Research Article

Reclamation of a limestone quarry: effect of poultry manure and humic acid on the soil improvement

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Abstract

Limestone processing produces dust covering the soil around the quarry site and may affect soil fertility. Post-mining activities in a forest area are mandatory to restore biodiversity, such as tree species of non-wood products. This study aimed to determine the impact of limestone dust on soil and measure the effectiveness of soil treatment for revegetation. This study employed a randomized block design with three soil groups, i.e. uncovered with limestone dust, covered with 2.5 cm limestone dust, and covered with 5 cm limestone dust. Each group had five replications and was treated with poultry manure (0 kg m\(^{-2}\), 5 kg m\(^{-2}\), 10 kg m\(^{-2}\), and 15 kg m\(^{-2}\)) and 2 L of 1% (v v\(^{-1}\)) humic acid. The amendment of manure and humic acid increased the soil organic C, total N, C/N ratio, and exchangeable K but increased the soil available P content. The soil respiration and total bacteria increased along with the thinning of the limestone dust. Overall, the treatments significantly affected pH, C/N ratio, exchangeable K, and electrical conductivity. At the same time, the group significantly affected organic C, total N, C/N ratio, exchangeable K, electrical conductivity, cation exchange capacity, bulk density, total bacteria, and clay. Based on land suitability assessment guidelines, the soil required nutrient improvement and pH reduction to grow proper non-wood products tree species.

Keywords: humic acid, limestone quarry, poultry manure, reclamation, soil improvement

Introduction

As a developing country, Indonesia still depends on exploiting natural resources for national income sources. Mining commodities are exploited natural resources, such as limestone mining in West Bandung Regency, Indonesia. Environmental impacts due to mining include landscape alteration, pit lake (void) formation, decreased biodiversity of flora and fauna, and changes in soil conditions (Howladar, 2016; Sonter et al., 2018; Benidire et al., 2020; Sakellari et al., 2021; Mulenga, 2022). Limestone is a sedimentary rock for raw material in the cement industry, which is derived from the remains of marine organisms (Eksan et al., 2019). The main content of limestone is the mineral calcium carbonate (CaCO\(_3\)), which occurs due to chemical and organic processes. In general, the mineral content in limestone is 95% calcium carbonate calcite, 3% dolomite, and clay minerals (Apriliani et al., 2012). In addition, according to Widiarso et al. (2017), the chemical composition of limestone was also influenced by minerals consisting of two kinds, namely: low-Mg calcite, when formed in cold areas and MgCO\(_3\) composition <4%; and high-Mg calcite when formed in warm areas with a composition of...
quality, increases the availability of soil nutrients, increases the ability of water holding capacity, and enhances plant growth. The application of compost as organic material also increased the yield of agricultural commodities (Brock et al., 2021).

Other amendments such as humic acid are also important to loosen the soil, transfer nutrients into plants, increase water retention, and promote microbial growth. Humic acid plays a role in reconditioning the soil as a growing medium. Humic acid also bound water in the soil, provided high ion exchangeability, and increased soil fertility and plant growth (Suwahyono, 2011).

The purpose of this study was to determine the impact of limestone dust covering the soil and the effect of poultry manure and humic acid on the improvement of soil conditions. Furthermore, this study aimed to evaluate the suitability of ex-mined soil for non-wood products.

Materials and Methods

Study site

The research was conducted at the limestone mining site of PT Akarna Marindo in West Bandung Regency, West Java Province, Indonesia, located in a state forest company (Perum Perhutani) territory from September to December 2020 (Figure 1). In detail, the study area is located at 107°23'56.755" E and 6°51’10,246 S. Some of the PT Akarna Marindo products are CaCO₃ (calcium carbonate), CaO (quicklime), Ca(OH)₂ (hydrated lime), dolomite, and zeolite.

Experimental design

The experimental design used in this study was a completely randomized block design with five replicates. Three groups of soil were used, namely uncovered with limestone dust, covered with 2.5 cm limestone dust, and covered with 5 cm limestone dust. Each group had five replications and was treated with poultry manure from a poultry farm (0 kg m⁻², 5 kg m⁻², 10 kg m⁻², and 15 kg m⁻²) and an additional 2 L of 1% (v/v) humic acid (Figure 2). Based on a previous study conducted by Suhartini et al. (2020), poultry manure used for this study contains 34.66% organic carbon and 3.89% nitrogen. Azmi et al. (2019) stated that poultry manure also contains macronutrients such as phosphorus, potassium, calcium, and magnesium.

