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Study of Soil Chemical Properties on Palm Oil Productivity in PT. Gemilang Sejahtera Abadi in East Kalimantan

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ABSTRACT

East Kalimantan is a region that contributes to palm oil production. Industrial development in the area still needs to be improved in some plantations because there is a limiting palm oil productivity. This study examined the chemical properties of the soil on the PT. Gemilang Sejahtera Abadi (GSA) plantation. Observations were made in four fields with the same variety but different productivity levels. Correlation analysis and simple linear regression were used to identify factors influencing productivity. The soil on the plantation land was dominated by Typic Hapludults soil type, included in the Ultisols order. The highest productivity was found in Afdeling 1, 2, and 5, while the lowest was in Afdeling 4. The pH in each afdeling was classified as acidic, and the Organic-C, N, and base saturation contents were low. The CEC in afdeling 1 and 2 was classified as medium, while in afdelings 4 and 5 was low. All correlation analyses showed a positive relationship between the variables and palm oil productivity, with low correlation coefficients for pH, organic-C, N, P, and base saturation. The correlation coefficient between CEC and palm oil productivity has a strong relationship.

Keywords: Oil palm, productivity, soil chemical factors

INTRODUCTION

Palm oil is a significant commodity in Indonesia. Based on the PPKS data (2020), there are currently more than 1,700 palm oil companies in Indonesia, both state-owned and private. As the palm oil industry develops, the demand for raw materials increases (Prawiradijaya and Kurniawan, 2020). Indonesia is the world's largest producer and exporter of palm oil, contributing around 85-90% of the world's total palm oil production (Ngakan et al., 2014).

East Kalimantan Province is one of the regions that significantly contributes to palm oil production. In 2020, the area of oil palm plantations in East Kalimantan reached 1.3 million ha with fresh fruit bunches (FFB) production of 17,721,970 tons or the equivalent of 3.8 million tons of *Crude Palm Oil* (Dinas Perkebunan, 2021). This figure is expected to continue to increase, considering the East Kalimantan Province Regional Spatial Planning Plan, which includes developing agropolitan areas (Perda, 2016). Therefore, it is essential to improve the productivity potential of palm oil.

In the development of oil palms in East Kalimantan, there are still many plantations whose productivity levels have yet to reach their maximum potential. It can be seen in one of the palm oil plantations owned by PT. Gemilang Sejahtera Abadi (GSA) in East Kalimantan. Palm oil productivity in the last four years, from 2019 to 2022, were 17.68 Mg ha^{-1}, 20.37 Mg ha^{-1}, 21.09 Mg ha^{-1}, and 23.22 Mg ha^{-1}. Even though these figures show increased productivity, they must be considered more optimal. According to Hidayati et al. (2016), the potential productivity of palm oil plantations can generally reach 25-30 Mg ha^{-1} yr^{-1}.

This difference in productivity is caused by several limiting factors, one of which is the soil factor (Pratiwi and Gustiani, 2013). Decreased soil fertility is a significant factor that affects soil productivity. Therefore, adding nutrients to the soil through fertilization is essential for increasing agricultural production (Walida et al., 2020). Soil properties are closely related to oil palm productivity, and soils with different chemical properties ultimately produce different quality and quantity of production (Harahap and Munir, 2022). Efforts to increase palm oil production can be achieved by improving cultivation technology, one of which is to improve the chemical properties of the soil. Critical aspects of soil chemistry that influence plant growth and production include soil pH, N, P, K, and organic-C levels, and soil CEC (Rahmah et al., 2014).

Productivity analysis examining the factors influencing palm oil growth is necessary to increase palm oil productivity (Yohansyah and Lubis, 2014). This study aimed to examine the chemical properties of soil that are limiting factors for palm oil productivity.

MATERIALS AND METHOD

This research is located on the plantation of PT. GSA is in Long Mesangat District, East Kutai Regency, East Kalimantan Province (Figure 1), from March to September 2023.

Soil analysis was conducted at the Chemical Laboratory of the Soil Department, Faculty of Agriculture, Brawijaya University Malang. This research focuses on four fields (afdeling) with the same age (mature) and various criteria. Soil sampling used a *stratified random sampling* technique based on different productivity, namely land with productivity >30 Mg ha^{-1} yr^{-1}, 25 Mg ha^{-1} yr^{-1}, >20 Mg ha^{-1} yr^{-1}, <20 Mg ha^{-1} yr^{-1} with a depth of 0-30 cm. The soil sampling was done in three oil palm plantation areas, namely the fertilization area called the plate zone (PI), the harvest transportation area called the pickle market zone (PP), and the frond accumulation area called the wicket zone die (GM). The sampling was repeated three times.

