e-ISSN 2621-4113
p-ISSN 2615-8353

Study of Some Soil Chemical Properties in Several Different Land Uses

(Kajian Beberapa Sifat Kimia Tanah Pada Beberapa Tipe Penggunaan Lahan)

Debora Margaretta, Itang Ahmad Mahbub, Ermadani*

The Study Program of Agroekoteknologi, Faculty of Agriculture, Universitas Jambi

**Corresponding author: ermadani@unja.ac.id*

ABSTRACT

Soil chemical properties have a crucial role in determining soil fertility. Land use is one factor that determines soil chemical properties. The purpose of this study was to examine several soil chemical properties across different land uses. The study was conducted in Muhajirin Village, Jambi Luar Kota District, Muaro Jambi Regency, from March to May 2025. Soil sampling was conducted in oil palm, rubber, and areca nut plantations. The soil type at the study site is classified as an Ultisol with a slope of 3-8%. For each land use, a main plot and subplots were identified for soil sampling. Soil samples were taken at a depth of 0-30 cm using a soil auger. Soil chemical parameters included pH, organic carbon, total nitrogen, available phosphorus, and extra potassium. The results showed that soil pH across the three land use types was relatively similar, while the organic carbon, total nitrogen, and exchangeable potassium content in areca nut plantations was higher than in oil palm and rubber plantations. The soil available phosphorus content in oil palm plantations was higher than in areca nut and rubber plantations. Higher organic C content in the soil also indicates higher total N and exchangeable K content in areca nut plantations, while higher available P content in oil palm plantations is due to the application of phosphate fertilizer. The study aimed to examine the chemical characteristics of the soil under several different land uses.

Keywords: *soil chemical properties, different land use*

ABSTRAK

Sifat kimia tanah memiliki peran penting dalam menentukan kesuburan tanah. Penggunaan lahan merupakan salah satu faktor yang menentukan sifat kimia tanah. Tujuan penelitian ini adalah untuk mengkaji beberapa sifat kimia tanah di berbagai penggunaan lahan. Penelitian ini dilakukan di Desa Muhajirin, Kecamatan Jambi Luar Kota, Kabupaten Muaro Jambi, dari Maret hingga Mei 2025. Pengambilan sampel tanah dilakukan di perkebunan kelapa sawit, karet, dan pinang. Tipe tanah di lokasi penelitian diklasifikasikan sebagai Ultisol dengan kemiringan 3-8%. Untuk setiap penggunaan lahan, petak utama dan sub petak ditentukan untuk pengambilan sampel tanah. Sampel tanah diambil pada kedalaman 0-30 cm menggunakan bor tanah. Parameter kimia tanah meliputi

e-ISSN 2621-4113
p-ISSN 2615-8353

pH, karbon organik, nitrogen total, fosfor tersedia, dan kalium dapat ditukar. Hasil penelitian menunjukkan bahwa pH tanah di ketiga tipe penggunaan lahan relatif sama, sedangkan kandungan karbon organik, nitrogen total, dan kalium yang dapat dipertukarkan di perkebunan pinang lebih tinggi daripada di perkebunan kelapa sawit dan karet. Kandungan fosfor tersedia dalam tanah di perkebunan kelapa sawit lebih tinggi dibandingkan di perkebunan pinang dan karet. Kandungan C organik yang lebih tinggi dalam tanah juga menunjukkan kandungan N total dan K yang dapat dipertukarkan lebih tinggi di perkebunan pinang, sedangkan kandungan P tersedia yang lebih tinggi di perkebunan kelapa sawit disebabkan oleh pemberian pupuk fosfat. Penelitian bertujuan untuk mengkaji karakteristik sifat kimia tanah pada beberapa penggunaan lahan yang berbeda.

Kata kunci: sifat kimia tanah, penggunaan lahan yang berbeda

Diterima, 13 Juni 2026
Disetujui, 29 Juni 2026
Online, 30 Juni 2026

INTRODUCTION

Soil is a natural resource that serves as a medium for plant root growth and development, and supplies water and nutrients necessary for plant growth and development. The ability of soil to function as a medium for plant growth and development is influenced by the environment and soil properties, such as physical, chemical, and biological properties. According to Derakhshan-Babaei et al. (2021), physical, chemical, and biological properties of soil influence soil quality.

