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Dynamics of soil organic matter, bulk density and infiltration rate on mining reclamation land

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ABSTRACT

Post-mining land reclamation is carried out to restore the environmental functions of the land. Monoculture and multiculture planting patterns have different impacts on soil's physical properties. This study aimed to determine the effects of analyzing soil organic matter, bulk density, and measuring soil infiltration rates in monoculture and multiculture planting patterns. The research used survey methods, data analysis through tabulation, and statistical techniques. The results indicated differences in soil physical properties between the two lands and among the variables. Mahayung land exhibited higher organic matter content (1.08%) compared to Banko land (0.66%). Additionally, the average infiltration rate in Mahayung land (3.02 cm/hour) was higher than in Banko land (2.56 cm/hour), and the bulk density in Mahayung land (1.40 g/cm³) was lower than in Banko land (1.62 g/cm³). Organic matter content influenced the infiltration rate by 70.69%, and affected bulk density by 49.39%. Finally, the different planting patterns affect soil physical properties, and the relationships among variables show significant results.

Keywords: bulk density, infiltration rate, mining reclamation land, organic matter, planting patterns

INTRODUCTION

The coal mining sector is a significant driver of Indonesia's economy and national development. As of 2022, Indonesia's total coal reserves were estimated at 38.8 billion tons, with recorded resource reserves reaching 143.7 billion tons. Approximately 71.8% of coal production is exported to countries such as China, India, the Philippines, Japan, and various European nations (ESDM, 2022).

PT Bukit Asam, Tbk, a coal mining company in Tanjung Enim Village, South Sumatra, utilizes an open-pit mining system while implementing environmentally friendly practices under the principles of green mining. The company contributes to sustainability by enhancing reclamation techniques for exploited mining sites (Hirfan, 2016).

The decline in soil quality is the biggest problem of environmental damage caused by the mining process (Tambunan et al., 2018). Soil degradation leads to reduced soil quality and diminished land productivity. This process can be intensified by improper land management practices, which often result in excessive erosion. Low soil quality is characterized by low soil organic matter content, high soil bulk density, low porosity, and slow infiltration rates (Saputra et al., 2018).

Ministerial Regulation No. 07 of 2014 mandates reclamation efforts throughout all stages of mining to restore and enhance environmental and ecosystem quality for future use. Effective reclamation requires selecting fast-growing plant species that thrive on critical lands, such as post-mining areas (Asmarhansyah, 2017).

Lestari et al. (2022) identified 12 suitable plant species for coal mining reclamation, including Eucalyptus (*Melaleuca leucadendra*), Acacia (*Acacia mangium*), River tamarind (*Leucaena leucocephala*), Mahogany (*Swietenia macrophilla*), Tanjung (*Mimusops elengi*), Sea hibiscus (*Hibiscus tiliaceus*), Needle wood (*Schima wallichii*), Oil palm (*Elaeis guineensis*), Teak (*Tectona grandis*), Rain tree (*Samanea saman*), Amboyna wood (*Pterocarpus indicus*), and Peacock's plume (*Paracerienthes falcataria*).

Land cropping significantly impacts the physical, chemical, and biological properties of soil. Two main cropping systems include monoculture and multiculture. Monoculture involves cultivating a single crop or organism on agricultural or forest land, while multiculture entails growing two or more crops on the same land within a year, either simultaneously or at slightly different times (Alfaredzi et al., 2023).

Different vegetation types influence soil's physical properties by affecting organic matter content (Rahmayuni et al., 2017). Higher organic matter reduces soil bulk density and increases infiltration rates, improving the soil's ability to retain nutrients essential for plant growth (Arifin, 2010).

Soil organic matter plays a critical role in shaping the soil's chemical, physical, and biological properties. Understanding organic matter composition in coal mining areas is vital for estimating soil potential and devising strategies to mitigate environmental impacts in reclaimed lands. Specific studies on organic matter quality and dynamics in soils contaminated by coal, such as in southern Brazil, remain limited (Dick et al., 2006). Additionally, Chaudhari et al. (2013) emphasized that soil bulk density is a dynamic property influenced by structural conditions.

Zang et al. (2012) investigated the effects of coal mining subsidence on lateral seepage and vertical infiltration rates in sandy slopes. Soil bulk density and infiltration capacity are critical soil hydrological parameters that indicate soil degradation and drought conditions. Infiltration refers to the process by which water moves from the surface into the soil through gravitational flow.