Laboratory analysis and data analysis

Laboratory analysis included measurements of soil pH H2O (pH meter), organic C (Walkey-Black), total N (%) (*Kjeldahl*), available P (ppm) (*Bray-2*), K, Na, Ca, Mg (NH_4OAc 1 M), and CEC through distillation.

Collected data were tabulated and tested for normality. If the normality test showed a probability of d”0.05, then a logarithmic (square root) transformation was applied. Simple linear correlation and regression analysis of secondary data using the *R Studio* application were carried out to determine the relationship between each variable and determine the most dominant variables influencing palm oil productivity.

RESULTS AND DISCUSSION

General condition of the area

The research area is in Long Mesangat Estate (LME), the ninth plantation of PT. Gemilang Sejahtera Abadi (GSA). LME started operating in

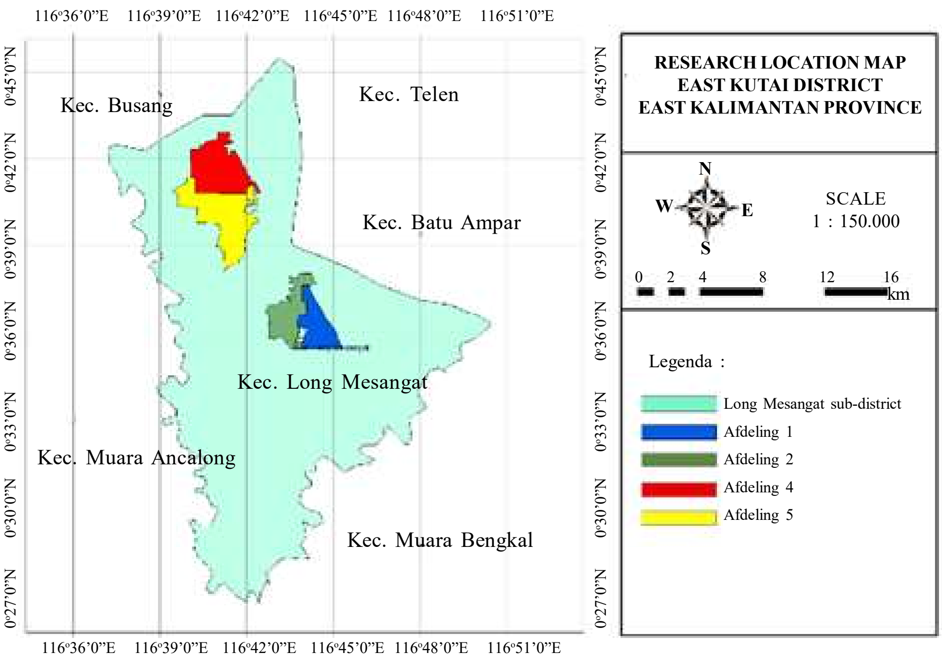

Figure 1. Research location (Data processed using ArcGIS).

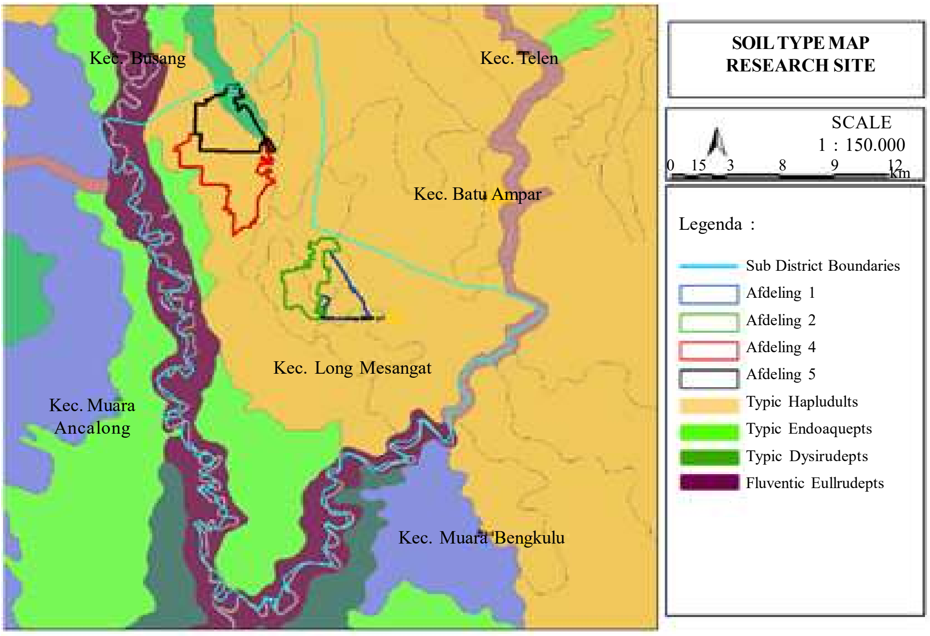

Figure 2. Soil Type at the Research Location. (Source: Kaltimprov SHP data, 2022) processedusing ArcGIS.

