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Changes in Soil Physical Quality of Post-Coal Mining After Revegetation of *Eucalyptus* Plants (*Melaleuca cajuputi*)

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ABSTRACT

Coal mining in Indonesia is generally carried out by open-pit mines so which impacts the decline of environmental quality degradation and damage to the soil's physical properties. One of the steps taken by PT Bukit Asam Tbk to solve this problem is to carry out land reclamation by using eucalyptus plants. This study aims to of the revegetation age of eucalyptus plants on changes in the soil's physical properties of post-coal mines. This research was carried out from October to December 2021 on post-coal mining land after the revegetation of eucalyptus plants for 3 years, 5 years, and 10 years in Pit Banko Barat, PT Bukit Asam Tbk. At the research location measurements and sampling were taken and followed by analysis at the Soil Science Laboratory, Bengkulu University. The data obtained were analyzed by descriptive statistics and normality test then continued analysis of variance and BNT test. The results showed that the age of eucalyptus plants has a significant effect and can improve soil density and root penetration at the age 5 and 10 years in post-coal mining land. The soil's physical quality showed that soil bulk density, particle density, liquid limit, root penetration, groundwater level, as well as increased porosity and C-organic. It has the same texture that is clay and some changes in the blocky structure to be granular

Keywords: coal mine, Eucalyptus plants, soil physical properties, reclamation

INTRODUCTION

Coal is the mining sector as the driving force of the national economy and development (Refliaty, 2018). Coal mining in Indonesia is generally carried out by open mining or backfilling methods so that it has an impact on reducing environmental degradation due to ecosystem damage. Damage to these ecosystems includes loss of forest ecosystems (flora and fauna), loss of soil layers, and damage to the soil's physical properties. For this reason, efforts are needed to repair environmental damage caused by mining activities to the soil quality and its function as a medium for growing crops with land reclamation (Suriadikarta & Setyorini, 2006).

One of the efforts to improve the environment through reclamation by planting plants that have high adaptability, can improve the soil physical, chemical, and biological properties and provide socio-economic benefits. The Eucalyptus plant (*Melaleuca cajuputi*) is one of the plants that can grow well in the post-coal mine land of PT Bukit Asam Tbk.

The selection of tree species is an important part of revegetation activities. The selected plant species should : the local pioneer species are fast-growing, resistant to exposure to the sun, produce a lot of litter and decompose quickly, have a good root system and symbiosis with certain microorganisms easy and inexpensive in propagation, planting, and maintenance (Parascita, 2015). Eucalyptus is a local species in Sumatra and can survive in critical land areas. Eucalyptus can also support land conservation and marginal land use efforts (Indrawan & Yuniawati, 2017).

Restoration of soil can be done by planting plants that are resistant to critical land and have improvement within a certain period of time. Increasing the productivity of reclaimed soils can be done through soil improvement, fertilization, and organic matter through the biological life cycle of eucalyptus plants. Organic matter derived from the piles of eucalyptus plants will accumulate over a period of time causing the soil to be moister and the lower more moist soil and lower light intensity (Saurmaria, 2017). According to Yamani (2007), the soil's physical properties of are very important and need to be known because they affect plant growth and production, determine root penetration in the soil, water retention, drainage, aeration, and plant nutrition, and affect the soil chemical and biological properties.

This research aims to analyze the effect of the revegetation age of eucalyptus plants on changes in the physical properties of the post-coal mine soil at PT Bukit Asam Tbk.

MATERIALS AND METHODS

Place and Time of Research

This research was carried out from October to December 2021 at the Pit Banko Barat Coal Mine, PT Bukit Asam Tbk, Tanjung Enim with coordinate points around 3°75'83"S, 103°79'25"E, Muara Enim Regency, South Sumatra Province. Soil analysis was implemented at the Soil Science Laboratory, Faculty of Agriculture, Bengkulu University.

Materials and Tools

The materials used in this study are soil samples, aquades, texture analysis materials, C-organic analysis materials, soil density analysis materials, and liquid limit analysis materials. The application used is Microsoft Office 2010. The tools used in this study are sample rings, field knives, stationery, a set of laptops, penetrometers, scales, texture analysis tools, C-organic analysis tools, soil density analysis tools, and liquid limit analysis tools.