The rate at which this process occurs is termed the infiltration rate, which is primarily influenced by soil characteristics (Bharati et al., 2002; Osuji et al., 2010; Thompson et al., 2010; Zhang et al., 2012). The purpose of this research was to understand these effects by analyzing soil organic matter, bulk density, and measuring soil infiltration rates in monoculture and multiculture planting patterns.

MATERIALS AND METHODS

Materials

This research was conducted on coal mine reclamation land owned by PT. Bukit Asam, Tbk in Lawang Kidul Sub District, Muara Enim Regency, South Sumatera Province on monoculture field (6.8 ha) and multicultural field (5 ha). Land analysis was conducted at the Conservation Physics, Survey, and Evaluation Laboratory of the Soil Department, Faculty of Agriculture, Sriwijaya University. This study was carried out in October 2023 to November 2023.

There were several tools used in this field research namely: 1) stationaries, 2) ground drill, 3) wooden block, 4) double-ring infiltrometer, 5) 10 kg bucket, 6) GPS, 7) paper label, 8) rubber band, 9) rafts, 10) camera, 11) crowbar, 12 gauge, 13) hammer, 14) plastic clip, 15) sample ring, 16) stopwatch, 17) scrub and water material.

There were several tools used in the laboratory: 1) burette 50 ml, 2) Petri dish, 3) excitor, 4) erlenmeyer 250 ml, 5) measuring glass 10 ml, 6) measuring glass 100 ml, 7) analytic balance, 8) oven, 9) drop pipet, 10) Stainless steel clamp, 11) 10 ml measuring pipette, 12) hand sprayer, 13) stopwatch. The materials used at the laboratory research were: 1) quadades, 2) dense sulfuric acid, 3) dense phosphorus acid pa, 4) frorous ammonium sulfate 1 n, 5) indicator on diphenylamine, 6) potassium dichromate 1 n, 7) sodium fluoride 4 %, 8) soil samples.

Research Method

This research was carried out by using a purposive sampling method. Samples were taken at the coal postmining reclamation fields owned by PT. Bukit Asam, Tbk., the research was conducted with the monocultural planting system in the West Banko and Mahayung (Figure 1 & Figure 2) with a multicultural planting system, both were seven years old. Data analysis was conducted with a quantitative approach. Data was processed by statistical test to describe its observational object of deliberate data collecting results (purposive sampling).

Observations were conducted by measuring infiltration rate with the Horton equation model (Figure 3), organic materials with the walkey black method, and weight of the contents with the gravimetry method. To compare the research results of the infiltration rate value, organic materials, and weight content, statistical analysis was conducted by using T-test.

