Peatland characteristics and oil palm productivity at Siak Regency, Riau Province

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Abstract. The utilization of peatland as a source of livelihood from the agricultural sector is still important, especially for peatland-dominated areas. One example of its utilization is for oil palm commodities. The objective of this study was to analyze the existing condition of peatland in oil palm plantation in Siak Regency of Riau Province. The research method was field survey, literature study and interviews. The data collected was the chemical and physical properties of peat soil, groundwater table depth and oil palm productivity. The field study was carried out at 4 blocks representing sapric and hemic peat maturity. The study found that the depth of the groundwater table varies depending on the rainfall. Even though the canal blocking system has been implemented, the depth of the groundwater level still fluctuated. The productivity of oil palm increased with age and the highest was reached at the age of 14 years. The results of the chemical properties analysis showed that the land was categorized in good fertility, because of good agricultural practices management. Further research is needed regarding the dominant factor of peatland that causes fluctuations in water level depth.

1. Introduction
Tropical peatlands have an important role in the ecosystems of parts of the world because of their role in ecological functions and production functions. Ecological functions of peatlands associated with an environmental service provider, namely as carbon storage [1, 2, 3, 4] water management regulator or hydrologic function [5] and storage of germplasm/biodiversity including a population of rare [6, 7, 8]. Peatlands also has a production function related to their capacity to produce goods and services, both timber and non-timber forest products, which can be utilized to meet human needs so that they can become a source of livelihood for local communities who live in peat areas [6, 9].

Tropical peatland in Indonesia has an area of 13.43 million ha, which is spread over four main islands of Sumatra (5.85 million ha), Kalimantan (4.54 million ha), Papua (3.01 million ha) and Sulawesi (0.024 ha) [10]. The widest distribution of peatlands in Sumatra is in Riau Province, which is 3,573,955 ha [10].

The use of peatlands in Indonesia is quite rapid, especially for oil palm plantations. Wise use of tropical peatland has been emphasized taking into consideration the tradeoffs between development and conservation. While perennial crop cultivation such as oil palm on peatland can be seen as a solution for rural development [11,12]. An area of 2,435,626 ha of private oil palm plantations and 270,529 ha of
smallholder oil palm plantations are on peatlands or 18% of the total area of oil palm plantations [13]. Facts on the ground show that most peatlands used for agriculture and plantations are becoming unproductive wastelands, but others with good management were able to produce and have contributed to improving the welfare of the surrounding community [14].

Many of the tropical peat characteristics such as their depth, presence and nature of wood characteristics may impact the suitability and management of tropical peatlands for crops such as oil palm. These characteristics may impact the production input for oil palm management on peat as well as oil palm productivity. Peat characteristics are also expected to influence other factors such as greenhouse gasses emissions and performance [11]. In addition, it is important to know the characteristics of peatlands because oil palm productivity is influenced by soil fertility and plant age.

The objective of this study was to analyze the existing condition of peatland in one oil palm plantation in Siak Regency of Riau Province cultivated since 1996 by implementing the good agricultural practice.

2. Methods

The study was conducted on Kimia Tirta Utama, Pangkalan Pisang Village, Koto Gasib Sub Regency, Siak Regency, Riau Province. The initial approach was to study the existing information available on estates already planted with oil palm on peats. The research method was a field survey, literature study and interviews. The data collected was the chemical and physical properties of peat soil, groundwater table depth and oil palm productivity.

Soil samples were taken from four blocks representing sapric and hemic maturity levels on April 2021. In each block, 3 soil samples were taken with a depth of 0-20 cm. Direct soil characterization was carried out in the field using peat drills; samples were taken and analyzed at the laboratory. The observed characteristics were soil chemical properties (pH, C-organic, total N, available P, Potential P and K, exchangeable bases, Cation Exchange Capacity and ash content.

The water level data was measured using a piezometer, amounting to 9 units per block, which were taken from four selected blocks. Oil palm productivity data were taken from oil palm plantations with the same age of 16 years at different peat depths (medium, deep, very deep).

The data that has been obtained from the analysis carried out in the laboratory is then presented in the form of tables and graphs. Presentation of data in the form of tables and graphs and discussed descriptively.
3. Results and Discussions

3.1. Geographic Conditions
Oil palm plantation PT. Kimia Tirta Utama (KTU) is located in 3 sub-Regency’s, namely Koto Gasib, Sungai Mandau and Tualang Sub-Regency, Siak Regency, Riau Province. The geographic location of PT. KTU is located at 0°39’0” – 0°45’0” North Latitude and 107°40’48” - 107°48’0” East Longitude. This oil palm plantation has an area of + 6,599 ha, consisting of 10 Afdeling and 247 Blocks.

Based on the geological conditions, the physiography at PT KTU can be classified into 3 Physiographic/Landform Groups, namely the Tectonic Group, Peat Dome and Alluvial. The tectonic group in this area consists of subgroups formed from the lower quarter and tertiary acid sedimentary materials. These tectonic plains occupy a wide area in the PT. KTU. The shape of the area is flat to wavy and small hilly. The peat dome is located in the northern part of the plantation area which is a transition from the tectonic plain in the south to the vast peat dome area in the north. The shape of the flat area is slightly concave with obstructed to very obstructed drainage conditions. Physiographic alluvial in this area only in the form of streams or pelembahan lines between tectonic plains, with an area that is not so wide. The shape of the flat is and flat lightly concave area so that drainage is poorly and moderate poorly.