Soil chemical properties are crucial in determining soil properties and fertility (Rahmi, 2014). These properties include soil pH, organic carbon, and nutrient content such as N, P, and K (Hardjowigeno 2010). N, P, and K are essential for plant growth. Parjono (2019) states that the availability of N, P, and K in soil is determined by the parent material and human activities, namely soil cultivation, fertilization, irrigation, and plant vegetation.

Muhajirin Village is a village located in Jambi Luar Kota District, Muaro Jambi Regency. Muhajirin Village is one of the former transmigration areas, namely PIR NES II Bajubang, with an area of 3,654 hectares, the number of families is 875 with apopulation of 3,840 people (Muhajirin Village Government 2025). This village is located on an alternative road to Batanghari Regency (Dalimunthe *et al.* 2021). The majority of the population earns a living as farmers with the main commodity being rubber. In the year 2023, 60% of the land use in this village is rubber plantation. The rubber plantations in Muhajirin Village are smallholder rubber plantations that are more than 10 years old, covering an area of approximately 1,274.17 hectares with a production yield of approximately 1.62 tons/ha/year.

e-ISSN 2621-4113
p-ISSN 2615-8353

Rubber production in this village is relatively lower than in surrounding villages. Many rubber plants are no longer productive. Lack of fertilization is also a factor in low rubber productivity. This is consistent with research by Bakri *et al*. (2020) that found that fertilization can increase growth and increase latex production in rubber plants by 10 to 33%. Low rubber prices also force farmers to convert rubber land into other land uses such as areca nut and oil palm plantations. The community's oil palm plantations in Muhajirin Village cover an area of approximately 212.55 ha with varying plant ages, averaging 15 years. Average oil palm production in Muhajirin Village reaches approximately 26.52 tons/ha/year or approximately 5,636.8 tons/year. Oil palm farmers are more diligent in maintaining and fertilizing their plantations because they want good yields.

The nutrients available in the soil can affect plant growth and productivity. An imbalance of nutrients in the soil can cause problems for plants. Nutrient content in the soil can be provided through fertilization. Generally, farmers often use NPK fertilizers intended to supply the nutrients N, P, and K needed by plants in large quantities. Fertilization must be carried out according to the correct dosage so that the nutrients are absorbed by the plants perfectly and will increase plant productivity. Fertilization affects soil conditions such as changing the soil pH to become more acidic or more alkaline depending on the type of fertilizer used. Excessive and long-term use of chemical fertilizers can have negative impacts on the soil. One impact is a decrease in soil pH (soil acidification), particularly due to excessive use of nitrogen fertilizers. Soil acidification can reduce nutrient availability and disrupt plant growth. Furthermore, according to Sauza *et al.* (2023) continued use of chemical fertilizers without the addition of organic matter can cause soil compaction, reduce porosity, and reduce the soil's ability to retain water. Excessive application of nitrogen fertilizers can also increase the accumulation of nitrates and nitrites, potentially polluting the environment and degrading soil quality. Another impact is a decrease in the activity of soil microorganisms, which play a vital role in maintaining soil fertility (He et al., 2026). Mawaddah *et al.* (2016) also found that excessive application of chemical fertilizers such as urea can cause an increase in nitrite concentrations in the soil. Each plant requires different nutrients, both in quantity and type, to support its growth and development (Purba *et al.* 2021). Different land uses have different nutrient contents. Land use not only impacts soil properties but can also change the chemical, physical, and biological quality of the soil (Qi *et al.* 2018). The study aimed to examine the chemical characteristics of the soil under three different land uses

MATERIAL AND METHODS

This study was conducted over a three-month period, from March to May 2025.in Muhajirin Village, Jambi Luar Kota District, Muaro Jambi Regency. The soil at the study site belongs to the Ultisol order with slopes of 0-8%. The dominant land use is oil palm

e-ISSN 2621-4113
p-ISSN 2615-8353

plantations, followed by rubber plantations and then areca nut plantations. This research was conducted over a three-month period, from March to May 2025.

