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# The Influence of Soil Chemical Properties on Palm Oil Production (*Elaeis guineensis* Jacq) on Dry Acid Mineral Soil in Rokan Hulu Regency

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**Abstract**

Oil palm (*Elaeis guineensis* Jacq.) is one of Indonesia's leading commodities, significantly contributing to the national GDP, foreign exchange earnings, and tax revenues. As the world's largest producer and exporter of crude palm oil (CPO), Indonesia's palm oil industry plays a strategic role in maintaining economic stability and global competitiveness. Oil palm productivity is influenced by various factors, including soil chemical properties, particularly in mineral soils with varying fertility levels. This study aims to analyze the effect of soil chemical properties on oil palm fresh fruit bunch (FFB) production in Rokan Hulu Regency, Riau Province. The parameters analyzed include soil pH, organic matter content, cation exchange capacity (CEC), base saturation (BS), and macronutrient availability (nitrogen, phosphorus, potassium). The research methodology involves secondary data collection from plantation companies, multiple linear regression analysis, and Duncan's test to determine the effect of each soil parameter on oil palm production. The results indicate that soil chemical properties, including pH, CEC, BS, nitrogen, phosphorus, and potassium, significantly affect oil palm productivity. Optimal production was observed in soils with a pH of 4.9-6.5, high CEC (>3.8 cmol(+)/kg), and base saturation above 16.3%. The low nutrient content at the study site highlights the need for soil fertility management through liming and organic fertilizers. The study outputs include soil chemical property maps, soil-parameter-based models for predicting oil palm production, and recommendations for mineral soil management to optimize production.

**Keywords:** Base Saturation, Cation Exchange Capacity, Fresh Fruit Bunch Productivity, Soil Macronutrients, Soil Reaction (pH)

## 1. Introduction

Oil palm (*Elaeis guineensis* Jacq) is one of Indonesia's leading commodities, significantly contributing to the national GDP, foreign exchange earnings, and tax revenue. Over the past twenty years, oil palm has become a major national export commodity and is expected to substantially increase the income of oil palm plantation farmers and transmigrant communities in Indonesia (Wicaksono et al., 2023). Palm oil is widely used in the food, cosmetics, and biofuel industries. Since its introduction to Indonesia in 1848, oil palm cultivation has expanded rapidly across Southeast Asia, making it a major global producer. However, national productivity remains low, particularly on smallholder plantations, due to environmental factors, seed quality, and suboptimal cultivation management.

Palm oil productivity in Indonesia fluctuated from 1995 to 2024, with an average annual growth rate of only 0.44%. The monetary crisis contributed to the decline, with the lowest productivity recorded in 2004 at 2.83 tons per hectare and the highest in 2019 at 3.97 tons per hectare (Pusdatin, 2016). Riau Province, particularly Rokan Hulu Regency, is a key center for oil palm production, where soil chemistry significantly influences nutrient availability and, consequently, plant growth.

Mineral soils in Rokan Hulu have specific characteristics that influence fertility. Factors such as pH, organic matter content, macro- and micronutrient availability, and cation exchange capacity (CEC) influence productivity. High soil acidity is a major challenge because it can reduce the availability of essential nutrients such as

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phosphorus, calcium, and magnesium while increasing toxic levels of aluminium and iron. Therefore, pH management through lime and organic matter is essential.

In addition to pH, organic matter content significantly influences soil chemical properties. Mineral soils are generally poor in organic matter, thus having limited nutrient availability. Improvements can be achieved through organic fertilizers, soil conservation, and soil analysis-based fertilization to address macronutrient deficiencies, including nitrogen, phosphorus, and potassium. Nutrient balance is also crucial, as a deficiency or excess of one element can affect the uptake of others.

Soil microorganisms play a role in supporting fertility by decomposing organic matter and providing nutrients. This activity can be enhanced through biological approaches, such as the use of biofertilizers or the inoculation of beneficial microbes. By understanding soil chemistry, land management strategies can be directed toward appropriate fertilization, increased organic matter, and soil pH control. These steps formed the basis for the study entitled *"The Effect of Soil Chemical Properties on Oil Palm (Elaeis guineensis Jacq) Production on Mineral Soil in Rokan Hulu Regency, Riau."*

The results of research (SAHRUL et al., 2022) that oil palm requires the application of good cultivation techniques, especially balanced fertilization, and grows optimally in loose, fertile, well-drained soil with a pH of 4–6.5 and a solum >80 cm, are in line with the results of this study. This study shows that the highest fresh fruit bunch (FFB) production is obtained in land suitability class S1, characterized by a soil pH of 4.9–6.5, higher cation exchange capacity and base saturation, and better availability of macronutrients. Thus, the results of this study strengthen previous findings that the level of land suitability, as determined by actual and potential limiting factors, plays an important role in supporting oil palm productivity.