Soil sampling

At 1.5 months after the treatments, soil samples were taken using a soil ring for physical properties and a soil auger with a depth of 0-30 cm for chemical and biological properties. The soil samples were analyzed in the soil laboratory of Padjajaran University, Bandung City, West Java Province, Indonesia, using the standard methods used in the laboratory (Table 1).
Figure 1. Study area of PT Akarna Marindo.

Figure 2. Randomized block design: a) no limestone dust cover; b) covered with 2.5 cm limestone dust; c) covered with 5 cm limestone dust.

Note:
- Red: Treatment point for 0 kg
- Green: Treatment point for 10 kg
- Orange: Treatment point for 5 kg
- Blue: Treatment point for 15 kg
- Dust
Table 1. Parameter and method of soil analysis.

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Parameter</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical properties</td>
<td>Electrical conductivity</td>
<td>Conductivity meter</td>
</tr>
<tr>
<td></td>
<td>Soil texture: sand, silt, and clay</td>
<td>Hydrometer</td>
</tr>
<tr>
<td></td>
<td>Bulk density</td>
<td>Soil ring</td>
</tr>
<tr>
<td>Chemical properties</td>
<td>pH: H₂O and CaCl₂</td>
<td>SNI 03-6787-2002</td>
</tr>
<tr>
<td></td>
<td>Organic Carbon (OC)</td>
<td>SNI 13-4720-1998 (Walkley and Black)</td>
</tr>
<tr>
<td></td>
<td>Total N</td>
<td>SNI 13-4721-1998 (Kjeldahl)</td>
</tr>
<tr>
<td></td>
<td>Available P₂O₅</td>
<td>(Bray I/II)</td>
</tr>
<tr>
<td></td>
<td>Exchangeable K⁺</td>
<td>Buffer extract NH₄OAc 1.0 N pH 7.0</td>
</tr>
<tr>
<td></td>
<td>Cation Exchange Capacity</td>
<td>Buffer extract NH₄OAc 1.0 N pH 7.0</td>
</tr>
<tr>
<td>Biological properties</td>
<td>Soil respiration</td>
<td>Using 0.5 N KOH solution to absorb CO₂</td>
</tr>
<tr>
<td></td>
<td>Total soil microorganism</td>
<td>Culture method</td>
</tr>
</tbody>
</table>

**Data analysis**

The laboratory analysis results of the soil properties were then statistically analyzed using the Statistica version 12 program and R-software to determine whether there was any influence from the treatment on the groups. The soil parameters were compared to the land suitability assessment guideline provided by the Indonesian Ministry of Agriculture to analyze proper vegetation to grow non-wood product tree species (Djaenudin et al., 2011; Ritung et al., 2011).

**Results and Discussion**

**Block analysis**

In general, the Principal Component Analysis-Biplot (PCA-Biplot) results from limestone dust groupings (block) showed that the covers of 2.5 cm and 5 cm limestone dust affected the values of soil properties parameters (Figure 3). The cover of 0 cm limestone dust grouping only affected some soil properties, namely silt, sand, clay, pH, organic C, bulk density, and C/N ratio.

![Figure 3. PCA-Biplot for block analysis.](image-url)
Lime addition can increase soil pH, N, organic C, available P, exchangeable K and Mg, as well as decrease exchangeable Al and Al saturation (Chao et al., 2014; Wijanarko and Taufiq, 2016). The lime application can also cause changes in the soil biological properties. However, changes in soil characteristics depend on soil type, intrinsic soil properties and climate (Mahmud and Chong, 2022). Lime is often recommended to encourage earthworm colonization. The activity of earthworms and the release of various metabolic compounds have a direct impact on soil structure and macroporosity. In the tropical area, lime application has beneficial effects on the quantity and community composition of almost all types of soil organisms (Mahmud and Chong, 2022).