Materials used in the study included disturbed soil samples and chemicals for soil analysis. The tools used in this study included a mineral soil drill, a Munsell Soil Chart, a GPS (Global Positioning System), Microsoft Office software, ArcGIS software, Avenza Maps software, a field knife, plastic sample bags, label paper, a hoe, sacks, a tape measure, an Abney level or clinometer software, Statistical Package for Social Sciences (SPSS) software, rubber bands, stationery, a plastic rope, a digital scale, and documentation tools.

Soil sampling at a depth of 0-30 cm was carried out based on several different land uses: oil palm, rubber, and areca nut, each of which was more than 15 years old. The soil order was the same, Ultisol, and the slopes were 3-8%. For each land use, a main plot and subplots were identified for disturbed soil sampling. The main plot for each land use was 100 m x 20 m (Figure 1) (Hairiah *et al.* 2011), with subplots measuring 20 m x 20 m, with a distance of 5 m between subplots (Figure 2, Figure 3, Figure 4). Each plot consisted of four subplots as replications (Toru and Kibret 2019).

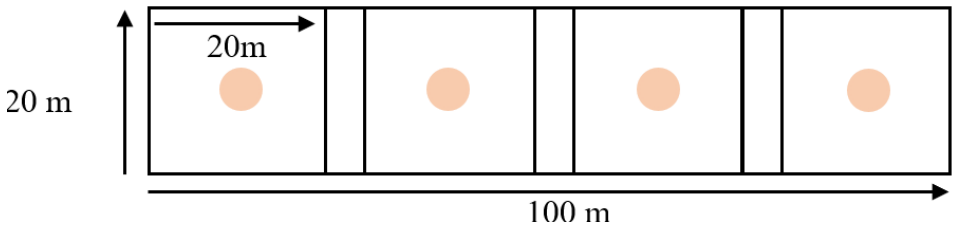

Figure 1. Main plot of soil sampling

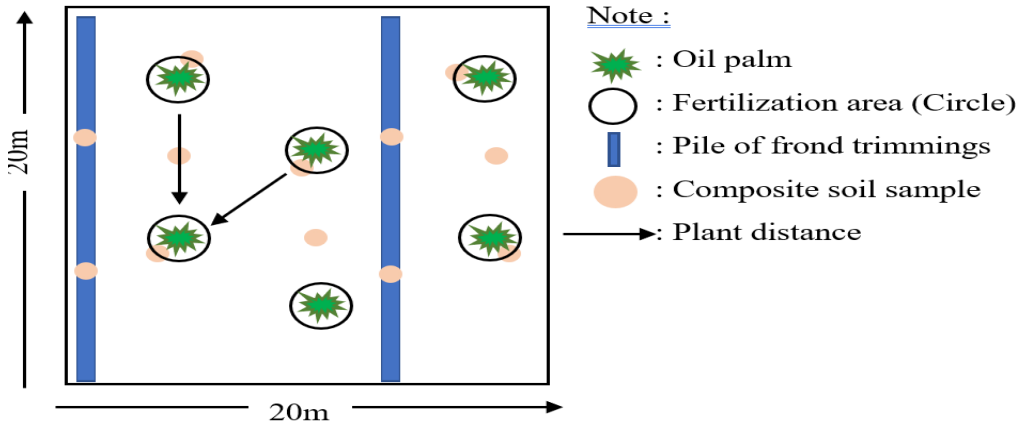

Figure 2. Layout of composite soil sampling on oil palm plantation

e-ISSN 2621-4113
p-ISSN 2615-8353

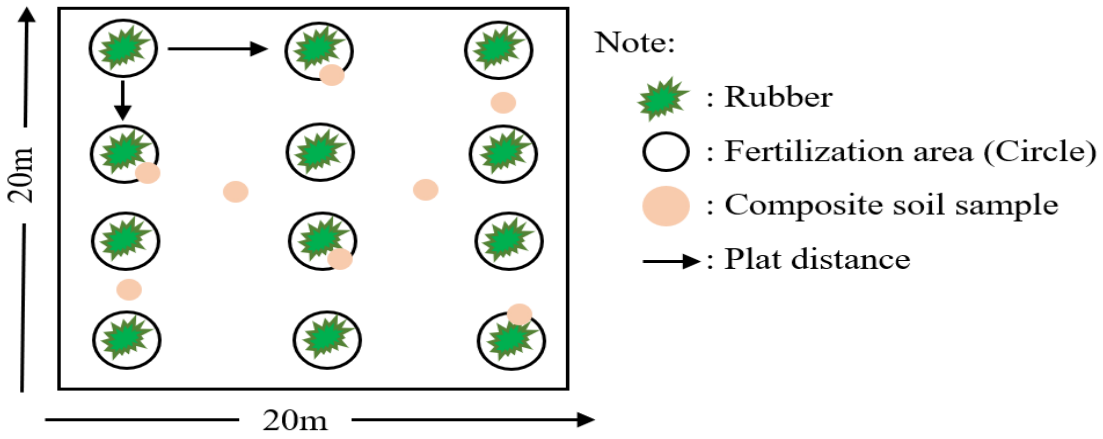

Figure 3. Layout of composite soil sampling on rubber plantation

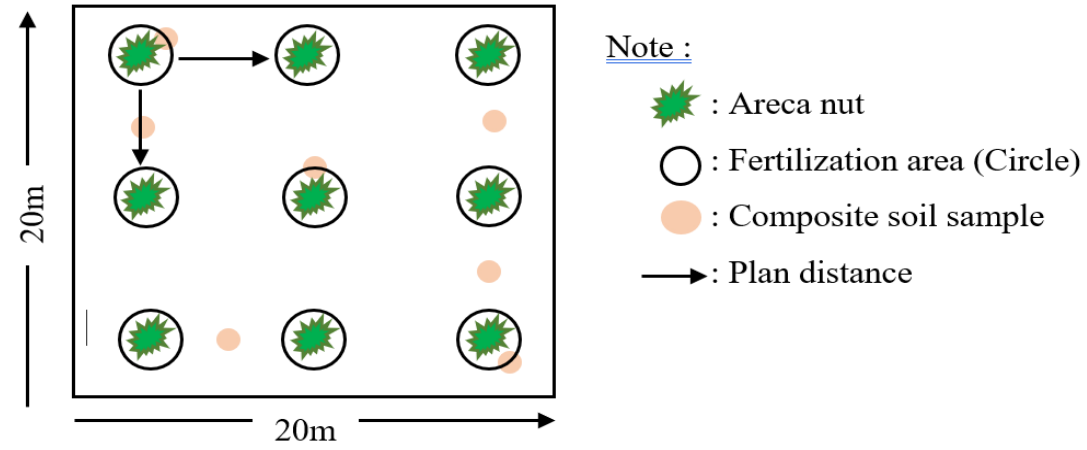

