Impact of Drainage Canal Conditions on the Characteristics and Physical Properties of Peat Soil at PT Batanghari Sawit Lestari Oil Palm Plantation, Ramin Village, Kumpeh Ulu

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Abstract. Peat soil is naturally formed from remains of plant tissue, with varying decomposition stages of organic matter. Impact of construction and condition of drainage canal on peat soil can alter peat soil characteristics. This study aimed to determine differences in soil characteristics in oil palm plantations due to modifying drainage conditions. Transect with a 300 m distance between points was implemented obtain 14 observation points to understand peat soil characteristics, water level. The results showed that in well-maintained drainage, sapric decomposition stage was >0.2 g/cm³, with C-organic of <48.20%, and specific gravity was 1.50. Water content and total pore space would be smaller if peat decomposition stage is more developed, with water content of <276.78% and total pore space of <81.13%. When drainage canal is not maintained, decomposition stage of surface layer (0-60 cm) is hemic and fibric, with volume weight is < 0.2 g/cm³, and C-organic > 48.20%, and has a specific gravity of 1.40 and 1.30. For water content and total pore space of peat soil, raw decomposition rate indicated water content > 304.81% and total pore space of > 81%. The use of peatlands for plantations needs to maintain peat conservation methods to avoid damages to physical properties of peat soils and peat ecosystems as a whole.

1. Introduction

Indonesia has the largest peatland area in the tropics, estimated about 21 million hectares [1]. Peatlands in Jambi Province occupy about 676,341 ha [2]. Peat formation in Jambi was observed only 0.9 mm yr⁻¹ [2], or roughly 0.1-1.23 mm yr⁻¹ [3]. Rapid increase in pressure over peatlands has been due to imbalance between inhabitants and available lands for agriculture. Nowadays, the most prominent peatland utilization is conversion of peatlands to oil palm plantations [4].

The use of peatlands for oil palm plantations needs to pay attention to drainage system and water treatment technology, including construction of drainage canals. Canals are usually equipped with floodgates to maintain groundwater levels [5]. Construction of drainage canal on peatlands leads to land subsidence and creating a more aerobic condition, especially in upper peat layers. Constructed drainage over the test site during 1997 included primary canals, secondary canals, and micro canals with different size.
This research aimed to study physical properties of peat soils planted by oil palm with various canal conditions. The outcome of this study is expected to better understand on peatland management for oil palm plantations.

2. Methodology
The research was conducted at PT Batanghari Sawit Lestari oil palm plantation located between 1°28'20.23" - 1°29'48.29" South and 103°47'52.52" - 103°50'16.50" East (Figure 1). Research site was about 500 ha, located in Ramin Village, Kumpeh Ulu District, Muaro Jambi Regency, during August 1st to October 31st, 2020.

This research employed surveying to collect point-wise ground data. Sample points were taken using transects with a distance of 300 m on each block, based on a baseline map of 1:25,000, covering areas of 500 ha. Sample points were arranged across drainage canal on each block. Main observation point was positioned in the center of a block with a distance of 150 meters from each drainage canal. This allowed 14 samples to be collected. Observations included drainage system, peat thickness (cm), peat maturity, water level depth (cm), substratum under peat, C-organic (%), moisture content (%), volume weight (gr/cm3) and total pore space (%).

3. Results and Discussion

3.1. Drainage system
Well-maintained canals were fairly free from water weeds and grass, without silt. On the opposite, canals were overgrown with weeds and thick grass with silt was observed in the canals.

There were two primary canals at the research site with a width of 15 meters and around 1.5 meters bordering Ramin village community garden, PT Erasakti Wira Forestama and PT Ricky Kurniawan Kertapersada; both are connected to two rivers, namely Kumpeh River and Batanghari River. Table 1 presents observation over the canals.
Table 1. Dimensions and conditions of primary canals

| Dimensions (m) | Long | wide | deep | Direction of water flow | Function                           | Condition                                                                 |
|---------------|------|------|------|--------------------------|------------------------------------|--------------------------------------------------------------------------|
| 5589          | 15   | 1.5  | 1    | to the river Batanghari   | Disposal of excess water when rainy season and maintaining stable condition of water level | Maintained: free from water weeds and grasses. Canal dimension both in depth and width was maintained |
| 4573          | 15   | 1.5  | 1    | unknown Known            | Disposal of excess water when rainy season and maintaining stability of water level | Not-Maintained: canal drainage was covered by weeds and thick grass. Veruse of peatlands |

This research indicated that canal condition (maintained and not maintained) affected physical properties of peat soil. Primary canals of 15 meters could speed up washing organic acids, hence the decomposition of peat soil.