2006 with an area of ± 6000 ha. The soil on plantation land is dominated by the Typic Hapludults, a soil type in the *United States Department of Agriculture* (USDA) soil classification system in the Ultisols soil order (Keys to Soil Taxonomy, 2014).

The soils were developed from clay and sandstone, often found on land with a more than eight percent slope, on tectonic landforms, hills, and mountains. Afdeling 1 and 2 are in hilly areas, while afdeling 4 and 5 are on flat landforms. The soil has a thick solum thickness (100 to 150 cm) and moderate to good drainage. The color of the top layer of soil is dark brown, and the bottom layer is yellowish brown to yellowish red; the texture is medium, the block structure is slightly rounded, and the consistency of the moist condition is firm (Waas et al., 2016).

Soil Texture

Soil texture refers to the relative proportions of various sized soil particles present in a soil sample. Soil particles generally consist of sand, dust and clay. The combination of the relative percentages of these three types of particles forms the soil texture (Soil Survey Staff, 2014) The following (Table 1) pre-

Table 1. Soil texture class in each afdelings.

Afdeling	% Sand	% Silt	% Clay	Texture Class
1	49.83	12.54	37.63	Sandy Clay
	42.35	15.72	41.93	Clay Loam
	12.89	46.46	40.65	Silty Clay
2	36.71	16.88	46.41	Clay
	32.30	9.67	58.03	Clay
	25.65	14.87	59.48	Clay
4	12.28	9.75	77.97	Clay
	71.65	18.04	10.31	Sandy Loam
	15.40	52.51	32.09	Silty Clay Loam
5	67.53	22.48	9.99	Sandy Loam
	66.35	14.02	19.63	Sandy Loam
	64.29	17.86	17.86	Sandy Loam

Data source: Soil Physics Laboratory Analysis Results

Table 2. Soil chemical properties in each afdeling.

Soil properties	Afdeling			
	1	2	4	5
pH	4.55 (S)	4.41 (S)	4.59 (S)	4.30 (S)
Organic-C (%)	0.98 (VL)	0.98 (VL)	0.48 (VL)	0.57 (VL)
N (%)	0.12 (L)	0.08 (VL)	0.06 (VL)	0.11 (L)
P (ppm)	47.34 (H)	52.19 (H)	46.82 (H)	46.82 (H)
Base Saturation (%)	45.09 (M)	43.99 (M)	30.86 (L)	35.04 (L)
CEC (me $100g^{-1}$)	18.12 (M)	17.69 (M)	13.56 (L)	14.90 (L)

Information: A = Acid, VL = Very Low, L = Low, M = Medium, H = High

Source: Soil lab results data (Soil characteristic criteria by the Soil Research Institute)

sents the soil texture class in each afdeling on the plantation. PT. GSA. Sand: Large. coarse particles. Sandy soil tends to have good drainage because the space between the particles is relatively large. silt: Medium sized particles between sand and clay. Soil has a fine texture and can hold water better than sand. Clay: Very fine particles and has high adhesive power. clay soil can store water well. but tends to lack drainage (Fries et al., 2020). Prasetyo and Suriadikarta, 2014 states that ultisol soil is very susceptible to soil erosion. Soil texture is the basis for assessing soil properties and functions as an indicator for assessing soil water holding capacity. cation exchange capacity. aeration. and organic matter content. (Zainudin and Kesumaningwati, 2021) states that soil texture also affects the binding and loss of soil nutrients.

Soil factors on oil palm productivity

The productivity data obtained showed differences in productivity between afdeling; the highest productivity value was found in afdeling 1 plantation with a productivity value of 39.74 Mg ha^{-1} yr^{-1}. The next highest productivity value was found in afdeling 2 plantations with a productivity value of 26.04 Mg ha^{-1} yr^{-1}, afdeling 5 plantations with a productivity value of 23.62 Mg ha^{-1} yr^{-1} and the most minor productivity is in afdeling 4 plantations with a productivity value of 19.95 Mg ha^{-1} yr^{-1} (Figure 3).