Figure 4. Layout of composite soil sampling on areca nut plantation

Soil samples collected from the field were then air-dried, ground, and sieved using a 2 mm sieve. Subsequently, the soil samples were analyzed to determine soil pH (H_2O), organic carbon (Walkley and Black), total nitrogen (Kjeldahl), available phosphorus (Bray-1), and exchangeable potassium (NH_4OAc pH 7) (Estefan *et al.* 2013)

The influence of different land uses on soil chemical properties, namely total N, available P, and exchangeable K, pH, and organic C content were analyzed using analysis of variance. The average differences of each parameter in different land uses were analysed using Duncan's Multiple Range Test (DMRT) at 5% α level (Li *et al.* 2016).

RESULTS AND DISCUSSION

The characteristics of several soil chemical properties in three different land uses in Muhajirin Village are presented in Table 1. The soil pH values in oil palm, rubber and areca nut plantations did not show significant differences. The content of organic C, total N and exchangeable K in the soil in areca nut plantations showed significant differences

e-ISSN 2621-4113
p-ISSN 2615-8353

where the content of organic C (1.31%), total N (0.14%) and exchangeable K (0.06 cmol/kg) were higher than those in oil palm and rubber plantations. The content of soil available P in the oil palm plantation showed significant differences compared to the other two land uses, where the available P was higher at 2.71 ppm, while in the rubber and areca nut plantations they were 2.45 and 1.04 ppm.

