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Analysis of C-Organic, Nitrogen, and C/N Ratio Contents in Oil Palm Plantations Soil Owned by the People of Pulau Binjai Village, Kuantan Mudik District, Kuantan Singingi Regency, Riau Province

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Abstract

Land conversion from rubber plantations to oil palm plantations is increasingly common in Indonesia, including in Pulau Binjai Village, Kuantan Mudik District, Kuantan Singingi Regency, Riau Province. Land preparation for oil palm plantations can affect soil fertility, particularly nutrient content. This study aims to evaluate the nutrient content in one-year-old oil palm plantations. The methods used in this study included surveys and laboratory analyses. Soil sampling was conducted at 10 locations using purposive random sampling at a depth of 20 cm, with 5 locations sampled using the grid method and 5 using the disc method. Each sample location consisted of 5 subsamples, which were then composited. The results showed that the soil pH in the grid ranged from 5.96 to 6.48 (acidic category), while in the disc it ranged from 6.2 to 6.88 (acidic to neutral category). The organic carbon content in the grid ranged from 2.61 to 3.74 (medium to high category), and in the plate from 2.82 to 4.28 (medium to high category). The total nitrogen content in the grid ranged from 0.20 to 0.25 (low to medium category), while in the plate it ranged from 0.21 to 0.29 (medium category). The C/N ratio in the grid ranged from 11.16 to 17.00 (medium to high category), and in the plate from 10.44 to 14.75 (low to medium category). The key findings of this research include the identification of organic carbon and nitrogen content in the soil, which enables recommendations for the application of organic and nitrogen fertilizers in the study area.

Keywords: Analysis, Chemistry, Palm Oil, Public, Soil

1. Introduction

The oil palm (*Elaeis guineensis* Jacq.) is a plantation commodity that significantly influences the Indonesian economy (Gurusinga et al.,2023). According to Gusriati et al. (2023), land conversion from rubber plantations to oil palm plantations has been observed. This phenomenon also occurs in Pulau Binjai Village, Kuantan Mudik District, Kuantan Regency, Riau Province (Angela et al., 2025). This shift is attributed to the fact that income from oil palm plantations is more stable and guaranteed than that from rubber plantations.

The clearing of smallholder oil palm plantations is conducted using both heavy equipment (excavators) and manual methods (Anggliani, 2021). This process impacts the surface layer of the plantation soil (topsoil). When heavy equipment is used, the topsoil layer is often lost, whereas clearing without heavy equipment helps preserve the topsoil. In manual clearing, rubber trees are cut down using chainsaws, and the plant material decomposes naturally, preventing the removal of the topsoil layer.

The growth and productivity of oil palm plants are influenced by environmental factors such as climate and soil. Climate conditions are among the primary environmental factors affecting the success of oil palm cultivation. Over the long term, climate impacts soil fertility, including its chemical, physical, and biological

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properties. According to Hadi et al. (2023), changes in these soil properties occur as oil palm plantations mature. These physical changes include a decrease in clay content, a reduction in organic matter, a decline in the aggregate stability index, an increase in soil bulk density, and greater permeability

Fertilization of oil palm plantations should be conducted after assessing the soil's nutrient content and chemical properties. The chemical characteristics of the soil in smallholder oil palm plantations can be determined through soil chemical analysis. Land clearing without heavy equipment can result in high organic matter content, as decomposing rubber plants contribute to this increase. However, nitrogen levels tend to be low because the decomposition of felled rubber plants causes nitrogen to volatilize into the atmosphere. This process leads to an imbalance in the soil's carbon-to-nitrogen (C/N) ratio in smallholder oil palm plantations.

Conducting organic C analysis, nitrogen content, and C/N ratio is urgent because it is crucial to determine and improve soil fertility physically, chemically, and biologically. The correct organic carbon and nitrogen content, as well as a balanced C/N ratio, are crucial for providing plant nutrients, maintaining soil microbial health, and improving soil structure and water-holding capacity.