**Treatment analysis**

The Principal Component Analysis-Biplot (PCA-Biplot) results showed that the 10 kg m\(^{-2}\) of organic fertilizer plus humic acid treatment had a greater effect than 0 kg m\(^{-2}\), 5 kg m\(^{-2}\) and 15 kg m\(^{-2}\) treatments (Figure 4). The effect of the 5 kg m\(^{-2}\) and 15 kg m\(^{-2}\) organic fertilizer plus humic acid treatments on soil conditions generally was the same. Meanwhile, the 0 kg m\(^{-2}\) organic fertilizer plus humic acid treatment had a smaller effect on soil properties measured. The addition of manure with doses of 5 kg m\(^{-2}\), 10 kg m\(^{-2}\), and 15 kg m\(^{-2}\) affected all parameters of soil physical, chemical, and biological properties, while the 0 kg m\(^{-2}\) treatment only affected a few parameters of soil properties, namely sand, total N, clay, and pH variables. Rös et al. (2020) reported that the addition of manure increased the concentrations of P and K, while the addition of limestone increased Ca and Mg in the soil. Based on the results, the soil pH was affected only by limestone. Limestone and manure affect soil fertility in different ways. The increase in crop yield with an application of manure to the soil is often related to improvements in the soil biological, chemical and physical properties (Alabadan et al., 2009). The addition of organic fertilizers can raise the pH, with a consequent increase in cation exchange capacity and nutrient release (Ermadani et al., 2019). The manures are sources of Ca, Mg, S, and micronutrients, as well as important nutrients for soil fertility maintenance (Zamil et al., 2004). The benefits to soil physics of the application of manure include increased macroporosity, reduced soil density, and maintenance of aggregate stability (Cavalcante, 2019). The organic matter favors increased total porosity and reduced soil penetration resistance (Agbede, 2021). Alabadan et al. (2009) reported that the application of different poultry waste has different effects on the physicochemical and biological properties of soil, such as biological oxygen demand (BOD).

![PCA - Biplot](image)

**Figure 4.** PCA-Biplot for treatment analysis.
**Soil physical properties**

Soil physical properties related to the shape/condition of the original soil include texture, structure, soil density, porosity, stability, consistency, color, temperature, and others. Soil properties play a role in plant root activity, both in absorbing nutrients, water, and oxygen and limiting plant root movement. The soil texture degradation required attention due to management functions in limestone mining activities (Rosyidah and Wirosodarmo, 2013). The results of Analysis of Variance (ANOVA) showed that the electrical conductivity of the grouping (limestone dust) and the treatments (manure and humic acid) significantly affected (p<0.05) the bulk density and clay parameters. Only the grouping showed a significant effect (Table 2 and Figure 5a, Figure 5b and Figure 5c). Soil texture, namely sand and silt contents, showed an insignificant effect (p>0.05).

The electrical conductivity (EC) values of 5 kg m², 10 kg m², and 15 kg m² organic fertilizer treatments were not significantly different. However, the 0 kg treatment was significantly different with the lowest value. The thickness of the limestone dust affected the bulk density. The bulk density of groups 0 and 2.5 cm were significantly different, but the bulk density between 0 and 5 cm and 2.5 cm and 5 cm were not significantly different. At the same time, the treatments showed no significant difference in bulk density (p>0.05). Treatment and grouping did not show a significant difference in the value of sand and silt. However, the value of clay showed a significant difference between the group of 0 cm and 2.5 cm with 5 cm. Clay in the 5 cm grouping is higher when compared to 0 cm and 2.5 cm. According to the results, the soil texture in the ex-mined area consisted of 39-48% clay, 31-39% silt, and 17-21% sand in general. Soil texture indicates the coarseness of the soil. Fine-textured soil slows air and water movement even though there is a lot of pore space. Micro pores rather than macro pores dominate soils with fine textures. Sandy soils have a small surface area, so it is not easy to absorb (hold) water and nutrients. The result showed that poultry manure and humic acid did not affect the soil texture; however, it was influenced mainly by the limestone dust to increase soil stability.

EC is the ability of the soil to transmit electric current. Soil EC exists due to free salt content in groundwater levels and exchangeable ions contained on the surface of solid soil particles (Ismayilov et al., 2021). EC measurements have a significant relationship closely related to the properties and condition of the soil. The conditions and properties of the soil in question include water content, clay content, soil texture, cations exchange capacity, organic matter content, salinity, and subsoil condition. Soil with a water-filled pore connects to surrounding pores and conducts electricity more readily. High clay soil has more small water-filled pores and EC than sandy soil. Additionally, compaction normally increases the EC (Doerge et al., 2000).