Table 1. Characteristics of several soil chemical properties in several land uses

Land use	pH	Organic-C (%)	Total-N (%)	Available - P(ppm)	Exchangeable K (cmol/ kg)
Oil Palm Plantation	4,51 a	1,00 a	0,10 a	2,71 a	0,04 a
Rubber Plantation	4,60 a	1,10 ab	0,12 a	2,45 b	0,04 a
Areca Nut Plantation	4,64 a	1,31 b	0,14 b	1,04 b	0,06 b

Note: Numbers followed by different letters in the same column indicate significant differences according to Duncan's Multiple Range Test (UJBD) at the level α= 5%

Soil reaction (soil pH)

The relatively similar pH values across the three land uses are due to the Ultisol soils, which tend to have high acidity levels. The average soil pH across all land uses tended to be low, ranging from 4.51 (acidic) to 4.64 (acidic). This low pH can be a limiting factor for the availability of certain nutrients and the activity of soil microorganisms (Ermadani *et al.* 2019, Taisa *et al.* 2021).

The low soil pH in community plantations at the research site may be caused by H^+ and Al^{3+} ions in the soil solution. One way to address acidic soil is to apply lime as needed. Lime can increase soil pH due to its neutralizing properties. This is consistent with research by Febriani *et al.* (2024), which showed that lime application increased soil pH from 5.37 to 6.5.

In oil palm plantations, efforts to improve soil pH have been made by applying wood ash. Wood ash, the residue from burning wood, functions as an ameliorant or soil conditioner. Farmers applied wood ash in the hope of increasing the pH of acidic soil to a neutral pH. However, analysis results showed that wood ash application was not optimal in increasing soil pH. This aligns with research by Rozi and Kusumawati (2023), which found that wood ash application did not increase soil pH but instead lowered it from 6.85 to 5.10.

Soil acidity (pH) is crucial because it determines the availability of nutrients needed by plants, influences plant productivity, and can be used as a basis for determining fertilizer types and dosages (Siswanto, 2018). According to oil palm growing requirements, the optimal pH for oil palms is 5.0–6.5 (slightly acidic) (Djaenudin 2011).

Organic C

The organic C content in areca nut plantations is 1.31%, higher than that in oil palm plantations (1.0%) and rubber plantations (1.1%). Organic C content is determined by the presence of leaf debris or other plant debris around the plantation. Areca nut plantations have denser ground cover, resulting in higher accumulation of organic matter on the soil surface compared to oil palm and rubber plantations.

e-ISSN 2621-4113
p-ISSN 2615-8353

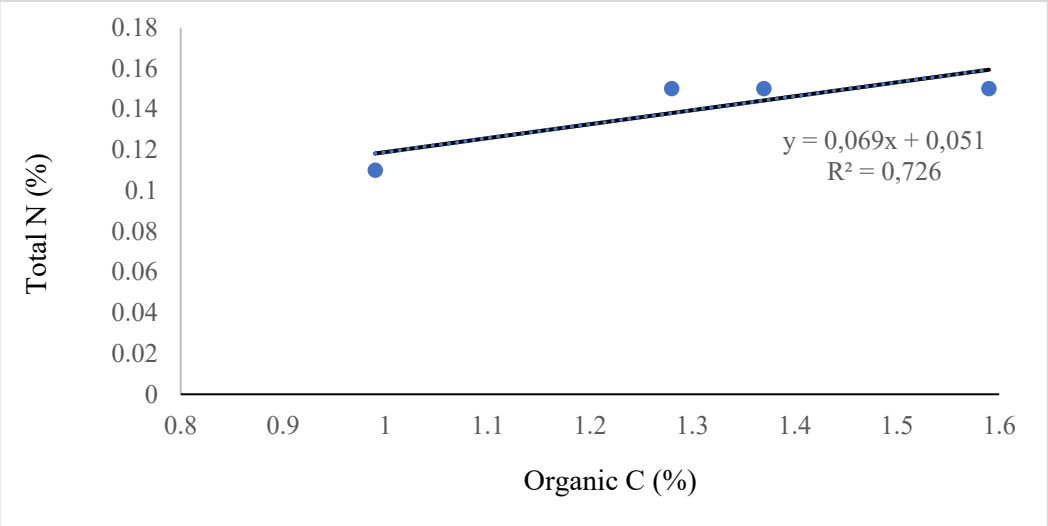

Figure 5. Relationship between organic C and total N in the areca nut plantations