A high C/N ratio can lead to decreased soil fertility due to reduced nitrogen availability for plants and inhibited beneficial microorganism activity. Previous research by Nopsagiarti et al.(2025) showed that the soil in the oil palm plantation area of Logas Village, Singingi District, Kuantan Singingi Regency, Riau Province has a pH of 6.05-6.55 with acidic to slightly acidic criteria, organic C content of 0.56 % -1.16 % (very low to low), total content Nitrogen 0.05 % -0.11 % (very low to low), as well as a C/N ratio with low to medium criteria.

Logas Village generally has rocky PMK soil due to former gold mining activities. This study differs from previous research in terms of soil type and land clearing methods. The soil type examined in this study was PMK, with land clearing conducted without the use of heavy equipment. Consequently, the organic carbon content, nitrogen content, and C/N ratio varied. The purpose of this study was to determine the organic carbon content, total nitrogen content, and C/N ratio in smallholder oil palm plantations.

2. Material and Methods

This research was conducted in Pulau Binjai Village (Figure 1), Kuantan Mudik District, Kuantan Singingi Regency, Riau Province, with coordinates -0.63951, 101.45843, and an altitude of 78 meters above sea level. Soil samples were then analyzed at the Central Plantation Services Laboratory of PT. Central Alam Resources Lestari. The research period was 4 months, from March to June 2025.

This research was conducted using survey methods and laboratory analysis. Soil samples were collected using purposive random sampling techniques using a Belgian drill (see Figure 2) at a depth of 20 cm.

Figure 1. Research Location

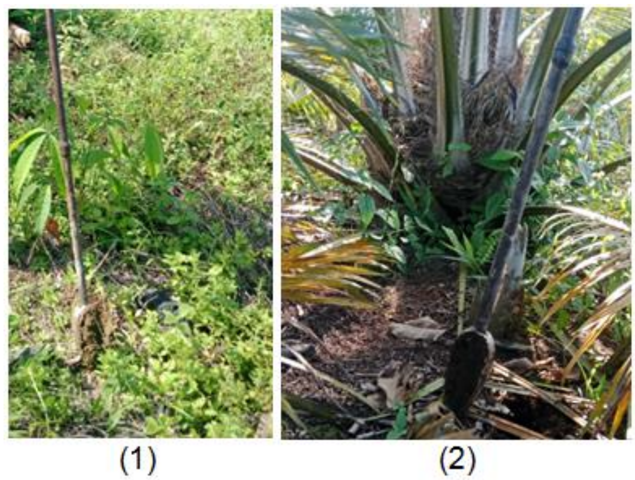


Figure 2. Soil sampling process: 1) Goblets, 2) Plates.

Soil samples were taken at 10 points, five on the grid and five on the plate. Each sample point consisted of 5 sub-samples, which were then composited. A 500-gram soil sample was taken at each point. The flow diagram in this study can be seen in Figure 3.

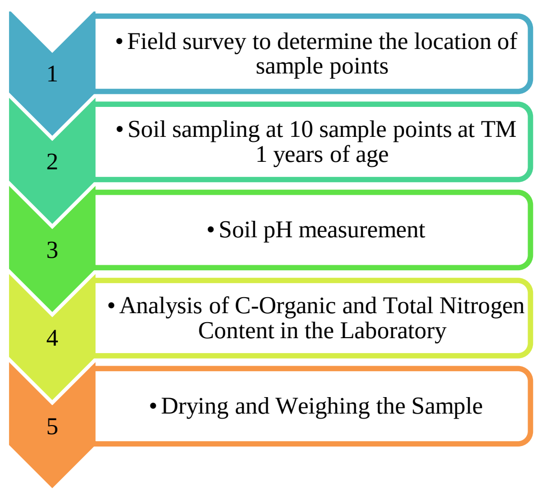


Figure 3. Research flow diagram.

The soil samples are then placed in bags labeled according to the sampling point or location. The soil is then air-dried (Figure 4) and sieved, ready for preparation and analysis in the laboratory.