<table>
<thead>
<tr>
<th>Grouping, Treatment and p-value</th>
<th>Electrical conductivity (ds m⁻¹)</th>
<th>Bulk density (g cm⁻³)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grouping (limestone dust thickness)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 cm</td>
<td>0.317 a</td>
<td>1.560 b</td>
<td>17.471 a</td>
<td>39.765 a</td>
<td>42.588 b</td>
</tr>
<tr>
<td>2.5 cm</td>
<td>0.240 b</td>
<td>1.881 a</td>
<td>19.529 a</td>
<td>38.529 a</td>
<td>42.000 b</td>
</tr>
<tr>
<td>5 cm</td>
<td>0.249 b</td>
<td>1.732 ab</td>
<td>21.059 a</td>
<td>32.294 a</td>
<td>53.357 a</td>
</tr>
<tr>
<td><strong>Treatment (poultry manure and 2 L of 1% humic acid)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 kg m⁻²</td>
<td>0.192 b</td>
<td>1.540 a</td>
<td>19.500 a</td>
<td>31.833 a</td>
<td>48.667 a</td>
</tr>
<tr>
<td>5 kg m⁻²</td>
<td>0.271 a</td>
<td>1.667 a</td>
<td>17.667 a</td>
<td>34.800 a</td>
<td>50.000 a</td>
</tr>
<tr>
<td>10 kg m⁻²</td>
<td>0.302 a</td>
<td>1.821 a</td>
<td>21.067 a</td>
<td>39.467 a</td>
<td>40.786 a</td>
</tr>
<tr>
<td>15 kg m⁻²</td>
<td>0.263 a</td>
<td>1.758 a</td>
<td>19.267 a</td>
<td>38.333 a</td>
<td>44.429 a</td>
</tr>
<tr>
<td><strong>p-value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>0.005*</td>
<td>0.098</td>
<td>0.389</td>
<td>0.702</td>
<td>0.227</td>
</tr>
<tr>
<td>Grouping</td>
<td>0.001*</td>
<td>0.002*</td>
<td>0.323</td>
<td>0.339</td>
<td>0.025*</td>
</tr>
</tbody>
</table>

Note: same letter means no significant; *significant p< 0.05.

The physical properties of the soil are very influential on the availability of water and air in the soil pores and indirectly affect the availability of plant nutrients. These properties also affect the potential land for maximum production. Some soil physical properties that need to be noted are soil structure degradation due to management activities, such as mining. Mining activities resulted in land clearing/opened land, increasing the erosion process and loss of organic matter (Yunanto, 2018). The addition of organic matter in this study is expected to improve soil structure by binding soil particles to form stable aggregates and soil nest so that it absorbs water faster (porosity) and the hydraulic conductivity of the soil.
arises. Soil porosity is influenced by organic matter content, where organic matter increases porosity and affects pore space. Soil with a lot of organic matter had good physical properties and the ability to absorb water up to several times its dry weight, and had a high porosity (Delsiyanti et al., 2016).

Humic acid is also added to improve soil conditions. In general, humic acid plays a role in reconditioning the soil as a better-growing medium. Humic acid binds to water in the soil, has a high cation exchange capacity, and increases soil fertility and plant growth. Physical benefits to the soil include soil structure improvement, and soil protection against loss of water and nutrients due to sunlight, especially on sandy soils. Simultaneously it also converts these nutrients by the path of soil decomposition to be useful. In very hard soil conditions, humic acid improves soil aeration and water retention; hence the soil can be optimally used for planting crops (Suwahyono, 2011).

**Soil chemical properties**

Mining activities are believed to affect soil fertility if they are not appropriately managed. Soil chemical properties are closely related to fertility levels because soil chemistry plays a major role in determining the presence and availability of nutrients in plant growth and production. Soil chemical properties are influenced by the soil basic nature, which has organic content, minerals, solutions in the soil, and processes that occur in the soil. The general characteristics of critical or low productivity land levels were characterized by high levels of soil acidity, deficiencies of P, K, C, and Mg nutrients, low ion cation exchange capacity, low base saturation and low organic matter content (Ahukaemere et al., 2012; Mutamminah et al., 2020).