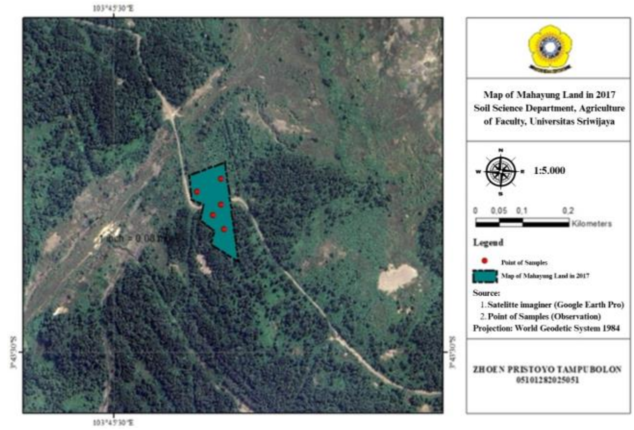

Figure 1. Map of Mahayung Land in 2017

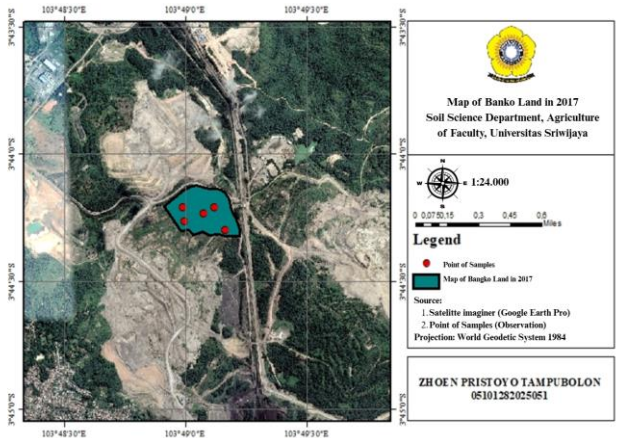

Figure 2. Map of Banko Land in 2017

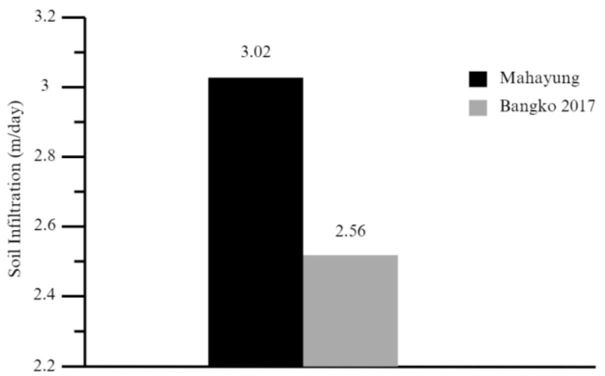

Figure 3. The Comparation of Horton infiltration rate level in Mahayung 2017 and Banko 2017

How It Works

The working methods used in this research are described as followed:

Data was collected by conducting literature studies and direct observations in the field. Literature studies were conducted to obtain information on post-mining land reclamation age, the location, and the area of revegetated post-mining areas. The types of data were primary data and secondary data. Primary data was taken by direct observation in the field. The data would be processed by using the Horton method, the results of infiltration rate measurement using a double ring infiltrometer, initial infiltration rate data (fo), final infiltration rate (fc), constants for soil types and their surfaces (k) (Dipa et al., 2021). Furthermore, organic material (Figure 4 & Figure 5) data would be bulk density by taking intact and non-intact soil samples in the field. Secondary data was data obtained from the related coal mining company, namely PT Bukit Asam, Tbk, Muara Enim Regency, South Sumatra in the form of a post-mining land revegetation map to determine the sampling point.

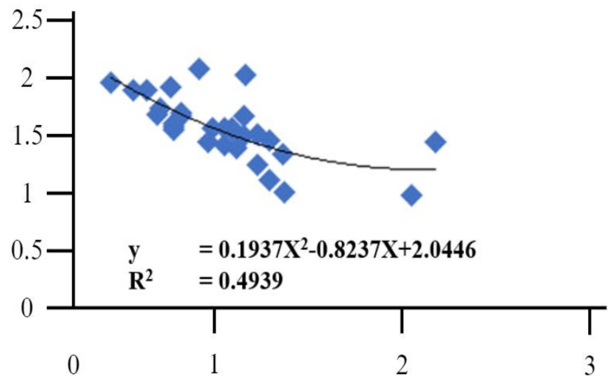

Figure 4. The relationship of organic material and weight content of soil

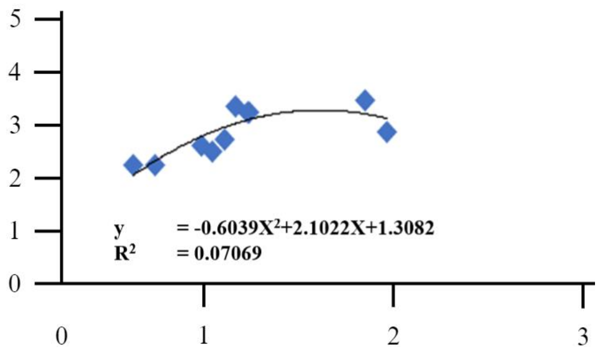

Figure 5. The relationship of organic material (%) and infiltration rate

Sampling Point Setting

Sampling point was conducted by using a purposive sampling method which is a deliberate sampling technique because of certain considerations to represent the research area. This sampling point was determined based on the planting system for each research location, in monoculture and multicultural land. The determination of sample points was based on a spatial model, with 5 sample points taken at each location. Three tests were conducted for soil samples at depths of 0–10 cm, 10–20 cm, and 20–30 cm. The collected soil samples were then composited across soil depths per sample point, thus obtaining a total of 10 sample points and a triple test for 30 soil samples.

Sampling and Measurement

The determined sampling point, an intact soil sample and a disturbed soil sample was taken. An intact soil sample was taken using a sample ring measuring 5 centimeters in diameter and 5 centimeters high for the weight analysis of the contents and the axis of the soil. Disturbed soil samples were taken using ground drills (Belgie drill) for organic analysis. Soil sample taken up to 1–2 kg at 0–10 cm depth, 10–20 cm, and 20–30 centimeters. Then the soil was inserted into plastic clips and labeled.

Soil samples were taken to the Physics, Conservation, Survey and Evaluation Laboratory of the Soil Department, Faculty of Agriculture, Sriwijaya University. The infiltration rate was directly measured and observed in the field using the flooding method without run-off and using a double-ring infiltrometer with a ring diameter of 60 cm and 30 cm. The double-ring infiltrometer was inserted into the soil to a depth of 5 cm. Then water was poured into the cylinder with a height of 15 cm from the surface. The decrease in water level was recorded at 3 minute intervals then water was added so that the water level reached its original height. Observations were stopped when infiltration rate was relatively constant. The infiltration rate was expressed in cm/hour. Measurements were performed 5 (five) times at the three measurement locations.