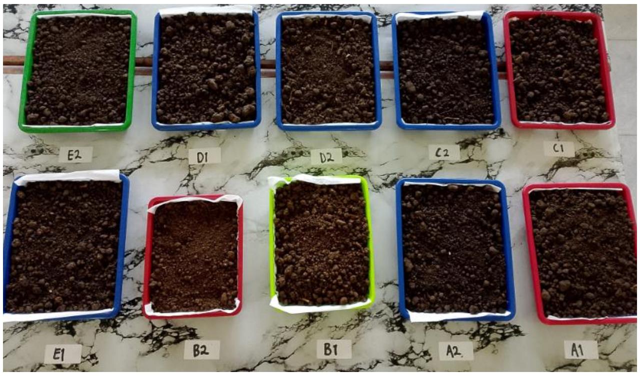
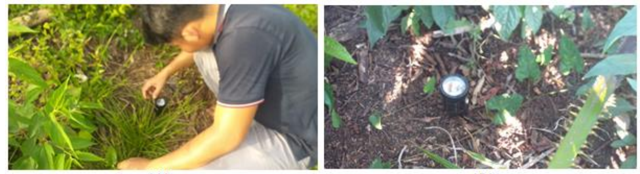


Figure 4. Drying of soil samples.

Next, the soil samples were analyzed in the laboratory to measure the soil pH content using a pH meter (Figure 5). The C-Organic content was measured using the Walkey and Black method, total nitrogen was determined using the wet digestion method (Kjeldahl), and the C/N value was calculated based on the comparison ratio. The range limits for pH, C-Organic, total nitrogen, and C/N values refer to the Soil Research Center (1983).

The data from the soil pH value measurements are then assessed for the level of soil acidity based on the limits of the range of soil pH values, as referred to by the Soil Research Center in 1983. The limits of the range of pH values can be seen in Table 1.



(1) (2)

Figure 5. Soil pH measurement process, 1) Gawangan, 2) Disc.

Table 1. pH Value Range Limits.

No	Ph Value	Category
1	< 4.4	Very Acidic (Extreme)
2	4.5–5.0	Very Acidic
3	5.1–6.5	Acidic
4	6.6–7.3	Neutral
5	7.4–8.4	Alkaline
6	8.8–9.0	Very Alkaline
7	> 9.1	Very Alkaline (Extreme)

Furthermore, the research data on C-Organic content, total nitrogen, and C/N values are grouped into low and high categories, referring to the Soil Research Center in 1983. The categories for C-Organic content, total nitrogen, and C/N values can be seen in Table 2.

Table 2. Categories of organic C content, total nitrogen, and C/N value (%).

Soil Properties	Very Low	Low	Currently	Tall	Very high
C-Organic	< 1	1–2	2–3	3–5	> 5
N-Total	< 0.1	0.1-0.2	0.21-0.5	0.51-0.75	> 0.75
C/N	< 5	5-10	11–15	16–25	> 25

Source: Soil Research Center (1983).

3. Results and Discussion

3.1. Soil Reaction (pH)

Based on the analysis, the soil pH values in community-owned oil palm plantations in Pulau Binjai Village range from 5.96 to 6.88. The pH value graph is shown in Figure 6. The study results showed that the soil pH in the oil palm plantation area ranged from 5.96 to 6.48, classifying it as acidic soil.

This yield occurs because weathering takes place at the gate, and the decomposition of organic material from rubber trees felled with chainsaws causes the pH to become acidic.(Wasir et al., 2022) The accumulation of organic matter causes the soil pH to become acidic. (Nopsagiarti et al., 2020) Several factors, including the parent material, organic matter content, aluminum hydrolysis, oxidation reactions to certain minerals, and alkaline leaching, can influence soil acidity.

Meanwhile, the soil pH on the plates ranged from 6.2 to 6.88, categorized as acidic to neutral. This result was due to the dolomite application history, which indicated that the plates had been given 100 grams of dolomite per plant. This yield resulted in a neutral pH in some of the samples.

Adding dolomite to the soil can help increase soil pH. (Basuki & Sari, 2019) The use of dolomite has a significant effect on increasing soil pH. (Kurniasih et al.,2019) Dolomite contains a lot of Ca, which can increase the pH status of the soil.