The statistical analysis results showed three significant parameters for the addition of chicken manure and humic acid: pH, exchangeable K, and C/N ratio (p<0.05). At the same time, the limestone dust cover grouping had a significant effect on organic C, total N, C/N ratio, exchangeable K, and CEC (Figure 6a, Figure 6b, Figure 6c, Figure 6d, Figure 6e, and Figure 6f). There was a significant difference in pH value between the poultry manure for 0 kg m^{-2} with 5 kg m^{-2}, 10 kg m^{-2}, and 15 kg m^{-2} (Table 3). However, the pH values were not significantly different due to the grouping (p>0.05). The value of exchangeable K tended to decrease due to the thickness of limestone dust; on the contrary, the value of exchangeable K increased with poultry manure. In general, the value of chemical properties tended to be more influenced by the grouping of limestone dust thickness than poultry manure treatment.
### Table 3. The analysis of variance (ANOVA) of soil chemical properties.

<table>
<thead>
<tr>
<th>Grouping, Treatment and p-value</th>
<th>pH</th>
<th>Organic C (%)</th>
<th>Total N (%)</th>
<th>C/N ratio</th>
<th>P₂O₅ (ppm)</th>
<th>Exchangeable K (cmol kg⁻¹)</th>
<th>CEC (cmol kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grouping (limestone dust thickness)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 cm</td>
<td>8.141 a</td>
<td>0.452 b</td>
<td>0.059 a</td>
<td>8.000 b</td>
<td>8.583 a</td>
<td>1.306 a</td>
<td>33.822 a</td>
</tr>
<tr>
<td>2.5 cm</td>
<td>8.187 a</td>
<td>0.746 a</td>
<td>0.035 b</td>
<td>19.942 a</td>
<td>8.525 a</td>
<td>0.678 b</td>
<td>28.793 b</td>
</tr>
<tr>
<td>5 cm</td>
<td>8.153 a</td>
<td>0.777 a</td>
<td>0.043 ab</td>
<td>15.235 ab</td>
<td>8.583 a</td>
<td>0.410 b</td>
<td>33.839 a</td>
</tr>
<tr>
<td><strong>Treatment (poultry manure and 2 L of 1% humic acid)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 kg m⁻²</td>
<td>8.342 b</td>
<td>0.568 a</td>
<td>0.055 a</td>
<td>8.167 b</td>
<td>7.818 a</td>
<td>0.132 b</td>
<td>29.313 a</td>
</tr>
<tr>
<td>5 kg m⁻²</td>
<td>8.146 a</td>
<td>0.657 a</td>
<td>0.041 a</td>
<td>13.933 ab</td>
<td>9.589 a</td>
<td>0.698 ab</td>
<td>34.337 a</td>
</tr>
<tr>
<td>10 kg m⁻²</td>
<td>8.147 a</td>
<td>0.663 a</td>
<td>0.040 a</td>
<td>20.933 a</td>
<td>9.424 a</td>
<td>0.947 a</td>
<td>32.091 a</td>
</tr>
<tr>
<td>15 kg m⁻²</td>
<td>8.115 a</td>
<td>0.691 a</td>
<td>0.055 a</td>
<td>10.801 ab</td>
<td>6.968 a</td>
<td>1.016 a</td>
<td>31.162 a</td>
</tr>
<tr>
<td><strong>p-value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>0.009*</td>
<td>0.766</td>
<td>0.292</td>
<td>0.037*</td>
<td>0.449</td>
<td>0.044*</td>
<td>0.293</td>
</tr>
<tr>
<td>Grouping</td>
<td>0.582</td>
<td>0.000*</td>
<td>0.031*</td>
<td>0.009*</td>
<td>0.999</td>
<td>0.001*</td>
<td>0.023*</td>
</tr>
</tbody>
</table>

Note: the same letters mean not significant; *significant at p<0.05.

Figure 6. Response of treatments and block/groups on pH (a), organic C (b), total N (c), C/N ratio (d), exchangeable K (e), and CEC (f).
Soil chemical properties allow the soil to hold nutrients. They are enlisted as parameters in determining the chemicals added to the soil, such as fertilizers, organic matter, lime, pesticides, and herbicides. It is undeniable that the use of manure increases nutrients and improves the physical and biological properties of the soil. The content of nutrients in manure depends on the type of livestock, type of feed, water provided, age, and physical form of the livestock. The high exchangeable K value in the research site was likely caused by the amendment of poultry manure. The exchangeable K in poultry manure was higher than in cattle manure (Bakayoko et al., 2009). In addition, the CEC values also tended to be high, probably due to the soil pH, soil texture, amount of clay, types of clay minerals, and organic matter (Tomašić et al., 2013). The clay content in the research site was higher than the silt and sand content.