The soil samples taken were then subjected to laboratory analysis using the following determination methods: The content of organic matter in the soil was related to the physical properties of the soil, organic matter increased the stability of the structure and porosity of the soil, allowing it to accelerate the infiltration of water into the soil (Cardoso et al., 2013). Bulk density affects soil porosity, the value of the bulk density means the higher the soil density (dense) and the space between the pores decreases so that it could affect the movement of water into the soil surface and slow down the infiltration rate. The infiltration rate could be influenced by various physical properties of the soil, such as porosity. The total amount of soil porosity plays an important role in reducing surface water runoff and minimizing erosion. The high value of soil porosity drive water infiltration to the the soil surface. According to Endarwati et al. (2017), loose soil had a large soil pore space and a large distribution of soil pores so that it could increase soil infiltration rate.

Data Analysis

The analysis used in this research is described as mapping of the research area was conducted using the ArcGIS 10.8 software on post-coal mining reclamation land at PT Bukit Asam, Tbk Tanjung Enim. The T-test method was employed to compare infiltration rate values, organic matter, and soil bulk density at the research site. Quadratic regression analysis was used to measure the relationship between variables. The effect of independent variables on dependent variables was indicated by the coefficient of determination (R^2), which ranges from 0 to 1. Additionally, the infiltration capacity of the area was assessed using the infiltration classification according to the U.S. Soil Conservation Service. This research aids in understanding the relationship between planting systems and soil characteristics in the study area.

RESULTS

The results of the laboratory analysis were obtained as presented in Table 1. Data of organic matter in the soil planted with multi-cultures was 1.08 percent higher than organic matter in the soil planted with monocultures, as much as 0.66 percent. Table 2 showed a difference between monoculture and multicultural, comparison of these two conditions.

The analysis of soil bulk weight at the laboratory was presented in Table 3. The soil bulk weight on multiculture land was 1.40 g/cm^3 lower than land monocultures 1.62 g/cm^3.

Based on laboratory results presented in (Table 1), the values are categorized as low to moderate, with the highest recorded result being 2.20 in the multicultural area and 1.24 in the monocultural zone. Furthermore, (Table 2) illustrates the outcomes of the T-test analysis conducted on the observed variables.

For the observed parameters in (Table 2), a relationship is identified based on the comparison of averages with a 95% significance level, indicating that this relationship impacts the conditions between the two observed parameters. Subsequently, a bulk density analysis was performed, as detailed in (Table 3).

Table 1. The results of organic material data analysis

Sampling Point	Observation Location	
	Multiculture Area	Monoculture Area
T1U1	1.08	0.45
TIU2	0.55	0.38
T1U3	0.55	0.16
T2U1	1.16	1.00
T2U2	1.00	0.8
T2U3	1.01	0.71
T3U1	2.20	0.60
T3U2	0.92	0.47
T3U3	0.60	0.30
T4U1	2.05	1.24
T4U2	1.16	0.95
T4U3	1.08	0.87
T5U1	1.25	0.92
T5U2	0.87	0.55
T5U3	0.77	0.53
Average	1.08	0.66

Note : T : Sampling location, U : Repetition

Table 2. The results of paired T-Test

Research Location	*T*	D*f*	*sig 2 tailed*
A and B	4.3877		0.0006 14

Note : A) Mahayung 2017; B) Banko 2017; Significance Level 95

Bulk density, as presented in (Table 3), is essential for assessing the condition of soil across a specific area or region, whether planted or unplanted. This measurement serves as a foundational basis for evaluations to be conducted later. Furthermore, laboratory testing of samples has been carried out, including a T-test analysis, the results of which are displayed in (Table 4).

Table 3. The results of bulk density data analysis

Sampling Point	Observation Location	
	Multiculture Area	Monoculture Area
T1U1	1.46	1.62
TIU2	1.52	1.81
T1U3	1.54	1.88
T2U1	1.41	1.45
T2U2	1.61	1.5
T2U3	1.94	1.99
T3U1	1.39	1.6
T3U2	1.51	1.67
T3U3	1.63	1.82
T4U1	0.96	1.3
T4U2	1.08	1.35
T4U3	1.21	1.5
T5U1	0.99	1.49
T5U2	1.37	1.49
T5U3	1.39	1.84
Average	1.40	1.62

Table 4. The results of paired T- test

Sampling Location	T	Df	sig. 2 tailed
A and B	5.3076	14	0.0001

Note : A) Mahayung 2017; B) Banko 2017; Significance Level 95%

The T-test conducted on bulk density revealed a relationship between the two regions, where the variation in laboratory analysis results indicates a strong correlation, as evidenced by a significance value of <0.05. Additionally, another physical test performed was the average infiltration analysis, using the Horton model, with the results presented in (Table 5).