The difference in productivity in palm oil plantations is caused by several factors, one of which is the soil. Soil is essential to palm oil's growth, development, and production. An analysis was conducted to assess the influence of soil properties on each afdeling's productivity (Table 2).

Analysis of soil chemical property variables (Table 2) show differences in soil nutrients in each afdeling. In each afdeling, the pH is classified as acidic, and treatment needs to be carried out to increase the pH, such as providing routine liming at time intervals, such as fertilization. According to Tampubolon and Thalia (2022), mineral soil is generally needed for the growth and productivity of oil palm plants and requires optimum soil acidity (pH), namely 5.0-7.0.

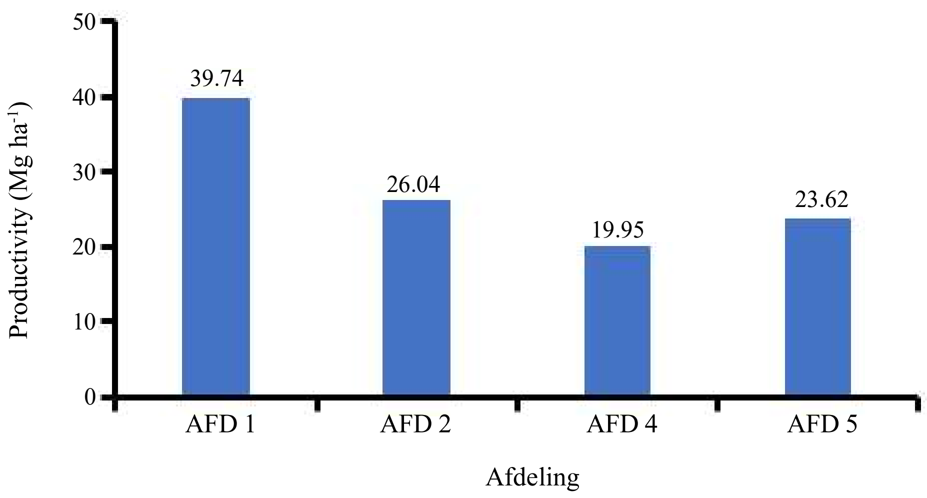

Figure 3. Palm oil productivity in each afdeling.

Table 3. Correlation between soil factors and oil palm productivity.

Variable	r	Relationship Level
pH	0.09	Very Low
Organic C (%)	0.33	Low
N (%)	0.33	Low
P (ppm)	0.04	Very Low
Base Saturation (%)	0.27	Low
CEC (me $100g^{-1}$)	0.61	Strong

The organic C content in each afdeling was classified as very low because the organic material in the plantation land was not appropriately decomposed. For example, fronds are a source of organic C, many of which are found in drainage channels that cause the fronds anaerobic; therefore, they decompose very slowly. Therefore, it is necessary to monitor the placement of organic materials in the field. Farrasati et al. (2020) stated that organic C is essential in supporting sustainable agriculture, especially as a primary indicator of soil fertility, nutrient availability maintenance, soil physical properties improvement, and soil microorganism survival. (Hapsoh et al., 2020) addition of organic matter to the soil will increase the air content because the pores of the soil increase so that the air binding capacity increases. Therefore. it is necessary to add and manage organic matter in the soil through other sources such as empty oil palm bunches (TKKS) and organic fertilizers.

The soil available P in each afdeling was in high criteria. Based on soil fertility criteria, the application of Rock Phosphate (RP) fertilizer is thought to influence the high P content of the soil. In acid soils such as Ultisols, P is usually adsorbed by Al, Fe (cations, oxides, and hydroxides), and clay soils. Apart from that, sufficient P is also significant to support the growth and development (Santi et al., 2022) of plants' vegetative and reproductive parts, improve the quality of yields, and plant resistance to disease. Therefore, managing P nutrients is crucial in increasing oil palm production (Siregar and Fauzi. 2017).

The total N content of the plantation land was classified as low to very low. Nitrogen is nutrient plants require for the formation and growth of vegetative parts. Nitrogen also forms green leaf substances (chlorophyll) necessary for photosynthesis (Harahap et al., 2023). Various factors, including nutrient leaching, evaporation, and plant absorption, can cause low N levels. Research Asih et al. (2019) stated that a decrease in nitrogen content occurs because N (NO3-) produced from the mineralization process of organic materials is converted into NO2, N2O, and N2 by microbes through the denitrification process and is ultimately lost due to evaporation (volatilization).

Base saturation concentrations show deficient levels in each afdeling due to the content of base cations such as (K+, Mg2+, and Na+). Apart from that, the low pH of the soil causes acid cations such as Al to be mobile. Bhalerao and Prabhu (2020) proves a significant correlation between phytotoxic Al and low pH, related to reduced exchangeable base cations in the soil solution.