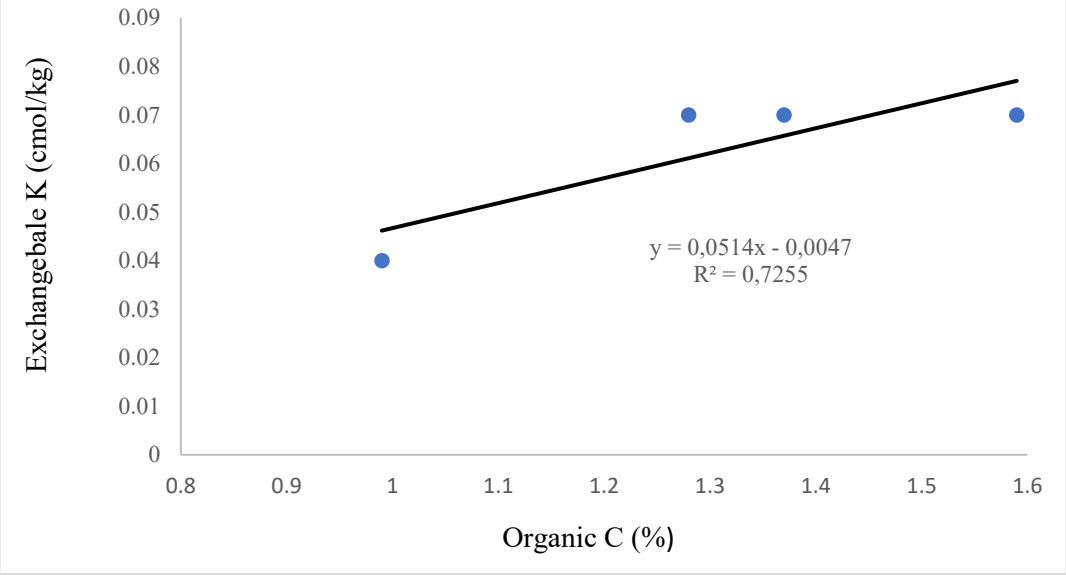

Figure 6. Relationship between organic C and total N in the areca nut plantations

This increase in organic C content is accompanied by an increase in total N and exchangeable K content in the soil in areca nut plantations (Figures 5 and 6). This is in accordance with Hermansah *et al.* (2017) where the increasing soil organic C increases total N and K exchangeable in the soil and also the soil cation exchange capacity. Organic C is an indicator of soil fertility, playing a role in improving the chemical, physical, and biological properties of the soil. Anti et al., (2023) stated that land use influences the amount of organic C content in the soil. In general, vegetation under different land uses will affect the physical, chemical, and biological properties of the soil. High organic C values in areca nut plantations can occur due to dense vegetation, such as shrubs. This vegetation density occurs due to a lack of plantation maintenance, such as weed removal. This makes shrubs

e-ISSN 2621-4113
p-ISSN 2615-8353

a significant contributor of organic biomass to the soil. This aligns with research by Iswanto *et al.* (2023), which showed that shrubs have a higher organic carbon content than other land uses.

Total N

Nitrogen is an essential nutrient required by plants in large quantities for growth, leaf and stem development, and productivity. The total N content in the three land use types at the study site was considered low. The highest total N content was found in the areca nut plantation at 0.14%. The lowest total N content was found in the oil palm plantation at 0.10%. The other land use type was the rubber plantation at 0.12%.

The high total N content in the areca nut land use type is due to the high organic matter content in this land use type. This is in line with research by Bakri *et al.* (2016), which states that the higher the organic matter content in the soil, the higher the nitrogen content. Meanwhile, the low total N content in oil palm plantations is due to inadequate maintenance and fertilization by farmers. Increasing age of oil palms is also a factor in the low total N content due to increased nutrient absorption capacity and higher nutrient demand. This is consistent with research by Sihaloho *et al.* (2024), which showed that the total nitrogen content of oil palms decreases with increasing plant age. The total nitrogen content of 8-year-old oil palms is 0.08%, while that of 25-year-old oil palms is 0.04%.

