fully decomposed. In addition to vegetation, climatic conditions such as rainfall also affect soil nitrogen content, as nitrogen is leached away by water. The low total nitrogen content in post-mining soils is further attributed to the low organic carbon content, losses due to volatilization, and runoff (Syahputra et al., 2015).

The available nutrient analysis (Bray I Method) shows phosphorus (P_2O_5) at 0.67 ppm, which is classified as very low and may inhibit plant growth. Potassium (K_2O) is 46.80 ppm, categorized as moderate. Potassium supports stem strength and enhances plant resistance. The cation exchange capacity (CEC) is 10.00 meq/100 g, indicating the soil's ability to retain and supply nutrients. This value is considered low, suggesting that the soil has limited capacity to store nutrients.

The cation concentrations (NH_4O-Ac, pH 7) are Ca^{2+} 0.48, Mg^{2+} 0.62, K^+ 0.17, and Na^+ 0.06. All base cations are at low levels, indicating low base saturation. The Al^{3+} concentration of 7.33 and H^+ concentration of 1.33 show very high aluminum content, which can be toxic to plant roots and inhibit nutrient absorption.

The 25% HCl extraction results show K_2O at 6.61 ppm and P_2O_5 at 0.51 ppm, indicating low total potassium and phosphorus contents.

The base saturation is 13.31%, while aluminum saturation is 73.35%, indicating very low base saturation and very high aluminum saturation. This condition shows that the soil is highly acidic and unsuitable for optimal plant growth.

The heavy metal content in the soil shows that Pb (lead) is 10.26%, which is relatively high and potentially toxic if it exceeds environmental thresholds. Cd (cadmium) is detected at 0.30%, a small amount but still noteworthy due to its toxic nature. Cu (copper) is 8.75%, a significant level that may originate from industrial activities or rock weathering. Zn (zinc) is 9.75%, also high, potentially derived from anthropogenic or geogenic sources.

The impact of high Pb content can reduce soil fertility by disrupting soil microorganism activity, thereby disturbing nutrient cycles. It also affects plant growth by inhibiting photosynthesis and respiration, leading to leaf chlorosis and stunted growth. High Zn content causes toxicity in plants, manifested as chlorosis (yellowing leaves), stunted growth, and reduced yields. Nutrient imbalance further interferes with the absorption of other elements such as Fe, Mn, and Cu.

The soil texture shows sand at 41.10%, with coarse fractions being relatively dominant, contributing to good drainage and soil aeration. Silt is 22.70%, with medium fine fractions that help retain water and nutrients. Clay is 36.20%, with a high clay content that increases the soil's capacity to hold water and nutrients but may reduce permeability. The soil is classified as sandy clay loam or clay loam.

Clay-textured soils, due to their finer particle size, have a larger surface area per unit weight, which provides a higher capacity to retain water (Hardjowigeno, 2007). However, soils with fine textures such as high clay content make root development difficult, as roots struggle to spread due to low soil porosity. Plant roots face challenges in penetrating compact soil structures, resulting in poor root system development. Furthermore, high clay content tends to cause soil pH to become acidic (Tambunan, 2008).

The soil has a bulk density of 1.47 g/cm³, which indicates a normal level of compaction, not too dense, and still supportive of root growth. The total porosity is 43.22%, considered fairly good, allowing adequate movement of air and water within the soil. The soil moisture content is 26.70%, categorized as moderate, showing that the soil is capable of storing a sufficient amount of water. The permeability is 3.36 cm/hour, classified as moderate infiltration rate, suitable for plants that are intolerant to waterlogging.

The results of the soil laboratory tests were compared with the soil acidity classification table to evaluate soil fertility status. The findings are presented in the following table:

Table 2. Chemical Fertility Status of Soil in the Study Area

Sifat Kimia	Hasil	Kriteria
C %	0,66 %	Sangat rendah
N%	0,06 %	Sangat rendah
C/N ratio		
P_2o_5 Brai 1(ppm)	0,67	Sangat rendah
K_2o HCL25% (meq/100g)	6,61 ppm	Sangat rendah
KTK (CEC) (meq/100g)	10.00 meg/100 gr	Rendah
Na	0,06	Sangat rendah

Mg	0,62	Rendah
Ca	0,48	Sangat rendah
KejenuhanBasa (%)	13,31 %	Sangat rendah
pH	3,72	Sangat rendah

Based on the soil chemical analysis, it is concluded that the chemical fertility level of the study area is classified as very low (Soil Research Center, 1983).

b. Soil Improvement

1) Fertilizer Application

The rehabilitation of post-mining land through the application of organic and inorganic fertilizers at appropriate doses, along with proper plant maintenance, can improve the chemical and biological properties of soils that have been degraded by mining activities, making them suitable and useful for revegetation (Lawing, 2020).