The addition of humic acid in this study also affected the chemical properties of the soil. Suwahyono (2011) stated that the benefit of chemical humic acid in soil was to neutralize acidic or alkaline soil conditions by regulating the pH value of the soil. Humic acid increases and optimizes the intake of nutrients and water by plants. Humic acid acts as a chelator for metallic elements in alkaline soil conditions and aids uptake into plant roots. Furthermore, the benefits of humic acid in soil chemistry are to help the conversion of elements in nutrients (such as nutrients N, P, K, Fe, Zn, and other microelements) in a form that is easily absorbed by plants and increases nitrogen intake by plants.

**Soil biological properties**

As degraded soil, ex-mined land required a soil improvement to grow the plants. Compost is an organic material source for soil microbes and increases the number of soil microbes (Widodo and Kusuma, 2018). Microbial slime and organic colloidal compost affected the soil pores adhesive (Rashid et al., 2016). Nenobesi et al. (2017) reported that the poultry manure and bio-slurry increased microbial colonies in the soil, particularly from poultry manure. Moreover, Suwahyono (2011) stated that acid-humic substances could remediate the soil even contaminated by heavy metals and are more effective than compost.

The results of ANOVA showed that the poultry manure and humic acid treatments had no significant effect on the value of soil respiration and total bacteria (p>0.05). The value of soil respiration and total bacteria was influenced mostly by the grouping (limestone dust thickness) (Figure 7). Soil respiration increased with the thinning of the limestone dust thickness (Table 4). The application of poultry manure increased the number of soil microorganisms. Organic matter influenced the development of soil microorganisms (Mohammadi et al., 2011). The amount of CO$_2$ produced by the activity of soil microorganisms was directly proportional to the number of soil microorganisms, in which the action of microorganisms was high; the CO$_2$ production also increased. The amount of CO$_2$ produced by the activity of soil microorganisms was influenced by organic matter.

<table>
<thead>
<tr>
<th>Grouping, Treatment and p-value</th>
<th>Soil respiration (mg CO$_2$-C kg$^{-1}$ day$^{-1}$)</th>
<th>Total bacteria (CFU g x 10$^9$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grouping (limestone dust thickness)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 cm</td>
<td>18.432 a</td>
<td>6.047 a</td>
</tr>
<tr>
<td>2.5 cm</td>
<td>16.254 a</td>
<td>4.800 a</td>
</tr>
<tr>
<td>5 cm</td>
<td>15.689 a</td>
<td>3.082 b</td>
</tr>
<tr>
<td><strong>Treatment (poultry manure and 2 L of 1% humic acid)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 kg m$^2$</td>
<td>17.553 a</td>
<td>5.750 a</td>
</tr>
<tr>
<td>5 kg m$^2$</td>
<td>16.492 a</td>
<td>4.660 a</td>
</tr>
<tr>
<td>10 kg m$^2$</td>
<td>16.144 a</td>
<td>4.627 a</td>
</tr>
<tr>
<td>15 kg m$^2$</td>
<td>17.435 a</td>
<td>4.200 a</td>
</tr>
<tr>
<td><strong>p-value</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>0.737</td>
<td>0.408</td>
</tr>
<tr>
<td>Grouping</td>
<td>0.084</td>
<td>0.000*</td>
</tr>
</tbody>
</table>

Note: the same letters mean not significant; *significant at p<0.05.

Moreover, the activity of soil microorganisms was also influenced by moisture, aeration, and energy sources. However, because the microbial activity requires time to improve soil quality, the duration of soil testing may be added to define the improvement.

Providing nutrients through compost and manure, water, and oxygen were able to enrich soil microbial (Zhen, 2014). Moreover, the mulch application protected the nutrient source for microbes and reduced the risk of certain diseases and pests due to increased surface temperature. The soil booster must be appropriately selected to grow non-wood product tree species in ex-limestone quarry sites. Sumarni et al. (2010) reported that higher zeolite amendment affected the increase of Bacillus sp. and the decrease of Azotobacter. Moreover, higher doses of NPK

Table 4. The analysis of variance (ANOVA) of soil biological properties.
fertilizer suppressed the growth of Azotobacter. The selection of manure was also impacted the soil microorganism presence. Horse manure contained more Bacillus sp. The implementation of compost, manure, and biofertilizer with the addition of fungi and bacteria such as Azotobacter chroococcum, Azotobacter vinelandii, Azospirillum sp., Pseudomonas cepacia, Penicillium sp., and Acinetobacter sp. also increased the yield of sweet corn (Kalay et al., 2018).