From the results of identification in the field and supported by data from laboratory analysis, the soil found at the KTU location mostly developed from tertiary sedimentary rock (sandstone) parent material and partly organic material and river sediment (alluvium). Based on the identification results, the soil found consisted of 4 Orders, which resulted in 12 subgroups, namely Histosols (Typic Haplofibrists, Typic Haplohemists, Sapric Haplohemists, Typic Haplosaprists), Entisols (Typic Psammaquents, Typic Udipsamments), Inceptisols (Typic Endoaquestrudepts, A Fluventic Dystrudepts, Oxic Dystrudepts), Ultisols (Typic Kandiudults, Typic Kanhapludults).

From the survey results, the observation blocks have different criteria for maturity level and peat depth. Blocks OD 23 and OE 13 are peatlands with sapric maturity level with medium peat depth (100 < 200 cm), blocks OD 22 and OE 4 are peatlands with hemic maturity level and very deep peat depth (300 < 500 cm).

3.2. Chemical and Physical Properties
The chemical characteristics of the soil from the survey and laboratory analysis of peatlands in the observation block are presented in Table 1. The results of the analysis of the chemical properties of the soil showed that the level of soil acidity was classified as acidic, both at the level of sapric and hemic maturity. It was following the discussion by [15], which states that the acidity of peatlands is closely related to the content of organic acids, namely humic and fulvic acids. Generally, the soil acidity in the top layer is higher than that of the bottom layer.

The organic carbon content in the research block is categorized as very high, both at the level of sapric and hemic maturity. Tropical peat generally contains about 18 to 55% organic C [16]. The total nitrogen content from the analysis was high because it comes from organic N, but in fact, the availability of N was low [15]. The phosphorus content in the peatlands in the research block was in the high category. However, similar to the element N, the element P which was analyzed was organic P, which must be mineralized by micro-organisms so that it becomes available to plants [15]. One of the important criteria of peatland is the ash content which indicates the mineral content in the peat [16]. The ash content at the study site varies, for sapric maturity, it has a higher ash content than the hemic maturity level.

From the chemical characteristics of this soil, it can be seen that the peatlands in the study area are topogenous peatlands with eutrophic fertility levels. Optimal land management must continue to be carried out to support sustainable growth and production of oil palm plantations.
3.3. Groundwater Level

Observation of the depth of the groundwater table was carried out on the depth of the water level in the last 2 years (2019–2020). In Figure 2, it can be seen that blocks OD-22 and OD-23 tend to have shallower groundwater levels than blocks OE-5 and OE-13. This groundwater level fluctuation is strongly influenced by rainfall [18], [19], especially on the previous day’s rainfall.

At OD 23, the depth of the groundwater level ranges from 15-91 cm and at OE13 ranges from 27-91 cm. Meanwhile, at OE 22, the depth of the groundwater table was 8-85 cm and k E 5 was 30-97 cm. The shallowest groundwater level was found at OD-22 in October 2020 with 153.2 mm of rainfall, while the deepest groundwater level occurred at OE5 block in September 2019 with 66.60 mm of rainfall. Research in Jabiren, Central Kalimantan, shows that the depth of the groundwater table tends to be the same during the rainy season (January – early March 2010) in the range of 9.0-10.5 m. Starting in mid-March 2010 the groundwater level began to fall or further away from the land surface and reached its peak at the end of August [19].

At the research location, there were differences in annual rainfall between 2019 and 2020, which cause differences in fluctuations in the depth of the groundwater table. In 2019, the depth of the groundwater table tends to be deeper than in 2020. The results of research in Central Kalimantan and Riau, showed that during the El-Nino, the depth of the groundwater table drops to below 150 cm, while during the rainy season the depth of the groundwater table increases to 30-50 cm in Central Kalimantan and 50-70 cm in Riau [20].

Water level management has been applied to PT KTU by constructing a drainage system on peatlands that functions to remove excess water during the rainy season. In general, there is a combination of 3 types of channels in oil palm plantations, namely primary, secondary and tertiary channels. The water