Table 2. Detailed dimensions and conditions of primary canals

| Block Plantation | Dimensions (m) | Condition                                                                 |
|------------------|----------------|--------------------------------------------------------------------------|
|                  | Long | Wide | Deep |                         |                                                                         |
| **Maintained canals** |      |      |      |                         |                                                                         |
| E23 B            | 494  | 3    | 1    | Maintained: the condition of drainage canals was clean                  |
| E24 A            | 699  | 3    | 1    | from water weeds and grasses that cover drainage canals.               |
| E24 B            | 874  | 3    | 1    |                                                                         |
| E25 A            | 1043 | 3    | 1    |                                                                         |
| **Not-maintained canals** |      |      |      |                         |                                                                         |
| E25 B            | 1242 | 3    | 1    | Not-maintained: drainage canals were filled with water weeds and thick grass. This condition cannot drain excessive water on peatlands. |
| E26 A            | 1298 | 3    | 1    |                                                                         |
| E26 B            | 1311 | 3    | 1    |                                                                         |
| E27 A            | 1477 | 3    | 1    |                                                                         |
| E27 B            | 1656 | 3    | 1    |                                                                         |
| E28 A            | 1861 | 3    | 1    |                                                                         |
| F23 B            | 2212 | 3    | 1    |                                                                         |
| F24 A            | 2013 | 3    | 1    |                                                                         |
| F24 B            | 1828 | 3    | 1    |                                                                         |
| F25 A            | 1639 | 3    | 1    |                                                                         |

There are 16 secondary canals at the research site. Well-maintained canals, located in block E23 B-E25 A, affected physical properties of peat soil, i.e. peat decomposition rate or the level of peat maturity and soil depth.

It appears that unkempt secondary canals can slow down the peat decomposition. Peat depth was considerably deep and very deep, with dominant maturity levels were hemic and fibric. Anaerobic conditions and slow decomposition were expected to occur in blocks E25 B-E28A and F23 B-F25A. According to Widyati [5], cultivating oil palm over peatlands must establish proper drainage systems. Macro drainage systems control water region-wide, while micro drainage systems administer water in
land units. The key to controlling ground water level is the dimension and the arrangement of drainage canals, especially the depth and floodgate installation to regulate water table [6].

3.2. Groundwater level
The depth of groundwater is measured below soil surface under saturated water. Observing groundwater level was carried out every ten days starting from August to October 2020, so there were nine observations. The data were combined with rainfall measurement from the same period.

Water level in peatlands is closely related to decomposition process of peat materials and vegetation cover. Fluctuation in water levels is the main driving factor for decomposition process of peat organic matter.

Fluctuation in groundwater levels at the research site is presented in Figure 2. Canal condition affects water fluctuation on peatlands. Maintained secondary canals accelerate drainage; hence, water level appeared deeper as shown in points of observation E1-E4. Meanwhile, observing E5-E10 and F1-F4 suggested that in neglected canals, weeds, grasses and silts affect fluctuations and inhibit water to move outside the soil system. Despite rainfall may influence fluctuations, observation during August-October 2020 was benefitted from the dry seasons; hence, it was negligible to this research. Observation point of E1, which was over mineral soil, showed that groundwater level was deeper and was influenced by terrain.