Putra and Jalil (2018) argue that high levels of organic matter in the soil can cause the soil pH to become low or acidic. (Greetings, 2020) The decomposition process of organic material produces organic acids that release hydrogen ions (H+), which ultimately lowers the soil pH.

Research by Rozi dan Prastia (2019) was conducted in Rantau Keloyang Village, Pelepat District, Bungo Regency, Jambi Province. The application of dolomite lime at a dose of 1.0 kg/tree showed the best results for the production of TM 15 oil palm plants, namely 22.49 kg per bunch.

Research by Nopsagiarti et al. (2025) indicates that the soil pH of oil palm plantations in Logas Village is acidic to slightly acidic. The results of the soil pH analysis show a pH value of 6.05-6.55. The results of the soil pH analysis on oil palm plantations aged 3.5 and 7 years in Logas Village ranged from 6.05 to 6.55 with moderate criteria. The lowest soil pH was found in the 5-year-old plantation (6.05) and the highest in the 7-year-old plantation (6.55).

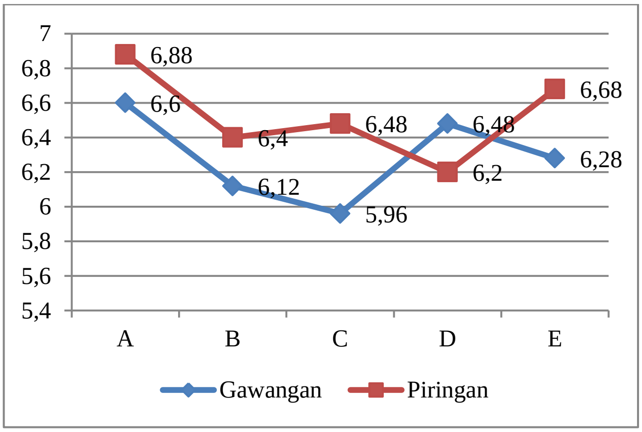


Figure 6. Results of pH Value Analysis.

3.2. Organic C Content (%)

Organic carbon refers to the carbon content in soil organic matter, reflecting the presence of organic matter in the soil. Laboratory analysis results indicate that soil organic matter content ranges from 2.61% to 4.28%. The results of the soil organic carbon analysis can be seen in Figure 7.

The research results showed that the organic carbon content in the grates ranged from 2.61% to 3.74%, categorized as moderate to high. Meanwhile, the discs ranged from 2.82% to 4.28%, categorized as moderate to high.

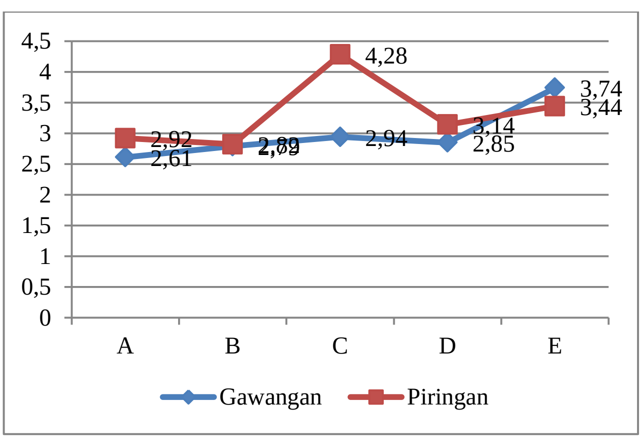


Figure 7. Results of the analysis of soil organic carbon content

This result is because the process of clearing land for oil palm plantations uses chainsaws (not heavy equipment), allowing the remaining rubber tree trunks, branches, and leaves to decompose naturally. This decomposition process provides organic carbon to the soil.

Nopsagiarti et al. (2025) say that the land clearing process affects soil organic carbon. Khusrizal et al. (2022) stated that organic materials, such as plant remains, contain carbon. Siringoringo (2014) found that when this organic material is decomposed by microorganisms (bacteria and fungi), carbon is released, and some is bound in the soil as organic carbon. Ziliwu and Lase (2025) found that microorganisms decompose organic matter, producing carbon as one of their products.