Table 5. The results of Horton infiltration rate

Observation Location	fc (cm/hour)	f0 (cm/hour)	k	ft (cm/hour)
Mahayung 2017	2.7	8.78	7.389	2.7
Mahayung 2017	3.2	8.48	7.794	3.2
Mahayung 2017	3.3	6.94	12.804	3.3
Mahayung 2017	3.1	6.96	11.620	3.1
Banko 2017	2.3	7.67	7.477	2.3
Banko 2017	2.5	8.79	8.253	2.5
Banko 2017	2.3	8.05	6.856	2.3
Banko 2017	3.1	8.71	6.840	3.1
Banko 2017	2.6	8.75	8.474	2.6

The infiltration test results, as presented in (Table 5), were conducted to evaluate the soil's capacity to absorb and transmit water. This test is essential for understanding and assessing the soil's performance in multicultural and monocultural areas, which serve as the basis for this research. Subsequently, (Table 6) provides the outcomes of the T-test analysis performed to examine the relationships between the observed variables.

Table 6. The results of paired T- test

Research Location	*T*	D*f*	*Sig. 2 tailed*
A and B	5.6622	4	0.0048

The T-test conducted in this study, as presented in (Table 6), aimed to assess the soil's infiltration capacity. Based on the results, there is a relationship between the variables within the research area. Additionally, (Table 7) showcases laboratory findings regarding the total soil pore space in the studied areas.

The total soil pore space, as analyzed in (Table 7), is considered an integral component of soil physical analysis, serving as one of the primary datasets in evaluating soil physical properties. Additionally, (Table 8) presents the T-test results for the tested parameters.

Overall, the variables presented in (Table 8) indicate a relationship between them based on the T-test results. The comparison between soil organic matter and bulk density is detailed in (Table 9). Furthermore, (Tables 10 and 11) present the outcomes of R-square analysis, which was utilized to assess the influence of the variables.

Table 7. The calculation results of total pore space

Sampling Point	Observation Location	
	Multiculture Area	Monoculture Area
T1U1	0.45	0.39
TIU2	0.43	0.32
T1U3	0.42	0.29
T2U1	0.47	0.45
T2U2	0.39	0.44
T2U3	0.27	0.25
T3U1	0.48	0.4
T3U2	0.43	0.37
T3U3	0.39	0.32
T4U1	0.64	0.51
T4U2	0.59	0.49
T4U3	0.55	0.44
T5U1	0.63	0.44
T5U2	0.48	0.44
T5U3	0.48	0.31
Average	0.47	0.39

Table 8. The results of paired T- test

Research Location	T	Df	Sig.2 tailed
A and B	5.1602	14	0.0001

Note : A) Mahayung 2017; B) Banko 2017; Significance rate 95%

(Table 9) presents the laboratory test values for the examined samples. Subsequently, a determination coefficient (R-square) test was conducted, as outlined in (Tables 10 & 11). (Table 10) displays the R-square results showing the relationship between soil organic matter and bulk density, while (Table 11) highlights the R-square analysis results for the average infiltration variables and soil organic matter within the scope of the conducted research.

Table 9. The comparation results of organic material and bulk density

Sampling Number	Multiculture Area		Monoculture Area	
	A	B	A	B
T1U1	1.46	1.08	1.62	0.45
TIU2	1.52	0.55	1.81	0.38
T1U3	1.54	0.55	1.88	0.16
T2U1	1.41	1.16	1.45	1
T2U2	1.61	1	1.5	0.8
T2U3	1.94	1.01	1.99	0.71
T3U1	1.39	2.2	1.6	0.6
T3U2	1.51	0.92	1.67	0.47
T3U3	1.63	0.6	1.82	0.3
T4U1	0.96	2.05	1.3	1.24
T4U2	1.08	1.16	1.35	0.95
T4U3	1.21	1.08	1.5	0.87
T5U1	0.99	1.25	1.49	0.92
T5U2	1.37	0.87	1.49	0.55
T5U3	1.39	0.77	1.84	0.53
∑	1.40	1.08	1.62	0.66

Note : A) Weight content (g cm^{-3}); B) Organic Material (%).