Research Stages

The research site is the post-coal mine land of PT Bukit Asam Tbk, namely in the west Banko mine IUP. There were three treatments of eucalyptus plant age consisting of 3 years, 5 years, and 10 years, each treatment had 10 replications. At the sample point location is carried out topsoil samples were taken 0-20 cm using a sample ring and disturbed soil, as well as observing soil structure and measurement root penetration resistance. Physical property analysis is carried out in the Soil Science Laboratory, Faculty of Agriculture, Bengkulu University consisting of soil bulk density, soil density, liquid limit, groundwater level, C-organic porosity, and texture.

Research Flow Chart

The research flow diagram is presented in Figure 1.

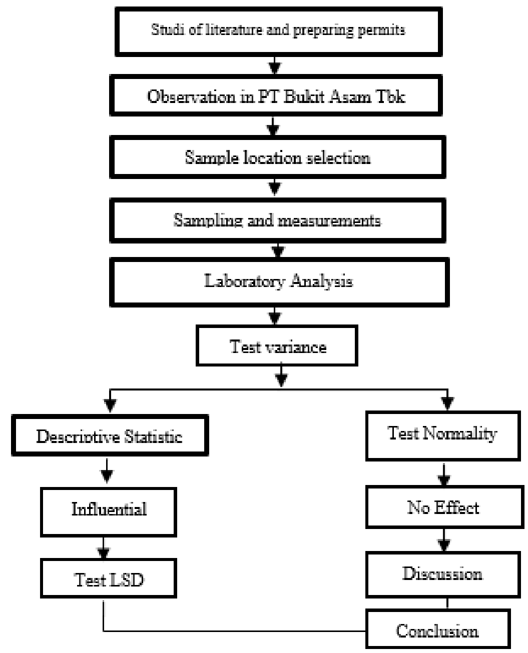

Figure 1. Research Flow Diagram

Data Analysis

Data of this research is processed and analyzed descriptively quantitatively and normality tests first and then followed by a variance analysis (ANOVA) based on Table F 5%. If there is a significant effect, then followed by further testing of LSD at the level of 5%.

RESULTS AND DISCUSSION

A summary of the soil's physical properties from the laboratory analysis is presented descriptively (Table 1) which shows that the standard deviation value is smaller than the average value. This means that the data of all observed variables are less varied. Then the Normality test was carried out using the Kolmogorov-Smirnov method, it can be seen that the data in this research were normally distributed because of the value of D < of the K value of the table.

Table 1. Characteristics of the soil physical properties at all three ages of the plant

Characteristics of the soil physical properties	3 yr				5 yr				10 yr			
	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev
Soil Bulk Density	0.76	1.32	1.04	0.15	0.67	1.15	0.98	3.14	0.70	1.25	0.96	0.17
Ground Water Level	19.7	34.6	23.6	4.52	15.8	28.1	23.5	3.96	2.12	41.2	9.54	19.4
Soil Density	1.36	2.22	1.80	0.25	1.21	2.06	1.55	0.25	1.22	2.09	1.52	0.23
Soil Porosity	13.9	65.8	33.7	17.3	26.3	55.6	37.2	8.02	9.70	58.9	40	16.2
Liquid limit	2.00	4.30	3.22	0.81	2.20	3.20	2.57	0.28	2.10	4.20	2.95	0.64
Root Penetration	8.17	10.8	9.7	0.72	7.33	8.67	8	0.44	8.17	10.8	9.7	0.72
C-Organic	1.03	2.73	1.77	0.51	1.21	2.97	2.12	0.54	0.97	3.54	1.99	0.69
Texture	Clay				Clay				Clay			
Soil Structure	Granular				Granular				Granular			

Variance Analysis

Analysis of variance shows the age of the plant has a significant effect on root penetration resistance and soil density. However, it had no significant effect on soil bulk density, porosity, groundwater level, and liquid limits (Table 2).