The land suitability classification for oil palm plantations will then be analyzed. The analysis will be conducted using a matching method that accounts for limiting factors based on existing parameters. The land suitability classification for oil palm plantations is as follows: 1. S1 (Highly Suitable): Land units that have no more than one light limitation (optimal). 2. S2 (Suitable): Land units that have more than one light limitation and/or no more than one moderate limitation. 3. S3 (Somewhat Suitable): Land units that have more than one moderate limitation and/or no more than one severe limitation.

**Table 1.** oil palm land suitability criteria

| Land Characteristics | S1 (Highly Appropriate) | S2 (Appropriate) | S3 (Somewhat Appropriate) | N (Not Appropriate) |
|---|---|---|---|---|
| Elevation (masl) | < 149 | < 149 | - | - |
| Rainfall (mm) | 1,371–1,971 | 1,031–1,371 / 1,971–2,836 | < 1,031 / > 2,836 | - |
| Dry month | 1 | 2–4 | > 4 | - |
| Wet month | 6 | 5 | < 5 | - |
| Drainage | 1 | 1–2 | 2 | > 2 |
| Sand (%) | 37.4–75 | 27.9–37.4 / 75–84.7 | < 27.9 / > 84.7 | - |
| Clay (%) | 11.8–36.8 | 7.4–11.8 / 36.8–45.3 | < 7.4 / > 45.3 | - |
| Texture | Sandy loam, clay | Dusty clay, dusty clay | Sandy clay, dusty clay | Dust, clay sand |
| Effective depth (cm) | 82.3–110.9 | 71.9–82.3 | < 71.9 | - |
| CEC (cmol(+)/kg) | > 3.8 | < 3.8 | - | - |
| pH | 4.9–6.5 | 4.3–4.9 / 6.5–6.9 | < 4.3 / > 6.9 | - |
| C-organic (%) | > 1.1 | 0.6–1.1 | < 0.6 | - |
| Base saturation (%) | > 16.3 | 9.3–16.3 | < 9.3 | - |
| Al Saturation (%) | < 39.4 | 39.4–65.1 | > 65.1 | - |
| N-total (%) | > 0.06 | - | - | - |
| P-available (ppm) | > 16.8 | 2.8–16.8 | < 2.8 | - |
| K-dd (cmol(+)/kg) | > 0.1 | 0.02–0.1 | < 0.02 | - |
| Slope gradient (%) | < 11.6 | > 11.6 | - | - |

Source: Development of land suitability criteria for oil palm (*Elaeis guineensis* Jacq.) at PT Perkebunan Nusantara-lll, North Sumatra

This study aimed to systematically examine the influence of soil chemical properties on oil palm (*Elaeis guineensis* Jacq.) production in Rokan Hulu Regency, by analyzing the role of soil pH, cation exchange capacity (CEC), base saturation (KB), and macronutrient content including nitrogen (N), phosphorus (P), and potassium (K) on fresh fruit bunch (FFB) production. In addition, this study aims to identify the soil chemical properties parameters that most influence oil palm productivity, analyze the relationship between soil chemical characteristics and production levels, classify oil palm land suitability based on limiting factors into classes S1, S2, and S3, and formulate applicable soil fertility management recommendations to support the increase and sustainability of oil palm production in a location-specific manner.

## 2. Material and Methods

Method was conducted at a plantation location in Riau Province in Rokan Hulu Regency, 0°15' - 1°30' North Latitude and 100° - 101°52' East Longitude, with an altitude of 70 to 86 meters above sea level (MDPL). The research was conducted by analyzing secondary data, namely historical plant and environmental data from 2003 to 2012. Modelling, proposal development, data analysis, and discussion were conducted from March to June 2025.