3.3. Peat depth and maturity level of surface layer (0-60 cm)
Depth and maturity level are peat soil characteristics directly observable in-situ. In general, peat depth at the research site was very deep (>300 cm) and has all three levels of decomposition, i.e. sapric, hemic and fibric. Peat depth measurements and maturity levels are presented in Table 3.
Table 3. Peat thickness

| Block | Point Observation | Peat depth (cm) | Peat class | Code Sample | Peat maturity (von Post level) |
|-------|-------------------|----------------|------------|-------------|------------------------------|
|       |                   |                |            |             |                              |
| E24 A | E2                | 75             | shallow    | E2 (0-60 cm) | H9 Sapric                    |
| E24 B | E3                | 60             | shallow    | E3(0-60 cm)  | H9 Sapric                    |
| E25 A | E4                | 340            | very deep  | E4 (0-40 cm.) | H9 Sapric                    |
|       |                   |                |            | E4 (40-60 cm) | H7 Hemic                     |
| E25 B | E5                | 322            | very deep  | E5 (0-26 cm) | H8 Sapric                    |
|       |                   |                |            | E5 (26-40 cm) | H4 Hemic                     |
|       |                   |                |            | E5 (40-60 cm) | H3 Fibric                    |
| E26 A | E6                | 295            | deep       | E6 (0-30 cm) | H4 Hemic                     |
|       |                   |                |            | E6 (30-60 cm) | H3 Fibric                    |
| E26 B | E7                | 460            | very deep  | E7 (20-20 cm) | *                            |
|       |                   |                |            | E7 (20-40 cm) | H4 Hemic                     |
|       |                   |                |            | E7 (20-60 cm) | H3 Fibric                    |
| E27 A | E8                | 615            | very deep  | E8 (20-20 cm) | H5 Hemic                     |
|       |                   |                |            | E8 (20-60 cm) | H3 Fibric                    |
|       |                   |                |            | E9 (0-15 cm) | *                            |
| E27 B | E9                | 525            | very deep  | E9 (15-60 cm.) | H4 Hemic                     |
|       |                   |                |            | E9 (0-15 cm) | *                            |
| E28 A | E10               | 960            | very deep  | E10 (15-60 cm.) | H4 Hemic                     |
| F23 B | F1                | 385            | very deep  | F1 (0-60 cm) | H4 Hemic                     |
| F24 A | F2                | 580            | very deep  | F2 (0-45 cm) | H5 Hemic                     |
|       |                   |                |            | F2 (45-60 cm) | H4 Hemic                     |
| F24 B | F3                | 510            | very deep  | F3 (0-60 cm) | H5 Hemic                     |
|       |                   |                |            | F4 (0-15 cm) | *                            |
|       |                   |                |            | F4 (15-50 cm) | H4 Hemic                     |
| F25 A | F4                | 765            | very deep  | F4 (15-60 cm) | H3 Fibric                    |

Information:

*) It was suspected that mineral soil buried due to frequent floods
1) Blocks with well-maintained secondary canals: manicured gardens, producing palm oil trees
2) Blocks with secondary canals were not maintained: abandoned gardens, juvenile palm oil trees

Figure 3. Peat depth at block E1-E10 (left) and block F1-F4 (right)

Figure 3 shows two blocks of depth observation, namely block E and block F. In block E, there were ten depth observation points, namely points E1-E10, while four observations were made over block F.
namely point F1-F4. This study showed that primary and well-maintained secondary canal greatly affected soil depth. As seen at points E1-E4, peat layer was shallower than other observation points. Well-maintained canals can drain excess water out into drainage canals, creating aerobic conditions that accelerate the decomposition process. In abandoned secondary canals (E5-E10 observation points), peat remained deep.

Peat found on top layer (0-60 cm) showed more mature, despite maturing peat is often found in deeper layers. This indicated that peat was formed in several periods, suggesting that peat in inner layer was once in surface. According to Agus et al. [7], a high level of maturity indicates that decomposition is nearly complete and lowers carbon reserves.

Table 3 shows three categories of peat maturity. Sapric maturity level was found in points E2-E5 (0-26); von Post method determined a level of maturity of H9. This can be seen from nearly perfect decomposition of fibers. Sapric maturity was associated with shallow to moderate peat depth, which was influenced by drainage canals. Drainage canals at these four observation points were connected to secondary drainage and primary drainage canals.

This research found that surface layer (0-60 cm) was predominantly hemic and fibric, which was affected by the condition of drainage canals. Different maturity level was observed in solum, where upper layer was more mature than the substratum. According to Masganti et al. [8], hemic peat is a transitional peat, has a fiber content of 33-66%, a volume weight of 0.1-0.19 g/ cm-3, a moisture content of 450-850%, with dark gray brown color to dark reddish brown. Meanwhile, sapric peat is the most mature, characterized by the lowest fiber content of <33%, volume weight ≥0.2 g/cm-3, water content <450%, and very dark to pitch black color.