### Table 1. Chemical properties of peat surface (0-20 cm) layer at the study site in PT KTU

| Parameters          | OD-23 (Sapric, medium) | OE-13 (Sapric, medium) | OD-22 (Hemic, very deep) | OE-5 (Hemic, very deep) |
|---------------------|------------------------|------------------------|--------------------------|-------------------------|
| pH H2O              | 4.17                   | 3.43                   | 3.57                     | 3.57                    |
| pH KCl              | 3.37                   | 2.67                   | 2.80                     | 2.53                    |
| C-organic           | %                      | 32.80                  | 33.17                    | 35.57                   | 38.87                   |
| N-Kjehdahl          | %                      | 1.13                   | 1.05                     | 1.14                    | 1.15                    |
| P (Hcl 25%)         | mg kg⁻¹                | 102                    | 21                       | 26                      | 16                      |
| K (HCl 25%)         | mg kg⁻¹                | 82                     | 40                       | 212                     | 19                      |
| P- Bray             | ppm                    | 97.60                  | 66.57                    | 52.07                   | 27.10                   |
| Exchangeable Ca     | cmol kg⁻¹              | 19.18                  | 11.38                    | 11.51                   | 10.19                   |
| Exchangeable Mg     | cmol kg⁻¹              | 2.91                   | 1.51                     | 2.24                    | 1.30                    |
| Exchangeable K      | cmol kg⁻¹              | 1.59                   | 0.76                     | 3.93                    | 0.34                    |
| Exchangeable Na     | cmol kg⁻¹              | 0.31                   | 0.35                     | 0.52                    | 0.40                    |
| Cation exchange capacity | cmol kg⁻¹ | 67.46                  | 64.09                    | 67.98                   | 71.14                   |
| Base saturation     | %                      | 36                     | 20                       | 27                      | 17                      |
| Ash content         | %                      | 30.02                  | 31.73                    | 21.38                   | 18.59                   |

Soil physics data were obtained from literature studies, which stated that the bulk density at the research site at PT KTU ranged from 0.09 – 0.15 g cm⁻³, the soil water content at a depth of 0 – 30 cm was 205 – 405% while at a depth of 30 – 50 cm it ranged 461 – 474%. The bulk density (BD) of the top layer of peat varies between 0.1-0.2 g cm⁻3 depending on the level of decomposition. Fibric peat which is generally in the lower layer has a BD < 0.1 g cm⁻³ [15]. Regarding soil moisture content, peat moisture at the permanent wilting point was still relatively high at 50%-60% of volumetric, with the peat visually wet but the water may not be available for plant use [17].
level in the secondary canal is generally maintained at a depth of 60-70 cm during the rainy season. Considering the shape of the average water table on peatlands that is curved (according to the distance from the channel), the water level on peatlands is generally shallower, ranging from 40-50 cm [21]. From the results of field visits and interviews, PT KTU has implemented a water management system by making canal blocking so that the groundwater level is stable. However, from the observations of the depth of the groundwater table, this condition has not been achieved.

![Figure 2](Spatial dynamics of groundwater depth and rainfall at PT KTU (2019-2020))

### 3.4. Palm Oil Productivity

Oil palm productivity is determined by several factors, namely plant genetics, plant age, land fertility, and climate. The productivity fluctuates according to time which is influenced by climate, especially water dynamics in oil palm plantations [22, 23]. Productivity data were taken on oil palm plantations planted in the same year (2004), at different peat depths, namely medium peat depth (100 – 200 cm), deep peat depth (200 – <300 cm) and very deep peat depth (300 cm - <500 cm). The productivity of oil palm plantations during the period from planting to the year of observation is presented in Figure 2.

At the beginning of the production year, oil palm productivity on peatlands was lowest on very deep peatlands, followed by deep peatlands and the highest productivity on medium peatlands. It was due to the availability of nutrients on peat with medium depth which is more affordable for oil palm plants than on very deep and deep peatlands. However, after the plants were over 9 years old, the difference in productivity was not very significant between the peat depths. It was due to the implementation of Good Agricultural Practices in the plantation company which minimizes the limiting factors of peatland for oil palm, including water management/management, application of fertilizer recommendations based on the results of plant nutrient analysis. Therefore, fertilization applied to plants with low productivity can increase crop productivity so that productivity is ultimately the same at all three peat depths.

The production potential shown in Figure 3 is the potential for oil palm production on mineral land suitability class S3 (marginally suitable) because peatlands are categorized as moderately suitable for oil palm plantations. Oil palm productivity increases until the age of 14 years and then declines. Similarly, oil palm production at the research site. The productivity of oil palm at the study site was not different from the results of research on oil palm plantations in Riau Province which showed that the productivity of oil palms aged 14 years ranged from 22.3 to 28.7 t ha\(^{-1}\) yr\(^{-1}\) at a water table depth of > 25 cm [24]. Generally, the productivity of oil palm on topogenous peatlands is higher than on ombrogen peat. At the same plant age of 6-10 years, the productivity of fresh fruit bunch (FFB) production on topogenous peatlands reached 19.64-25.53 t ha\(^{-1}\) yr\(^{-1}\), while on ombrogen peatlands it is only 9.93-13.51 t ha\(^{-1}\) yr\(^{-1}\) [25].
4. Conclusions

PT Kimia Tirta Utama’s oil palm plantation has good peat characteristics from the aspect of land fertility, as can be seen from the high availability of macronutrients. This is because these plantations have minimized the limiting factors of peatlands to make them suitable for oil palm growth and are practicing good agricultural practices in their cultivation. The depth of the groundwater table varies depending on the rainfall. Even though the canal blocking system has been implemented, the depth of the groundwater level fluctuates. The productivity of oil palm plants increases with age and the highest is reached at the age of 14 years. Further research is needed regarding the dominant factor of peatland that causes fluctuations in water level depth.

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