The materials used include production data and soil analysis data. The data are secondary, obtained from PT. Perkebunan Nusantara IV Regional III Kebun, Rokan Hulu Regency, Riau. Data processing using a *personal computer* equipped with *Microsoft Word, Microsoft Excel, and RStudio.*

Identify the chemical properties of soil most closely related to oil palm production, and look for mathematical relationships between soil chemical properties and crop production variables. Initially, there were 8 soil properties, namely total N, available P, available K, KB, CEC, and pH. These variables were then analysis of variance test.

Based on the oil palm land suitability class, if there are only two comparisons, the analysis of variance uses a t-test. In analysis of variance, the t-test is used to compare two treatment averages to determine which group differs significantly after ANOVA indicates a treatment effect. The purpose of this comparison is to determine whether there is a significant difference between the group means or whether random variables can explain the difference. If there are more than 2 comparisons of oil palm land suitability classes, the last observation data from each treatment is analyzed statistically. If the calculated F is greater than the F table, then Duncan's Multiple Range Test (DMRT) is continued at the 5% level.

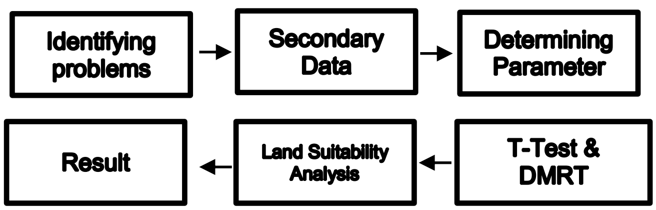


**Figure 1.** Research flow diagram

## 3. Results and Discussion

### 3.1. K-dd

Data from observations of K-dd element levels in oil palm (*Elaeis guineensis* Jacq.) production on mineral soil in Rokan Hulu Regency, after analysis using the T test, showed a significant effect on oil palm production in Rokan Hulu Regency. The average results of observations of K-dd element levels in oil palm production after the T test are shown in Figure 1.

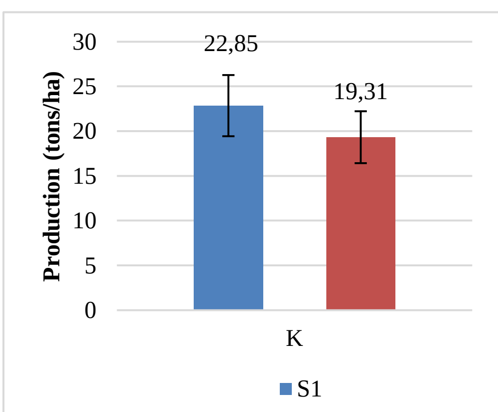


**Figure 1.** K-dd available to palm oil production (ton/ha)

Based on Figure 1, the analysis of exchangeable potassium (K-dd) content shows that this element significantly influences the productivity of oil palm fresh fruit bunches (FFB). Based on the land suitability class with land class S1, the K-dd content is in the range <0.1, in land class S2 in the range 0.02-0.1 and in land class S3 in the range 0.02. In the S1 criterion, 22.85 were suitable for oil palm plants, significantly different from the S2 criterion, which was 19.31. The resulting degrees of freedom were 4.96***.

Several factors, including external supplementation, soil fixation, and contributions from external sources, influence potassium availability in soil. Unlike nutrients such as nitrogen (N), sulfur (S), and phosphorus (P), which play a major role in building plant structure, potassium plays a key role in regulating various plant physiological processes. This element functions catalytically in important processes such as photosynthesis, carbohydrate translocation, protein synthesis, and other metabolic activities (Hanafiah, 2005).

The results of this study indicate that K-dd content significantly influences the production of fresh fruit bunches of oil palm, where land suitability classes with higher K-dd values produce significantly greater production than land classes with lower K-dd values. This research aligns with the findings of a previous study (RR Darlita et al., 2017), which reported that potassium is the main limiting nutrient in acid mineral soils and Ultisols due to high leaching losses. However, this study shows that the effect of K-dd on production is more optimal on land with a higher cation exchange capacity (CEC), because the soil can better retain and supply K ions to plants. This strengthens and complements research (Subandi, 2011) that states that limited potassium sources in Ultisols are a major constraint, by emphasizing that, in addition to the availability of K sources, CEC conditions and land suitability also play an important role in determining the effectiveness of potassium fertilization and increasing sustainable oil palm productivity.