3.4. C-organic, moisture content, bulk density and total pore space peat soil

Physical properties of peat soils are characterized by C-organic content, moisture content, volume weight, type weight and total peat soil pore space. The nature of peat soil at the research site was influenced by the condition of drainage canals. Contents of C-organic, moisture, bulk density (BD), particle density (PD) and total pore space is presented in Table 4.

C-organic content ranged from 38.05%-56.15% (Table 4), suggesting that the content was relatively high, except at points E2, E3, and E4 at a depth (0-40 cm). Low C-organic content at these points was influenced by well-maintained drainage canals, decomposition rate of peat soil and its location close to primary and secondary canals.

Decomposition process of organic matter leads to a reduced C level in peat soil; this was found at points E2, E3, and E4 at depths (0-40 cm). Rohiman [9] stated that C-organic content in peat soil depends on the level of decomposition. Generally, peat soil at advanced decomposition levels, such as hemic and sapric, has a lower soil C-organic content compared to fibric. With the condition of water saturated, peat soil was predominantly at maturity levels of hemic and fibric.

Peat with sapric maturity level has a lower C-organic level compared to hemic and fibric, because most organic matters in hemic and fibric remain intact in anaerobic condition. This environment inhibits decomposition process.

Peat soil is formed primarily from organic matters, causing peat soil ability to absorb high quantity of water compared to mineral soils. Water content at E2, E3, E4, and E5 was between 205.20 and 304.81%. Observation points around abandoned secondary canal contained high water content. Meanwhile, at point F4, middle (15-50) and bottom soil column (50-60) has water content of 462.18% and 528.37%, respectively. In this sense, different maturity level can probe groundwater storage. Susandi et al. [10] discovered that maximum water binding capacity for fibric peat was 580-3000%, while hemic and sapric was 450-850% and < 450%, respectively. Suwondo et al. [11] found that ability of fibric soils to absorb and to bind water was greater than the ones of hemic and sapric, in this order.
Peat soil has a pore space that can absorb and store water that has a higher capacity. The soil pore space is where water and air are stored, as well as the place of movement of water and plant nutrients. The roots in the plant will grow and develop in the pores of the soil. In Table 4, the total peat soil pore space at the research site ranged from 75.65%-89.79%. The pore space in peat soil is affected by the level of maturity and drainage canals created. Canals greatly affect the pores of peat soil if excessive

| Garden block | Observation point | Sample | C-organic(%) | Water content (%) | BV (g/cm³) | BJ (g/cm³) | TR P (%) |
|--------------|------------------|--------|--------------|------------------|------------|------------|----------|
| E24 A        | E2               | E2 (0-60 cm) | 38.05        | 205.20           | 0.37       | 1.50       | 75.65    |
| E24 B        | E3               | E3 (0-60 cm) | 38.52        | 260.22           | 0.28       | 1.50       | 81.08    |
| E25 A        | E4               | E4 (0-60 cm) | 38.63        | 239.75           | 0.32       | 1.50       | 78.77    |
|               |                  | E4 (40-60 cm) | 41.18        | 455.05           | 0.18       | 1.40       | 86.83    |

Secondary ducts - maintained

| Garden block | Observation point | Sample | C-organic(%) | Water content (%) | BV (g/cm³) | BJ (g/cm³) | TR P (%) |
|--------------|------------------|--------|--------------|------------------|------------|------------|----------|
| E26 A        | E6               | E6 (0-30 cm) | 50.41        | 304.81           | 0.22       | 1.40       | 84.27    |
| E26 B        | E7               | E7 (20-60 cm) | 53.07        | 516.75           | 0.17       | 1.30       | 87.04    |
| E27 A        | E8               | E8 (0-20 cm) | 53.65        | 362.29           | 0.23       | 1.40       | 83.57    |
| E27 B        | E9               | E9 (15-60 cm) | 52.84        | 399.81           | 0.21       | 1.40       | 84.92    |
| E28 A        | E10              | E10 (15-60 cm) | 54.52        | 443.09           | 0.19       | 1.40       | 86.35    |
| F23 B        | F1               | F1 (0-60 cm) | 50.41        | 369.01           | 0.23       | 1.40       | 83.45    |
| F24 A        | F2               | F2 (0-45 cm) | 47.80        | 336.01           | 0.27       | 1.40       | 80.99    |
| F24 B        | F3               | F3 (0-60 cm) | 50.58        | 480.44           | 0.18       | 1.40       | 87.42    |
| F25 A        | F4               | F4 (15-60 cm) | 51.62        | 528.37           | 0.16       | 1.30       | 87.49    |