Table 2. Summary of the value of analysis variance of the influence of plant life on physical properties

Variable	F-value	F-table
Soil bulk density	0.597 ns	3.354
Groundwater	1.195 ns	3.354
Soil density	3.517*	3.354
Porosity	0.430 ns	3.354
Liquid limit	2.460 ns	3.354
Root penetration resistance	9.466*	3.354

Note : ns= non-significant difference, * = Significant difference at the 5% probability level

Soil Bulk Density

The age of eucalyptus plants showed had no significant effect on soil bulk density (Table 2). In addition to organic matter, the soil bulk density is also affected by texture. Soil that has a smooth texture will have a higher percentage of total pore space than coarsely textured soils. The soil bulk density value shows that the older the age of the plant the soil bulk density value decreases (Figure 2). By following Saurmaria research (2017) the older the age of *Eucalyptus* plants, the soil bulk density decreases. The decrease in the soil bulk density over the length of life of *Eucalyptus* plants on reclaimed land is caused by an increase in the content of organic matter in the soil. Based on the soil bulk density of the plant is five and ten years old including the soil bulk density, while at the age of the plant three years belongs to the high soil bulk density (Hillel, 1982).

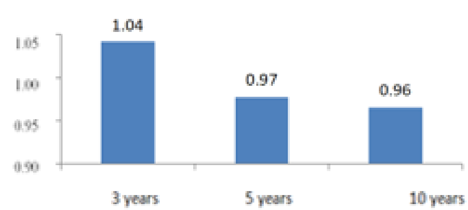

Figure 2. Average soil bulk density three ages of *Eucalyptus* plants

Groundwater Level

The age of *Eucalyptus* plants showed no significant effect on groundwater level (Table 2), this was due to the groundwater level was also influenced by various factors such as soil texture, soil organic matter, vegetation, soil strength, and soil depth. Groundwater level decreases with the age of the plant (Figure 3), this is following accordance with the research of Saurmaria (2017) that the three reclamation age shows a decrease in groundwater level with the length of life of *Eucalyptus* plants. The moisture groundwater level increases with increasing density. This is because in dense soil conditions water cannot move in the soil, causing the measured groundwater level to be high in soil density (Mualim *et al*., 2009). However, this water cannot be utilized by plants because of the dense soil that causes the water to be tightly bound by micropores and soil matrix.

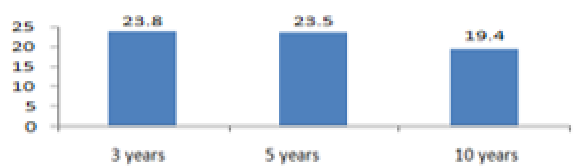

Figure 3. Average groundwater level at three ages of *Eucalyptus* plants

Soil Density

The age of *Eucalyptus* plants showed a significant effect on the soil density (Table 2). The effect of the plant age on the reclamation land on the soil particle density is in the increase of organic matter from the eucalyptus plant. Organic matter plays a role in combining the soil particles. The average value of the soil density (Figure 4) indicates that the older the age of the plant decreases. The presence of pore space affects the decrease in soil density. The decrease in soil density is equal to the decrease in the weight value of the soil type.

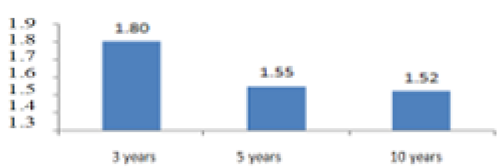

Figure 4. Average soil density of the breed at three ages of *Eucalyptus* plants.

The average value of soil density ranges from 1.5 g cm^3–1.8 g cm^3 (Table 3). This value is lower than the average weight of the type in general, for mineral soils the soil density is often assumed at about 2.55 g cm^3 (Hillel, 1982). The soil particle density showed a significant change between plant ages, this was due to soil particle density also being influenced by soil parent material and soil texture.

Soil particle density was not significantly at the age of 5 and 10 years, this means that at the age of 5 and 10 years *Eucalyptus* plants were able to improve the soil particle density. However, at the age of three years showed a real difference which means that at the age of three years the plant has not improved soil density, because it had a significant influence. The soil density will change with the addition of humus, weathering, and loss of minerals that make up the soils take a long time (Putinella, 2011).