In soils with a high CEC, most $K^{+}$ ions are in the form of K-dd, and a small portion is in the form of K-solvent. However, because K-dd and K-solvent are in equilibrium, K-dd rapidly releases K ions into the soil solution. At a high CEC, the supply of K-solvent is well guaranteed, and K loss due to leaching can be minimized. pH also indirectly influences K availability by affecting the dominant cation types in the soil sorption complex and the space between clay mineral layers.

### 3.2. pH

Data from observations of pH levels in oil palm (*Elaeis guineensis* Jacq.) production on mineral soil in Rokan Hulu Regency, after analysis using Duncan, showed that pH levels had a significant effect on oil palm production in Rokan Hulu Regency. The average results of pH observations on oil palm production after further testing by Duncan are shown in Figure 2.

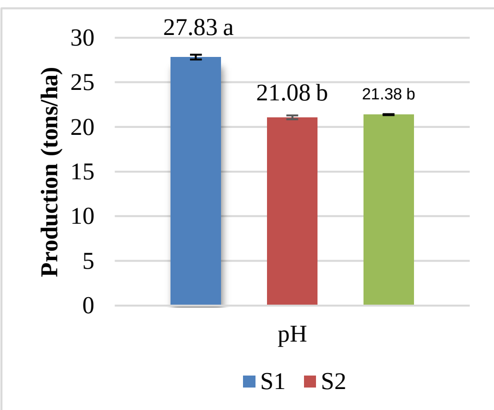


**Figure 2.** pH on palm oil production (tons/ha)

Based on Figure 2, it can be seen that nutrient availability criteria affect oil palm production at pH. Based on the land suitability class with land class S1, the pH level is in the range of 4.9-6.5, in land class S2 in the range of 4.3-4.9 and 6.5-6.9 and in land class S3 in the range of <4.3 and >6.9. In the S1 criteria, there are 27.83, which are suitable for oil palm plants and are significantly different from the S2 criteria (21.08) and S3 (21.38).

Soil acidity is an indicator of soil fertility because it reflects the availability of nutrients in the soil. Soil reaction indicates the acidity or alkalinity of the soil, expressed by the pH value. Soil pH values range from 4.3 to 6.9, with optimal production at 4.9–6.5 (grade S1). Soil that is too acidic (<4.3) results in a decrease in the availability of P, Ca, and Mg due to fixation by Al and Fe. Soil acidity is an important indicator of soil fertility because it affects nutrient availability. Soil reaction reflects the soil's acidic or basic nature (alkalinity) and is measured by pH.

The results of this study indicate that soil pH significantly affects the productivity of oil palm fresh fruit bunches (FFB), with optimal conditions at acidic to slightly acidic pH, in line with the findings of Minasny et al. (2016), who stated that soil pH is a key factor controlling biogeochemical processes and influencing nutrient availability and plant growth. In addition, this study's results support the research of Ayu et al. (2020), who reported that increasing pH through the role of organic matter, especially humic acid, can increase the soil’s negative charge, thereby improving its ability to retain and supply nutrients. Thus, this study strengthens prior findings by empirically demonstrating that proper soil pH management is an important factor in increasing oil palm productivity on mineral soils in Rokan Hulu Regency.

### 3.3. N-total (%)

Observation data on the total N content of oil palm (*Elaeis guineensis* Jacq) production on mineral soil in Rokan Hulu Regency, after analysis using the T-test, showed that the effect was significant. The average results of the T-test for total N content in oil palm production are shown in Figure 3.

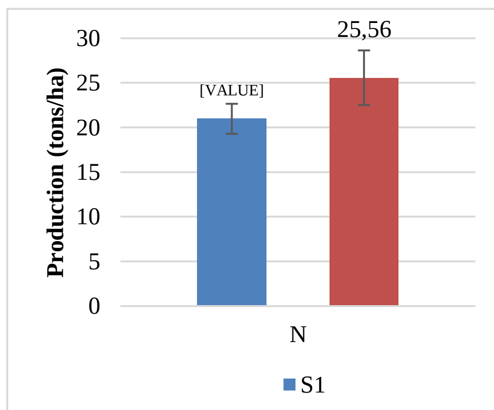


**Figure 3.** Total N to palm oil production (tons/ha)

Based on Figure 3, the nutrient availability criteria affect oil palm production in terms of total N. Based on the suitability class, if a class S1 sample with a total N content >0.06 has a value greater than S1, it is included in category S2. In the S1 criteria, 20.97 are suitable for oil palm plants, and in the S2 criteria, 25.56 are suitable.