Table 10. The regression analysis results of bulk density and organic material

Model	R	R Square	Adj R Square	Standard Eror	Sig.F
1	0.6629	0.4939	0.4187	0.1952	0.00007

Note : Significance Rate 95%; r Table = 0.6319.

Tabel 11. The regression analysis results of infiltration rate and organic material

Mode l	R	R Square	Adj R Square	Standard eror	Sig.F
1	0.669 6	0.7069	0.3794	0.291	0.034 1

Note : Significance Rate 95%; r Table = 0.6319.

DISCUSSION

The study examined parameters from two distinct land areas with varying cropping system: Mahayung land, characterized by a multiculture cropping system, and Banko land, which employs a monoculture cropping system. The observed parameters included organic matter content, bulk density, infiltration rate, and total pore space. As noted by Kurnia et al. (2006) soil physical properties pertain to attributes associated with its inherent state and structure. These properties encompass texture, structure, bulk density, porosity, aggregate stability, consistency, color, and temperature. Such characteristics are vital in facilitating plant root system activities, including the uptake of nutrients, water, and oxygen, while also influencing root penetration and mobility.

Organic Material

Organic material plays a role in the formation of soil aggregates because the particles on the surface of organic material bind the components of soil aggregates. Based on the analysis results in the laboratory, the data of organic material at the research location are presented in Table 1. Based on Table 1, we can see that the organic material content in the Mahayung 2017 land was 0.55%–2.2% and classified as moderate. Meanwhile, the results in Banko 2017 land was 0.16%–1.24% and classified as low category. Monoculture cropping system has homogeneous vegetation so it produces homogeneous results with fewer results compared to the multiculture cropping system with more diverse litter because it was produced by diverse plants. Soil depth also affects the organic matter content in the soil. We cansee in Table 1 that T1U1 has a lower organic matter content than T1U2 and T1U3, where T1U1 is at a depth of 0–10 cm, T1U2 at a depth of 10–20 cm and T1U3 at a depth of 20–30 cm. This is in line with Tarigan et al. (2014) research where the deeper soil, the lower organic material will be. This is because the accumulation of organic matter is concentrated in the upper layer. The calculation results of organic material on the Mahayung 2017 land were 1.08% and on the Banko 2017 land were 0.66%.

The average organic material on the Mahayung 2017 land was higher than the average organic material on the Banko 2017 land. This showed that land with a multicultural cropping system has higher organic material compared to monoculture cropping system. The results of statistical calculations showed that t value on land A and B were 4.3877 and t Table 2.9768 so that t statistic > t table. Meanwhile, according to the probability value (sig.2 tailed) of 0.0006 <0.05, it can be stated that the difference in planting patterns is significantly different from the value of organic matter content. Based on the statement of Supriyadi (2008) vegetation that grows above the soil surface has a function as an addition to soil organic material by shedding leaves, twigs, and stems that fall to the soil surface.

Bulk Density

Bulk density is an indication of the soil density, the denser the soil, the higher bulk density will be, meaning that water has difficulty in penetrating the soil, so it is increasingly difficult to continue to the plant roots. Bulk density indicates the weight of dry soil in a unit volume of soil, including soil pores. Based on the analysis results in the laboratory, the bulk density data at the research location is presented in Table 3. Based on Table 3, we can see that in Mahayung 2017 land, it ranges from 0.96–1.94 g cm-^{3}, and in the Banko 2017 land, it ranges from 1.3–1.99 g cm^{-3}. The average value of bulk content in Mahayung 2017 land was 1.4 g cm^{-3} and in Banko 2017 land was 1.62 g cm^{-3}. This showed that multicultural cropping system has a lower bulk content compared to monoculture cropping system. Bulk density is a parameter that can be used to assess the density of a soil. The smaller the bulk density of the soil, the looser the soil, conversely, the greater the bulk density, the denser the soil (Hartanto et al., 2022).

This can occur due to differences in organic material content in the two lands where organic material can affect soil aggregates so it also affects the soil bulk density. The results of statistical testing of the Mahayung (2017 land and Banko 2017 land, bulk density content showed a calculated t statistic of 5.3076 which is greater than the t statistic of 2.9768 so that the t statistic > t table. While when viewed from the probability value (sig. 2 tailed) of 0.0001 <0.05. So it can be concluded that the difference in cropping system has a significant effect on the value of soil bulk density (Table 4).