Table 3. Average Soil density at three ages of *Eucalyptus* plants

Eucalyptus plants Age (Year)	Soil density (g cm3)
3	1.80a
5	1.55b
10	1.52bc

Note : The numbers followed by different letters in the same column are significant different at LSD Test 5%

Porosity

Porosity is the volume of all pores in a whole soil volume expressed in percent. The age of *Eucalyptus* plants had no significant effect on soil porosity (Table 2). This is because the soil porosity is also influenced by the availability of organic matter in the soil bulk density, and the soil texture. According to (Arsyad, 2006) in the class of porosity, the average porosity value of porosity (Figure 5) can be seen that the age of three and five years, the porosity is not good and at the ten years, but the porosity of these three soils change progressively. The older the plant age, the higher of soil porosity.

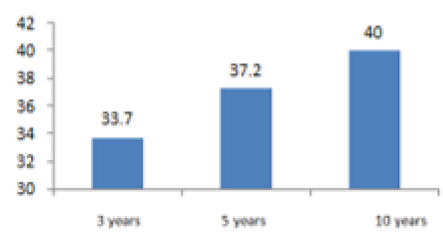

Figure 5. Average porosity of the soil at three ages of *Eucalyptus* plants

Liquid Limit

The age of *Eucalyptus* plants showed had no significant effect on the liquid limit of the soil (Table 2), this is because the liquid limit is affected by the soil of texture. Based on the plasticity class (Hardjowigeno, 1993) the average value of liquid limit (Figure 6) of the soil of these three plant ages is classified as low plastic so the soil of these three plant ages shows soil that is difficult to cultivate (Miswar & Yusrisl, 2013). However, the older the plant age indicates the decreasing value of the liquid limit.

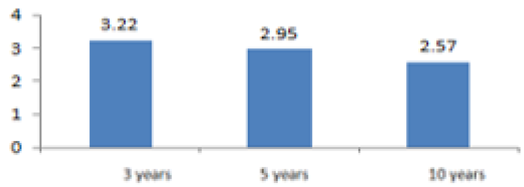

Figure 6. Average liquid limit at three ages of *Eucalyptus* plants

Root Penetration Resistance

Eucalyptus plant age showed a significant effect on root penetration resistance (Table 2). The older the plant age the lower the value of root penetration resistance (Figure 7), so it is better for roots to penetrate the soil. This is caused by several factors the amount of litter grass, and organic matter. Root penetration resistance is also influenced by soil density, the lower the soil density level, the higher the percentage of macropores and the lower resistance to root penetration.

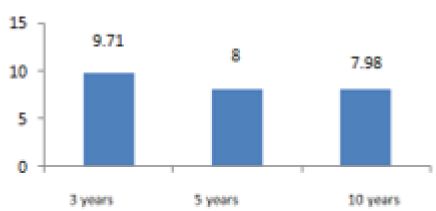

Figure 7. Average root penetration resistance at three ages of *Eucalyptus* plants

In this study, the average root penetration resistance ranged from 7.98 to 9.71 kgF cm^{-2}. This condition is still suitable for the roots generally in annual plants to penetrate the soil. Based on research conducted by Whalley *et al*. (2007) in general, the lengthening of plant roots will be limited to soil conditions with soil penetration resistance of 2.5 MPa or 25 kgF cm^{-2}.

Root penetration resistance (Table 4) shows that between the ages of plants five and ten years difference is not significant which means that at the age of five eucalyptus plants can already improve root penetration resistance. However, at the age of three years showed a significant difference which means that at the age of three years the plant has not improved the resistance of root penetration because it has a low influence. This is because the soil at the age of three years has a high soil bulk density and clay.

Table 4. Effect of plant life on penetration resistance

Eucalyptus plants Age (Year)	Root Penetration (kgF cm-2
3	9.71a
5	8.00b
10	7.98bc

Note : The numbers followed by different letters in the same column are significant different at LSD Test 5%

C-Organic

The value of C-organic soil at the age of three and ten years of plants is classified as very low, while at the age of three years plants are relatively low. According to Supriyadi (2008), the content of organic matter is said to be very low when <2% and low when >2%, the content of organic matter which ranges from 2-10% has an important role.