The results of this study indicate that total soil N significantly influences the production of fresh fruit bunches (FFB) of oil palm, with production in land suitability class S2 higher than in S1, even though S1 meets more optimal N criteria. This finding is in line with Darlita et al. (2017), which states that excess nitrogen can stimulate excessive vegetative growth, so it does not always increase fruit bunch formation. This condition also supports Hanafiah's (2005) statement that the availability and utilization of nitrogen by plants are influenced by the N source, the mineralization process, and soil conditions, especially pH. In acidic soils, such as those in this study, nitrogen is not always in a form easily absorbed by plants, so absorption efficiency decreases even though total N content is relatively high (Patti, 2013). Thus, the results of this study strengthen previous research that the effect of nitrogen on oil palm production is largely determined by the balance of dosage and its interaction with other soil chemical properties.

### 3.4. P-available (ppm)

Observation data on the levels of available P elements in oil palm (*Elaeis guineensis* Jacq) production on mineral soil in Rokan Hulu Regency, after analysis using Duncan, showed that the influence was significant on oil palm production in Rokan Hulu Regency. The average results of observations on the levels of available P in oil palm production after further testing by Duncan are shown in Figure 4.

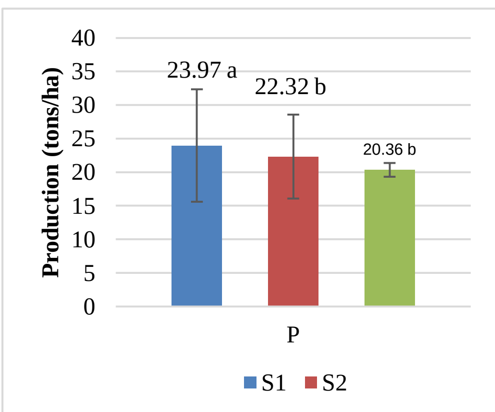


**Figure 4.** Available P to palm oil production (tons/ha)

Based on Figure 4, it can be seen that the nutrient criteria whose availability affects oil palm production are the P element. Based on the land suitability class with land class S1, the available P content is in the range <16.8, in land class S2 in the range 2.8 - 16.8 and in land class S3 in <2.8. In the S1 criteria, 23.97 are suitable for oil palm plants, which is not significantly different from the S2 criteria (22.32), which is significantly different from the S3 criteria (20.36).

The results of this study indicate that available phosphorus significantly affects oil palm fresh fruit bunch (FFB) production, with higher production in land suitability class S1 (available P > 16.8 ppm), while low P in class S3 (< 2.8 ppm) is the main limiting factor. This finding is in line with Fiqri et al. (2024), who reported that high phosphorus fixation in Ultisol soils limits P availability for plants. The results of this study reinforce the concept that phosphorus, after nitrogen, is an essential nutrient that plays an important role in root growth and flower formation, and that its availability is greatly influenced by soil chemical properties, especially pH and base saturation.

The relationship between phosphorus (P) and potassium (K) is neutral to synergistic, where K strengthens the root system, thereby increasing P absorption, while P supports the activity of enzymes affected by K. However, an imbalance in the dosage of both is rarely sufficient to cause direct antagonism; excess K can sometimes reduce the efficiency of P absorption.

### 3.5. Base Saturation (%)

Data from observations of base saturation levels on the production of oil palm (*Elaeis guineensis* Jacq) plants on mineral soil in Rokan Hulu Regency, after analysis using Duncan, showed that the influence was significant on oil palm production in Rokan Hulu Regency. The average results of observations on the levels of base saturation elements in oil palm production, after further testing by Duncan, are shown in Figure 5.