Infiltration Rate

Infiltration rate measurements were directly conducted in the field using the Double Ring tool and then the field results was analyzed using the Horton infiltration rate calculation. Horton infiltration is an infiltration capacity that is more controlled by factors operating on the ground surface compared to the water flow process in the soil. Infiltration capacity will decrease over time until it approaches constant. The calculation of the Horton infiltration rate is presented for each observation point across two distinct locations: the Mahayung 2017 land with a multicultural cropping system and the Banko 2017 land with a monoculture cropping system (Table 5). Notably, Horton observed that infiltration rates decrease over time until stabilizing at a constant rate (Yunagardasari et al., 2017).

The infiltration rate in Mahayung land in 2017 ranges from 2.7 to 3.3 cm/hour and it can be classified as moderate, and the infiltration rate in Banko 2017 land ranges from 2.3 to 2.6 cm/hour and it can be also classified as moderate class. Based on the average infiltration rate in Mahayung 2017 land and Banko 2017 land, both were classified in the moderate class, where Mahayung 2017 land has an average infiltration rate of 3.02 cm/hour and Banko 2017 land has an average of 2.56 cm/hour. Mahayung 2017 land with a multicultural cropping system has a higher average infiltration rate compared to Banko 2017 land with a monoculture cropping system. Several factors affect the infiltration rate, one of them organic material. Organic material affects the physical properties of the soil such as porosity because organic material can balance the pore space for water transmission and retention as well as aeration and drainage. Multicultural land has a higher organic material content than monoculture land because litter production on multicultural land is higher and more diverse than monoculture land.

Total Pore Space

Porosity needs to be identified because it is a picture of soil aeration and drainage. The number of soil pore sizes plays an important role in the mechanism of water absorption in the soil, Porosity properties can affect the growth and development of cultivated organisms because in the soil there are several pore spaces interconnected with each other. The smoothness of soil aeration and drainage is highly dependent on the soil pores in the soil. The results of the Total Pore Space calculation were taken from 2 different lands as presented in Table 7. Based on Table 7 we can see that the porosity value on the Mahayung land in ranges from 0.27%–0.64% while on the Banko 2017 land ranges from 0.25%–0.51% with the largest total pore space value of 0.64% on the Mahayung 2017 land and the smallest total pore space value of 0.25% on the Banko 2017 land. The pore space on the Mahayung 2017 land was 0.47% and Banko 2017 land was 0.39%. Organic material is one of the factors that affect the total pore space in the soil where organic material in the soil helps in the formation of soil aggregates by forming granules and enlarging the volume and pores of the existing soil so that the total soil pore space can increase. Soil with a lot of organic matter has thick humus so that it will have good physical characteristics, namely having the ability to absorb water up to several times than its dry weight and also having high porosity (Rizky et al., 2022). The results of statistical calculations of land A and B have a t value of 5.1602 with a t table value of 2.9768 where t statistic > t. Meanwhile, based on the probability value (Sig.2 tailed) 0.0001 <0.05, so it can be stated that the cropping system has a significant effect on the total value of soil pore space. The average value of the total pore space in the two lands, Mahayung 2017 land had a greater average value of total pore space than Banko 2017 land.

Relationship Between Organic Material and Bulk Density

Organic material is used to improve soil structure, increase soil temperature, increase aggregate stability, increase water retention capacity, and reduce soil sensitivity to erosion, as well as a source of energy for soil microorganisms. Soil with low C-organic content generally has a high bulk weight value. Based on the calculation results of the bulk weight value in the research area, it has a high/dense value and low C-organic content. The lower C-organic content in the soil, the denser/higher the soil bulk weight value (Tarigan et al., 2014). The comparison results of organic material and bulk density can be seen in Table 9. Based on the Table 9, we can see that the largest organic material value was identified in Mahayung 2017 land as many as 2.2%. Meanwhile, the lowest bulk density value was 0.99 g cm^{-3}. Based on the average value of organic material and bulk density, average organic material in the Mahayung 2017 land was higher than the Banko 2017 land and the Banko 2017 land has an average bulk density value higher than the Mahayung 2017 land.

Based on these values, we can see that the bulk density value will decrease as the organic C value in the soil increases. This is in line with the research of Yulnafatmawita et al. (2010) who reported that as organic matter increases, it generally decreases the soil bulk density (around 0.08–0.16 g cm^{-3}) and increases the total pore space (around 3.4-6.7%). The decrease in soil bulk density indicates that the soil is crumbly and has a lot of pore space that is not filled with solids. Correlation and regression analysis was conducted to analyze soil organic material and bulk density to see how much influence and direction of the relationship between the two. The results of the Pearson correlation analysis and quadratic regression are presented in Table 10. Based on Table 10 above, it can be seen that the coefficient of determination (R Square) value of 0.4939 means that the influence of soil organic material content on bulk density was 49.39% while the remaining 50.61% was influenced by other factors.