Based on the analysis of soil chemical properties, the soil in the IUP area of CV. Semoga Surya Sentosa is very low in fertility with strongly acidic pH. To compensate for nutrient deficiencies, dolomite lime and organic fertilizers need to be added to improve soil structure. Dolomite lime contains Ca (30%) and Mg (19%), which function to increase soil pH. The finer the particle size, the better the quality. Liming by mixing dolomite with the topsoil layer provides a relatively faster reaction (Rosmarkam and Yuwono, 2002). Calcium fertilization through the soil is more efficient because Ca is absorbed directly by the roots into plant tissues. For soils with acidity levels below pH 5, it is recommended to apply dolomite lime at 100 grams per planting hole to facilitate root absorption of soil nutrients (Sumarna, 2012; Lawing, 2020).

The nutrient content of manure is relatively low, but it has other advantages, such as improving soil physical properties including permeability, porosity, structure, water-holding capacity, and cation retention (Sutedjo, 1995). Goat manure contains nitrogen (N) at 0.60%, phosphorus (P) at 0.30%, and potassium (K) at 0.17%. According to Hardjowigeno (2007), organic fertilizers not only add nutrients but also improve soil structure, increase cation exchange capacity, enhance soil water-holding capacity, and stimulate soil biological activity. Trees aged 0–1 year require an organic fertilizer dosage of 2 kg per tree (Sumarna, 2012).

2) Fertilizer Dosage

To determine the amount of lime required, the lime requirement per planting hole is multiplied by the number of trees planted. In the northern pit, 667 trees were planted, so the calculation is 100 grams per hole × 667 trees. Therefore, the total dolomite lime required is 66.7 kilograms.

Goat manure is required at 2 kg per planting hole, multiplied by the total of 667 trees. Thus, the total amount of goat manure applied is 133,4 kg for 667 trees.

c. Revegetation

The removal of overburden and the spreading of topsoil in the post-mining area were carried out on waste piles in the former northern pit opening, which had been backfilled with a volume of 52,149 Bcm. The backfilling method refers to the gradual closure of mined-out pits

after the extraction of mineral reserves. This process involves excavation, hauling, and soil placement using heavy equipment such as bulldozers, excavators, and dump trucks.

In the nursery area, pioneer, endemic, and aesthetic plant species were prepared, including Ketapang (*Terminalia catappa*), Sengon (*Paraserianthes falcataria*), Johar (*Cassia siamea*), Meranti (*Shorea spp.*), Alaban (*Vitex pinnata*), Eucalyptus (*Eucalyptus spp.*), Pine (*Pinus spp.*), Mahogany (*Swietenia macrophylla*), Pulai (*Alstonia scholaris*), Bamboo (*Bambusoideae*), Trembesi (*Samanea saman*), Gmelina (*Gmelina arborea*), Waru (*Hibiscus tiliaceus*), and Jabon (*Anthocephalus cadamba*).

For revegetation in the study area, Sengon (*Paraserianthes falcataria*) and Trembesi (*Samanea saman*) were selected, with a planting distance of 3 × 3 meters.

Table 3. Revegetation Area and Number of Plants

Location / Area	Revegetation Area (m² or ha)	Number of Trees Planted	Plant Species
Northern Pit	1,3	667	Sengon, Trembesi

Planting was carried out to restore land degraded by mining operations using various local perennial species that provide ecological and economic benefits while preventing erosion. The first step after land preparation was the immediate establishment of land cover crops (LCC). In the study area, land cover crops were planted using hydroseeding and hand seeding methods. The hydroseeding materials included organic fertilizer, growth stimulants, inorganic fertilizer, adhesive agents, appropriate water, mulch, legumes, fast-growing tree seeds, and grasses.

Pioneer species planted in the study area consisted of 333 Sengon (*Paraserianthes falcataria*) trees and 334 Trembesi (*Samanea saman*) trees. Sengon and Trembesi were selected because they are highly suitable for post-mining areas. Sengon has strong adaptability to various soil conditions, including degraded mining soils (Munawar & Wiryono, 2014). The growth quality of Trembesi and Sengon in former diamond mining soils showed survival rates of 96% for Trembesi and 84% for Sengon (Subli M. et al., 2019). Similarly, Sengon and Trembesi planted in post-coal mining soils demonstrated good performance, with survival rates exceeding 80% (Thamrin, 2017).

The planting method applied was the potting technique, in which seedlings were grown in polybags. The polybags were placed into planting holes filled with soil. This method facilitates the control of soil nutrients and fertilizer application, while also reducing the risk of heavy metal contamination from mining activities. Each polybag containing soil was supplemented with 100 grams of lime per hole and then covered. One week later, mature organic fertilizer was added. The organic fertilizer used was derived from goat manure. The mature organic fertilizer was left for 1–2 weeks before planting the seedlings (Lawing, 2020).

4. CONCLUSION

Based on the results of the study, it can be concluded that the soil in the research area has a pH of 3.7. Dolomite lime was applied at 100 grams per planting hole to increase the soil pH. To improve soil structure, goat manure was added at 2 kg per planting hole. Sengon

(Paraserianthes falcataria) and Trembesi (Samanea saman) both demonstrated very good growth performance.

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