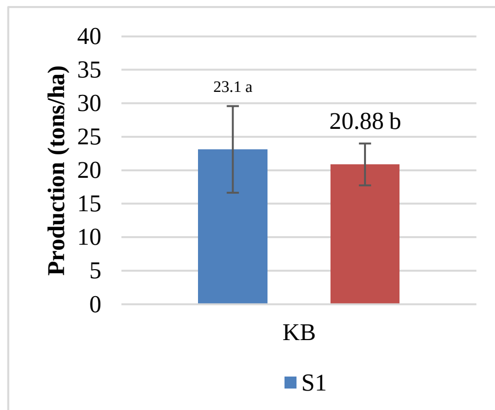


**Figure 5.** Base saturation on palm oil production (tons/ha)

Based on Figure 5, the nutrient availability criteria affect oil palm production through KB elements. Based on land suitability classes, with land class S1, KB levels range from >16.3, in land class S2, they range from 9.3 to 16.3, and in land class S3, they range from <9.3. According to the S1 criteria, 23.1 is suitable for oil palm plants and is significantly different from the S2 criteria (20.88).

The results of this study indicate that base saturation (BSA) significantly affects the production of fresh fruit bunches (FFB) in oil palm, with land suitability class S1 with BSA >16.3% producing higher yields than classes S2 and S3. The low BSA value in class S3 (<9.3%) indicates the dominance of $H^+$ and $Al^{3+}$ ions, reflecting very acidic soil conditions that reduce nutrient availability. This finding is in line with Wicaksono et al. (2023), who state that base saturation is closely related to soil pH, with soils with low pH generally having low base saturation. Thus, the results of this study confirm previous research that increasing base saturation through soil pH management is an important factor in increasing oil palm fertility and productivity.

Potassium ($K^+$) is one of the elements included in the base saturation (KB) component, although the amount is usually smaller compared to calcium (Ca) and magnesium (Mg). High base saturation plays an important role in retaining $K^+$ ions on the surface of the cation-exchange complex in soil, thereby maintaining their availability to plants. Conversely, in conditions of low base saturation, especially in sandy soils, $K^+$ ions are more readily leached from the root zone, thereby reducing their efficiency as an essential nutrient.

saturation (BSA) is closely correlated with soil pH. Generally, a high BSA results in a high soil pH, ranging from neutral to alkaline. Conversely, a low BSA tends to result in a low or acidic soil pH. Generally, a BSA value below 35% indicates acidic soil conditions, necessitating liming to raise the pH and improve soil fertility.

### 3.6. Cation Exchange Capacity (cmol(+)/kg)

Observation data on the levels of CEC elements on oil palm (*Elaeis guineensis* Jacq) production on mineral soil in Rokan Hulu Regency showed that the influence was significant, as analyzed using Duncan. The average results of Duncan's further testing of CEC element levels in oil palm production are shown in Figure 6.

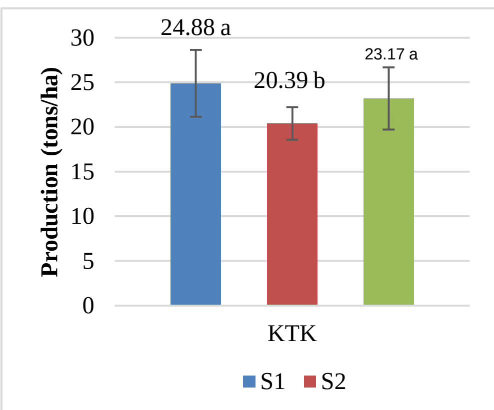


**Figure 6.** Cation Exchange Capacity on palm oil production (tons/ha)

Based on Figure 6, it can be seen that nutrient availability criteria affect oil palm production through the CEC element. Based on the land suitability class, the CEC content is>3.8 in land class S1, <3.8 in land class S2, and in addition to the figures in classes S1 and S2 in land class S3. The following is a picture of the relationship between CEC and production. In the S1 criteria, there are 24.88 suitable for oil palm plants, which are significantly different from the S2 criteria (20.39), and there are also 23.17 in the S3 class.

According to Hermita Putri et al. (2019), cation exchange capacity (CEC) is the ability of soil colloids to absorb and exchange cations. The CEC value is influenced by soil texture and organic matter content. Organic matter plays a crucial role in soil fertility because it has a greater cation absorption capacity than clay colloids. Therefore, the higher the soil organic matter content, the higher the CEC.

Potassium ($K^+$) has a direct relationship with cation exchange capacity (CEC), because it is the main essential cation exchanged on the surface of soil colloids such as clay and organic matter. Soil with high CEC has a greater ability to store $K^+$ ions, so that their availability for plants becomes more stable. On the other hand, in soils with low CEC, especially those with a sand texture, $K^+$ ions are more easily leached by rainwater or irrigation, thereby reducing their availability to plants.