Mahayung is planted with multicultural cropping system. This area has more vegetation diversity compared to Banko Land 2017 which has a monoculture cropping system so that the number of different plants affects litter production and affects the organic material in both lands. It is known that the significance value for the effect of organic matter on the bulk density is 0.00007 <0.05. The correlation of r statistic is 0.6629 and the r table value is seen from the r distribution table, the r value was 0.6319, so the r statisti > r table, so it can be explained that organic material affects the bulk density where the bulk density soil will decrease along with the increasing of organic material content in the reclaimed land area. Based on the results of the regression analysis, the relationship between organic material and bulk density is classified as moderate (0.40–0.59). The factors that affect bulk density are texture, structure, and organic material content as well as soil management and cultivation practices. Organic material content is generally affected, the topsoil has a lower bulk density value compared to the soil below it, this occurs due to the influence of organic material (Darmayanti, 2012). This is stated by Susanti et al. (2018) that organic material in the soil has a large influence. Organic material can reduce the bulk density value because organic material is much lighter than minerals (Nasution et al., 2021).

The Relationship Between Organic Material and Infiltration Rate

Organic material plays an important role in improving the physical characteristic of the soil which can also increase infiltration capacity. Soil organic material can protect macro pores and affect the presence of soil organisms. The presence of soil organisms will help improve soil structure and porosity. According to Yunagardasari et al. (2017), organic material can improve soil porosity, where one of the physical characteristics that can determine infiltration capacity is soil porosity. The comparison results of the soil organic material values with infiltration rates are presented in Table 11. The organic material content at each observation point in the reclaimed land was varies. The diversity can be influenced by the differences and density of vegetation in the reclaimed land. The average soil organic material content and infiltration rate can be seen in Table 11. Patiung et al. (2011) stated that vegetation from the revegetation activity in the reclamation area will increase the production of litter that is decomposed into organic matter by soil organisms so that it can improve the soil bulk density and accelerate the movement of water to the soil layer.

This is supported by the data in Table 4.23 above. It can be seen that the determination coefficient value (R Square) of 0.7069 means that the influence of soil organic material content on the infiltration rate was 70.69% while the remaining 29.31% was influenced by other factors. It is known that the significance value for the effect of organic material on the infiltration rate is 0.0341 <0.05. The correlation of the r count is 0.6696 and the r table value is seen from the r distribution table, the r-value is 0.6319, so r count> r table, so it can be explained that organic material affects the infiltration rate. The infiltration rate will increase along with the increasing of organic material content in the reclaimed area. Rizky et al. (2022) stated that vegetation affects soil organic material with more diverse vegetation in a land. The production of litter such as twigs, leaves, stems, and plant remains will be the main source of organic material that will affect the soil structure and soil bulk density, so the infiltration rate is relatively high.

Correlation and regression analysis was conducted for soil organic material and infiltration rate to see how much influence and direction of this relationship. The results of the Pearson correlation analysis and quadratic regression are presented in Table 11. Based on the regression results of the relationship between organic soil materials and the infiltration rate, it can be concluded that it was in the strong category (0.60%–0.79%). Based on the results of the study by Andriani and Hadi (2012), they reported that the infiltration rate was increased after being given additional organic materials because organic soil materials can affect the physical, chemical, and biological characteristic of the soil. Biologically, organic matter acts as a source of nutrition for soil microorganisms, especially soil mesofauna. The presence of soil mesofauna will form soil pores so that it can increase the capacity of soil water absorption or infiltration.

CONCLUSSION

The conclusions that can be taken in this research are the organic matter content, bulk density, and infiltration rate on mine reclamation land with monoculture and multiculture planting systems show significant differences. Mahayung land exhibits higher organic matter content (1.08%) compared to Banko land (0.66%). Additionally, the average infiltration rate in Mahayung land (3.02 cm/hour) is higher than in Banko land (2.56 cm/hour), and the bulk density in Mahayung land (1.40 g/cm³) is lower than in Banko land (1.62 g/cm³). There is a correlation between organic matter content, bulk density, and infiltration rate. Organic matter content influences the infiltration rate by 70.69%, classified as a strong influence, and affects bulk density by 49.39%, classified as a medium influence. Based on the results of this study, it is recommended to conduct further research related to parameters that affect the differences in organic material in monoculture and multiculture lands such as the amount of litter production and planting distance in the reclaimed mining land of PT. Bukit Asam, Tbk.

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