Another study aimed to improve the biological activity in post-limestone mining was conducted by growing cover crops and mycorrhizal inoculated plants. Prayudyaningsih et al. (2016) reported that the Formicidae family was found dominant in cover crops and mycorrhizal inoculated plant areas, which became an indicator of limestone quarry restoration.

**Suitability assessment**

In the ex-limestone quarry site, Legwaila et al. (2015) stated that the soils which have a high pH are classified as calcareous soils; hence they are proper to grow the calcareous vegetation. As the soils have limited and poor soil nutrients, the revegetation activities in the ex-limestone quarry site have many challenges in soil quantity and quality.

In this research, poultry manure treatment decreased the pH, although the pH was still high. All the samples had a high value of pH (pH>8.0, Table 5) due to the limestone dust content. Since the soil pH is classified as strong alkaline (Hillock et al., 2017), the soil requires some treatments, such as adding sulfur a year before planting in dry conditions to prevent the changing of sulfur. Nevertheless, the sulfur amendment has been reported ineffective for calcareous soils (Dilmaghani et al., 2012). Other treatments, for instance, adding organic matter such as compost, manure, and tea or coffee grounds, are advised to decrease the alkalinity and improve the micronutrient absorption of plants (Kasongo et al., 2011). High soil pH also results in low organic carbon, nitrogen, and phosphate (Ramrez-Rodrguez et al., 2005), while vegetation needs sufficient nutrients to grow (Wigena et al., 2009). The soil required organic matter in large portions to increase the organic carbon. Moreover, the addition of poultry manure did not affect the nitrogen content. According to Lamare and Singh (2020), the distance of cement plants containing limestone should be considered to increase the soil nitrogen content. Therefore, the application of manure to improve soil nitrogen content can be calculated based on the distance from the quarry site. Otherwise, the combination of goat manure and bio-activator was also advised to increase the nitrogen content (Winarni et al., 2013). The addition of a by-product in the beer industry called Brewer’s spent grain and compost increased the nutrient and reduced the pH in a similar type of soil (Aboukila et al., 2018). All soil samples had a high value of CEC (>16 cmol kg\(^{-1}\)) because of the high pH. Unlike the soil texture in calcareous soil, the soil in the research site was mostly clay that could hold cations. In general, the soil texture and CEC were suitable for planting the non-wood products tree species.

From previous research, the success of limestone mine reclamations in Georgia was dominated by shrubs (Akhalkatsi et al., 2018). It means that certain plants can survive on limestone quarry sites. Cohen-Fernández (2012) reported that the mixture of manure and biosolids increased soil nutrients, microbial biomass, viable fungi and bacteria, and plant establishment in the ex-limestone mining area. Cohen-Fernández (2012) found that the adequately planted vegetation were Picea, Pseudotsuga, and Populus.
Based on the guideline provided by the Indonesian Ministry of Agriculture (Ritung et al., 2011), the soil in the research site required nutrient improvement. The non-wood products tree species such as Coffea canephora, Myristika fragrans Houtt, Cinnamomum burmannii BL, and Aleurites moluccana Willd are advised with a condition of pH reduction below 7.0. In addition, the increase of total nitrogen to the minimum value of 0.2% and phosphate to a minimum of 15 cmol kg⁻¹ are also important to meet the release from the marginal soil criteria based on existing parameters. However, over time from the initial study, the application of poultry manure and humic acid at the study site could increase the fertility and suitability of the land for the species of plants to be planted in the ex-mining area.

Conclusion

The poultry manure and humic acid amendment significantly affected the soil chemical properties in the limestone mining site of PT Akama Marindo of West Java Province, while the limestone dust mostly influenced the soil physical and biological properties. Limestone dust had a significant effect on the number of total bacteria. The soil requires improvement on organic matter and nutrients such as phosphate to grow tree species of non-wood products. A strong alkaline reduction is also advised to achieve nutrient absorption. Further research should focus on the effectiveness of different amendments and fertilizers to improve the nutrient content before planting the crops.

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