Cation exchange capacity (CEC) is significantly influenced by soil pH. In low-pH conditions or acidic soils, the negative charge on soil colloids decreases, thereby reducing the soil's ability to retain and exchange cations. Conversely, at neutral to alkaline pH, soil colloids have a higher negative charge, which increases cation exchange capacity. Therefore, the effective CEC increases with increasing soil pH.

## 4. Conclusion

The results of this study indicate that cation exchange capacity (CEC) significantly influences the production of oil palm fresh fruit bunches (FFB). Specifically, land classified as suitability class S1, with a CEC greater than 3.8 cmol(+)/kg, yields higher production than class S2, which has a lower CEC. This finding aligns with Hermita Putri et al. (2019), who state that CEC reflects the soil's ability to absorb and supply essential nutrient cations to plants, a capacity largely influenced by clay and organic matter content. This study reinforces previous research by demonstrating that soils with high CEC can maintain nutrient availability, particularly potassium, thereby enhancing oil palm productivity on acidic mineral soils.

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**References**

Fiqri, M. H., Haris, A., & Hadi, A. (2024). Karakteristik kimia tanah pada areal kelapa sawit dan nilai konservasi tinggi (NKT) di Kabupaten Tapin, Provinsi Kalimantan Selatan. *Acta Solum, 1*(3), 121-125. https://doi.org/10.20527/actasolum.v1i3.2277

Hanafiah, K. A. (2005). *Dasar-dasar ilmu tanah*. PT Raja Grafindo Persada.

Hermita Putri, O., Rahayu Utami, S., & Kurniawan, S. (2019). Sifat kimia tanah pada berbagai penggunaan lahan di UB Forest. *Jurnal Tanah dan Sumberdaya Lahan, 6*(1). https://doi.org/10.21776/ub.jtsl.2019.006.1.6

Minasny, B., Young, S., Hartemink, A. E., & Hak, Y. (2016). Soil pH increase under paddy in South Korea between 2000 and 2012. *Agriculture, Ecosystems & Environment, 221*, 205-213. https://doi.org/10.1016/j.agee.2016.01.042

Patti, P. S. (2013). Analisis status nitrogen tanah dalam kaitannya dengan serapan N oleh tanaman padi sawah di Desa Waimital, Kecamatan Kairatu, Kabupaten Seram Bagian Barat. *Agrologia, 2*(1), 51–58. https://media.neliti.com/media/publications/288809-analisis-status-nitrogen-tanah-dalam-kai-53bd4435.pdf

Pusat Data dan Sistem Informasi Pertanian. (2016). *Outlook kelapa sawit tahun 2016*. Kementerian Pertanian Republik Indonesia. http://epublikasi.setjen.pertanian.go.id/arsip-outlook/75-outlook-perkebunan/421-outlook-kelapa-sawit-2016

Darlita, R. D. R., Joy, B., & Sudirja, R. (2017). Analisis beberapa sifat kimia tanah terhadap peningkatan produksi kelapa sawit pada tanah pasir di perkebunan kelapa sawit Selangkun. *Agrikultura, 28*(1), 15–20. https://doi.org/10.24198/agrikultura.v28i1.12294

Sahrul, M., Rembon, F. S., Leomo, S., Ginting, S., Zulfikar, Z., Namriah, N., Rustam, L. O., & Alam, S. (2022). Analisis sifat kimia tanah pada lahan kelapa sawit di Desa Anggotoa, Kecamatan Wawotobi. *Jurnal Berkala Ilmu-Ilmu Pertanian (Journal of Agricultural Sciences), 2*(2), 69–76. https://doi.org/10.56189/jagris.v2i2.27572

Subandi. (2011). Pengelolaan hara kalium untuk ubikayu pada lahan kering masam. *Buletin Palawija, 22*, 86–95.

Wicaksono, B., Sulakhudin, S., & Manurung, R. (2023). Karakteristik sifat kimia tanah Ultisol kebun kelapa sawit Desa Pangkalan Suka, Kecamatan Nanga Tayap, Kabupaten Ketapang. *Jurnal Sains Pertanian Equator, 12*(3), 624. https://doi.org/10.26418/jspe.v12i3.64124