In afdeling 1 and 2, the CEC is classified as moderate, possibly originating from the contribution of organic matter. Afdeling 1 and 2 are in hilly areas,

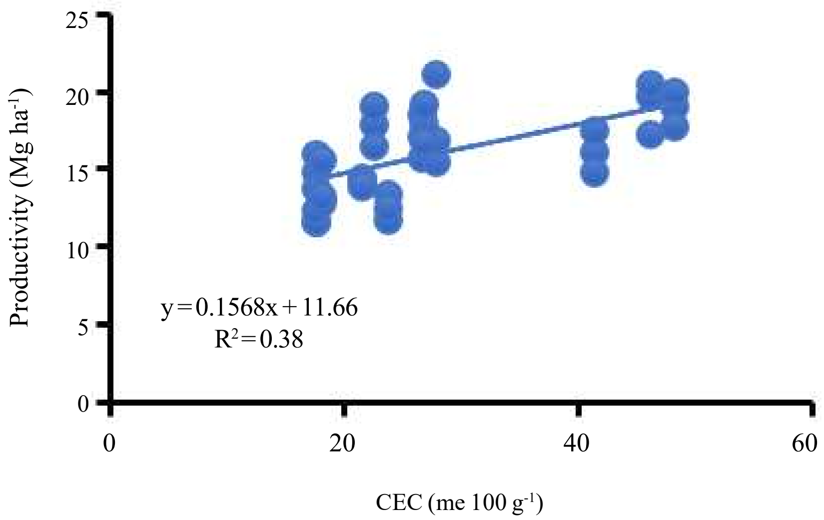

Figure 4. Regression between cation exchange capacity and palm oil productivity.

where no channels are flooded with water, thus allowing for better decomposition of organic materials. In afdeling 4 and 5, this was relatively low. Base saturation is closely related to pH. and soil pH increases with increasing base saturation (Bafadhal et al.. 2023). A low CEC is caused by a lack of clay content and a low organic-C content in plantation locations. Darlita et al. (2017) stated that low clay and organic-C content in the soil causes low CEC. Apart from determining the CEC value of the soil, the organic C content of the soil also dramatically determines the addition of nutrients such as N, P, K, Ca, Mg, S, and microelements (Andriani Luta et al., 2020).

Correlation between Soil Factors and oil palm productivity

The results of the correlation analysis between several variables on palm oil productivity show different coefficient values.

The relationship between pH and oil palm productivity (Table 3) has a correlation coefficient (r) of 0.09, where pH has a very low relationship. The relationship between pH and oil palm productivity is positive linear, which means that productivity will also increase if the pH is increased. The relationship between organic C and oil palm productivity (Table 3) has a correlation coefficient (r) of 0.33, where organic C has a low relationship. The relationship is positively linear, meaning that productivity will also increase if organic C increases.

The correlation coefficient (r) between N and oil palm productivity (Table 2) is 0.33. N has a low closeness and positive linear relationship, meaning productivity increases if N increases. The correlation coefficient (r) between P and oil palm productivity (Table 3) is 0.04, where P had a shallow and positive linear relationship, meaning productivity also increase if P increases. The correlation coefficient (r) between base saturation and oil palm productivity (Table 3) is 0.27, where base saturation has a low relationship, and the relationship is positive linear.

The correlation coefficient (r) between CEC and oil palm productivity (Table 2) was 0.61, where CEC had a strong positive linear relationship, which means that if CEC increases, productivity also increases. The soil CEC reflects the capability of soil colloids to absorb and exchange cations in the soil matrix. The higher the CEC of the soil, the greater its capacity to absorb, store, and exchange nutrients in its environment (Simarmata et al., 2017). The coefficient of determination (R2) value was obtained at 0.38 (Figure 4). It indicates that CEC influences palm oil productivity in plantations PT. GSA is 38%.

CONCLUSIONS

In each afdeling, the pH is classified as acidic, and the nutrient content of organic-C, N, and base saturation was classified as low to very low. The CEC in divisions 1 and 2 is classified as medium, while the CEC in divisions 4 and 5 was classified as low in PT. GSA plantations, CEC was the factor thaMg had the most influence on palm oil productivity.

The correlation coefficient values of pH, organic-C, N, P, and base saturation on oil palm productivity were classified as low to very low. Meanwhile, the CEC correlation coefficient value was considered vital to be quite strong. The correlation of each variable has a positive value, which means that by increasing the value of each variable, productivity will increase.

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