According to Sari et al. (2017), the average overall soil density at a depth of 0-30 cm ranged from 0.77-0.98 g/cm3. The results of the diversity analysis revealed a significant difference in soil density based on soil depth ($p>0.05$). Soil density was lower in the 0-5 cm soil layer and higher in the 20-30 cm soil layer. Soil density was not significantly different in the 5-10 cm and 10-20 cm soil layers, but was significantly different between the 0-5 cm and 20-30 cm layers. The results of the analysis of the diversity of soil organic carbon content based on depth showed a significant difference ($p<0.05$). The highest organic carbon content was found at a soil depth of 0-5 cm, while the lowest soil organic carbon content was found in the 20-30 cm layer. This result was caused by the accumulation of organic matter resulting from litter decomposition, which tended to be high in the topsoil layer, so that soil organic carbon in the 0-5 cm soil layer tended to be higher.

Research (Nopsagiarti et al., 2025). The results of the soil organic C analysis showed differences in organic C content between 3.5 and 7-year-old plantations. The highest amount of organic C was found in the 3-year-old plantation, namely 1.16%, and the lowest was in the 5-year-old oil palm land (0.56%). These results are included in the low and very low criteria.

3.3. Total Nitrogen (%)

Nitrogen is an essential element required by plants in large quantities. Soil nitrogen content varies widely and is influenced by various factors, such as climate, vegetation, topography, and the physical and chemical properties of the soil. Based on the analysis, the total soil N content ranged from 0.20% to 0.29%. The results of the total N content analysis can be seen in Figure 8.

Based on Figure 8, the total N content in the trellis falls within a low to medium category, ranging from 0.20 to 0.25, whereas the disc's content ranges from 0.21 to 0.29, categorized as medium. This result is due to the Nitrogen trellis, located in the oil palm trellis, which derives its nitrogen source from the decay of rubber plants, resulting in low nitrogen availability.

According to Hakim and Hermansyah (2025), nitrogen loss through evaporation can reach 70%, depending on the soil's cation exchange capacity (CEC). Permatasari et al.

(2019) stated that the high nitrogen loss resulted in only 10% being absorbed by plants. Gulo et al. (2024) added that nitrogen deficiency in plants can result in slow, weak, and stunted growth.

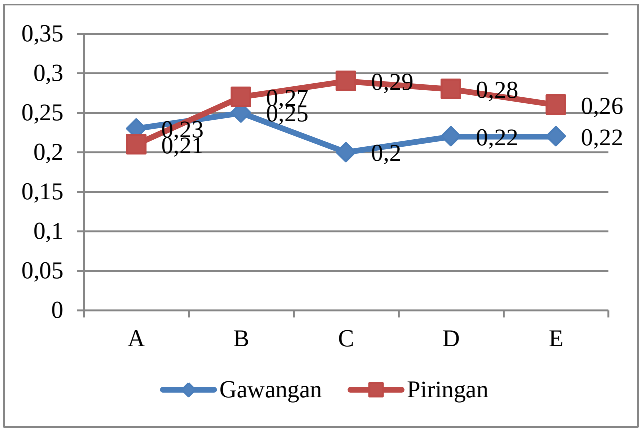


Figure 8. Results of the analysis of total N content

In oil palm plantations, nitrogen was applied by applying 300 grams of Mutiara 16:16:16 NPK fertilizer per plant in February 2025, resulting in moderate nitrogen availability. Putra et al. (2022) explained that nitrogen availability in the soil is influenced by fertilization. Hamid (2019) stated that Mutiara NPK fertilizer can provide nitrogen for the soil.

Purba et al. (2021) emphasized that nitrogen is an essential nutrient that is necessary for plant growth. Haq et al. (2024) also stated that nitrogen is needed in large quantities for plant growth. Lumbanraja et al. (2019) explain that in a reduced state, nitrogen is absorbed by plants in the form of ammonium (NH4^+), while in an oxidized state, nitrogen is absorbed in the form of nitrate (NO3^-).