Low soil nitrogen content results from nitrogen loss through plant uptake, evaporation, or leaching. Nitrogen loss due to leaching often occurs in soils with low organic matter content (Syahputera *et al.* 2024). Leaching of nitrogen from the root zone limits its availability to plants, negatively impacting plant growth and productivity. Furthermore, the lack of optimal fertilization and nitrogen uptake by plants, especially at harvest, results in low soil nitrogen content. Maintaining nitrogen balance in the soil can be achieved by adding inorganic fertilizers such as urea (Hartono *et al.* 2021).

Vegetation in all three land use types also affects the availability of N in the soil. Vegetation in areca nut plantations tends to be denser and more diverse than in rubber and oil palm plantations, resulting in increased vegetation biomass. This vegetation density directly contributes to increased nitrogen content in the soil, because the greater the biomass, the more organic matter is returned to the soil through leaf litter, twigs, and root remains. This is in line with research by Iswanto *et al.* (2023), which shows that land with shrub vegetation has a higher total N content compared to other types of land.

Available P

Based on the soil chemical properties assessment criteria (PPT 1983), the available P content in all three land uses was relatively low, ranging from 1.04 ppm to 2.71 ppm. The highest value (2.71 ppm) was found in oil palm plantations, while the lowest value (1.04 ppm) was found in areca nut plantations. The available P value in other land use types was 2.45 ppm in rubber plantations. The available P content in oil palm plantations was significantly different and higher than in rubber and areca nut plantations. The increase

e-ISSN 2621-4113
p-ISSN 2615-8353

in available P content in oil palm plantations was due to the addition of P fertilizers such as TSP and rock phosphate (Aprilia 2020).

Phosphorus (P) is an essential macronutrient, in addition to N, required by oil palm plants (Manurung *et al.* 2022). P plays a role in stimulating root growth and root system formation, as well as stimulating plant generative growth. Loss of P in the soil can affect plant growth. Lack of attention to optimal fertilization, especially during planting, also affects soil P availability.

Low available P content in areca nut plantations can be caused by plant entrapment, especially during harvest. Higher yields mean more nutrients are absorbed by plants (Wibawa *et al.* 2012). This condition results in low available P content in the soil. Furthermore, limited fertilization in Muhajirin Village also contributes to low available nutrient content in the soil. To address low soil P content, optimal fertilization can be achieved by applying inorganic fertilizers such as TSP or SP-36 (Tando 2018).

Exchangeable K

Exchangeable potassium refers to the portion of potassium in the soil that is loosely held on the surface of clay minerals and organic matter. Because it is weakly bound by electrostatic forces, it can be easily exchanged with other cations and is readily available for plant uptake. Exchangeable K is typically more readily absorbed by plants than Ca and Mg, therefore, dolomite application is recommended when fertilizing (Wirayuda *et al.* 2023). The exchangeable K values in oil palm and rubber plantations were not significantly different (Table 1). Conversely, areca nut plantations showed higher exchangeable K values (0.06 cmol/kg). This indicates that the exchangeable K values in areca nut plantations were significantly different from those in rubber and oil palm plantations.

The low exchangeable K in the soil at the study site could be caused by several factors. One factor is potassium leaching due to high rainfall, which is also common in tropical climates, causing potassium to be easily lost from the root zone (Muhlisin et al., 2022). Low exchangeable K availability in the soil can also be caused by acidic soil pH. Acidic soils cause potassium leaching, thereby reducing soil K availability. This is consistent with research by Sahrul *et al.* (2022) that found that oil palm plantations with a depth of 0-30 cm and an acidic soil pH (4.99) had a very low exchangeable K content of 0.29 mg/100 g. This is due to the high rainfall in that location. Low exchangeable K content in the soil can also be caused by plant uptake. Sihaloho *et al.* (2024) stated that potassium levels in oil palm leaf tissue are significantly influenced by the amount of potassium absorbed by the roots from the soil and transported to the leaves. K plays a role in assisting photosynthesis and also helps strengthen the oil palm fronds and leaves.

CONCLUSIONS

The three land use types showed relatively similar soil pH values, however, differences were found in organic carbon, total nitrogen, available phosphorus, and

exchangeable potassium. Areca nut plantation had higher organic carbon, total nitrogen, and exchangeable potassium contents than oil palm and rubber plantations, while oil palm plantations had the highest available phosphorus content.

ACKNOWLEDGMENTS

Thanks are expressed to the head of Muhajirin Village who gave permission to conduct research in Muhajirin Village.

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