At the age of a plant five years has the highest C-organic value, this is due to soil five years after revegetation due to a lot of organic matter from the grasses compared to both ten- and three-year-old soils (Figure 8). According to Hardjowigeno (2010), soil organic matter is all kinds of organic compounds found in the soil, including litter, fractions of light organic matter, biomass microorganisms, dissolved organic matter in water, and stable organic matter or humus.

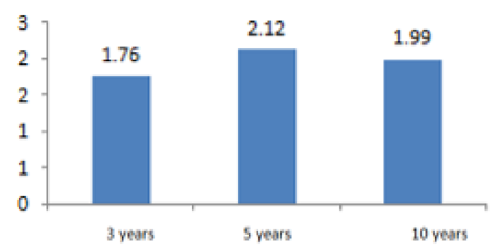

Figure 8. Average C-Organic at three ages of *Eucalyptus* plants

Soil Structure

Based on field observation the overall soil structure presented in Table 5 shows that the older the age the plant changes in the structure of the clot to granular at sample points one, three, and ten, this indicates a change in structure that is getting better. Hardjowigono (1993) explained that the structure of plate crumb and granular soil is a soil structure that is good at passing water and has nutrients that are more readily available to plants.

Sample points two, four, and five showed the same structure between the three plants namely granular. Sample points seven and eight showed the same structure between the three plant ages namely blocky. However, at the sample location, six and nine showed that the older the plant underwent granular changes into clumps, this was due to the influence of organic matter present in the soil at different sample points between plant ages, affecting the soil structure. The role of organic matter on the soil of physical properties is to increase the steadiness of soil aggregates and improve soil structure (Hakim *et al*., 1986)

Table 5 Structures on the third soil of plant life

Sampling	3 year	5 year	10 year
1	Blocky	Granular	blocky
2	Granular	Granular	Granular
3	Blocky	Granular	Granular
4	Granular	Granular	Granular
5	Granular	Granular	Granular
6	Granular	Blocky	Blocky
7	Blocky	Blocky	Blocky
8	Blocky	Blocky	Blocky
9	Granular	Granular	Granular
10	Blocky	Granular	Granular

Soil Texture

The distribution of particles is calculated into a triangle of textures, each soil of the three ages of the *Eucalyptus* plant is dominated by a clay texture. Based on the content of the soil constituent fraction (Table 6) the soil in the reclamation area is difficult to pass water because it belongs to the clay texture class. Because the higher the clay fraction or the lower the value of the sand fraction will affect other characteristics such as groundwater storage water porosity, organic matter, and others.

Sembiring (2008) states that high clay content generally has fewer pores, so soils containing a high percentage of clay retain less water. It is also said Intara *et al*. (2011) that clay-textured soils have a higher available water capacity than clay-textured soils. This is suspected because clay textured soils generally have more micropores so that the amount of water that can be retained is more which means that the available water capacity becomes higher.

Table 6 Texture classes on the soil of the third age of the plant

Eucalyptus plant age (Year)	Texture			Texture Class
	% Sand	% Clay	% Dust	
3	13.38	67.79	18.83	Clay
5	34.57	42.33	23.09	Clay
10	27.30	66.53	6.16	Clay

CONCLUSION

The age of *Eucalyptus* plants had a significant effect on the soil density and resistance of root penetration and has no significant effect on soil bulk density, groundwater level, porosity, and liquid limits. This is caused by many factors that affect these soil's physical properties.

Reclamation activities at PT Bukit Asam Tbk using *Eucalyptus* have been able to improve the soil density and resistance of root penetration in post-coal mine land from the age of five and ten years.

Quality of the soil physical properties of this research showed from the results of the study shows that the older the plant age decreases the soil bulk density, soil density, liquid limit, root penetration resistance, groundwater level, and increases C-organic and porosity. Post-coal mine land at three plant ages, three years, five years, and ten years have significant differences in the soil's physical properties but have the same texture, namely clay, and change the structure from blocky to granular. However, some physical traits have not experienced an increase in good physical property indicators.

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