Sari and Prayudyaningsih (2015) state that the source of nitrogen required by plants generally comes from N2 gas in the atmosphere, which plants can utilize through the fixation process. Zega and Lase (2025) add that nitrogen can also come from biological fixation between certain plants and bacterial symbiosis, or through the industrial process of nitrogen fertilizer.

Previous research by Nopsagiarti et al. (2025) indicates that in the oil palm plantations of Logas Village, the total N content in oil palms aged 5 and 7 years falls below the very low criteria, whereas in the land aged 3 years, it falls below the low criteria.

3.4. C/N Ratio

Based on the analysis, the C/N ratio of community-owned oil palm plantations in Pulau Binjai Village ranged from 10.44 to 17.00. A graph of the C/N ratio at the research site can be seen in Figure 9.

The research results showed that the C/N ratio in the manure ranged from 11.16 to 17.00, categorized as moderate to high. This result is because the decomposition process provides relatively high carbon availability, while nitrogen availability is limited because some of the nitrogen has evaporated. (Kurniawan et al., 2021) If carbon availability is excessive (the C/N ratio is too high) and nitrogen is limited, this will be a limiting factor for microbial growth. Meanwhile, on the disc, the carbon content ranges from 10.44 to 14.75, categorized as low to moderate. This result is because soil microorganisms have utilized some of the carbon. However, lower carbon levels in the soil will affect the activity of soil microorganisms. Meanwhile, the high nitrogen content in the soil is due to fertilization activities on the disc.

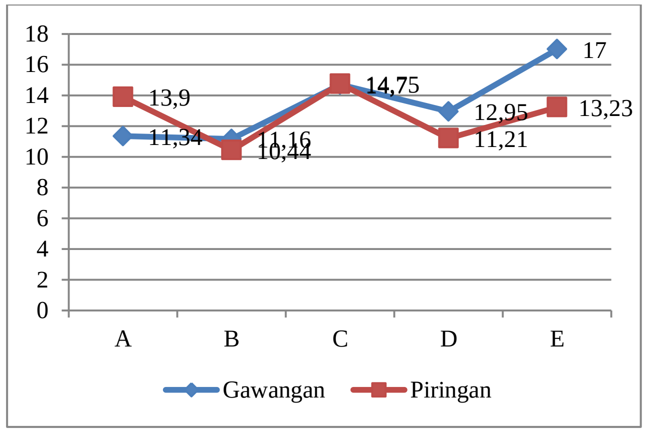


Figure 9. Results of soil C/N analysis

According to Pratama et al. (2019), if carbon availability is limited (the C/N ratio is too low), then there are not enough compounds that can be used as an energy source by microorganisms to bind all free nitrogen. Isiqomah et al. (2018) explained that free nitrogen will be released in the form of NH3 gas. They add that the availability of nitrogen in the soil can be increased by providing fertilizer containing nitrogen.

Previous research, Nopsagiarti et al. (2025), on oil palm plantation land in the village of Me reported moderate C/N ratio values. The C/N ratio was 10.55 at 3 years of age, 11.20 at 5 years, and 12.56 at 7 years.

4. Conclusion

The results of the study showed that the soil pH in the plank ranged from 5.96 to 6.48 (acidic), while in the plate it ranged from 6.2 to 6.88 (acidic to neutral). The organic carbon content in the plank was 2.61% to 3.74% (moderate to high), compared to 2.82% to 4.28% (moderate to high) in the plate. Total nitrogen content in the plank ranged from 0.20% to 0.25% (low to moderate), whereas in the plate it ranged from 0.21% to 0.29% (moderate). The C/N ratio in the plank was 11.16 to 17.00 (moderate to high), while in the plate it was 10.44 to 14.75 (low to moderate). This study's advantage lies in providing valuable information on soil properties in one-year-old TM oil palm plantations, which can guide users in making informed decisions regarding future fertilization.

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