Note:
1) Blocks with well-maintained secondary canals: manicured gardens, producing palm trees.
2) Blocks with abandoned secondary canals: drainage canals were covered in weeds (grass), neglected gardens and juvenile palm trees.

Volume weight determines solids in peat soil. This research found that volume weight varied greatly depending on decomposition levels. Mature peat soil has a greater volume weight. Fibric generally has a low volume weight because decomposition rate is limited, therefore, fiber content of organic material is more pronounced.

The weight of peat soil volume at the location of the study ranges from 0.13-0.32 g / cm³, can be seen from the data of the analysis of different volume weights at each maturity, the deeper the maturity level is raw so that the volume weight is smaller (Table 5). The weight value of fibrik peat soil volume in Indonesia is less than 0.1 g/cm-3 (0.06-0.15 g/cm3) and peat saprik is more than 0.2 g/cm3 and peat hemik/saprik between 0.1-0.3 g/cm3 (Masganti et al. 2014). The condition of the canal greatly affects the level of decomposition in the surface layer of peat soil, with the condition of maintained drainage canals can rain water out of the land to drainage canals so that it can create aerobic conditions on peatlands, this condition can accelerate the level of decomposition that occurs in peatlands. This is in line with hartatik leveling (2011) that the amount of peat soil volume weight is affected by drainage and mineralization so that the volume will shrink.
drainage canals result in irreversible peat soil conditions, in this condition peat soil will not reabsorb water.

The results of calculation data conducted by peat with saprik maturity have a total value of pore space ranging from 75.65%–81.13%, where drainage conditions at this observation point are maintained. So that it indirectly affects the level of peat maturity and affects the value of pores in peat soil, while peat with hemic and fibric maturity has a greater total pore space value between 80.99% to 89.79% which is affected by maturity or decomposition rates of peat soil. At this observation point has the condition of the secondary drainage canal that is not maintained, from the results of calculations carried out have a higher pore space value compared to the observation point whose condition of secondary drainage is maintained. Handayani [12] mentioned that the higher the volume weight of peat soil, the lower the total pore space and the lower the volume weight of peat soil, the higher the percent of total pore space. The decrease in the total pore space of peat soil indicates that fine-sized peat soil particles are increasing.

4. Conclusions
The impact of the condition of primary and secondary drainage canals with well-maintained and not-maintained conditions affect the characteristics and physical properties of peat soil on oil palm plantations of PT Batanghari Sawit Lestari. The depth and maturity level of peat is strongly influenced by the condition of drainage canals, the condition of drainage canals maintained shallower peat depth and the level of peat hardness in the surface layer (0-60 cm) sapric, while the condition of drainage canals that are not maintained gambunya depth is getting deeper and the level of peat maturity of hemic and fibric surface layers. Fluctuations in the height of peat groundwater levels at the research site are influenced by drainage canals and rainfall that occurs. Peat subratum at the research site was not affected by pyrite from observations made there was no indication of high pyrite content and the location of the research site was not affected by the tides of the sea.

C-organic content, moisture content, volume weight, type weight and total peat soil pore space at the research site were affected by drainage canal conditions and peat maturity levels, condition of well-maintained drainage canals weighing > volume of 0.2 g/cm3, C-organic < 48.20%, and type weight of 1.50. Water content and total pore space will be smaller if the maturity level of peat is getting mature seen in the water content of <276.78% and the total pore space <81.13%. While in the condition of drainage canals that are not maintained the level of maturity of the surface layer (0-60 cm) is hemic and fibrik, the volume weight < 2 g / cm3, C-organic > 48.20%, and has a type weight based on maturity levels of 1.40 and 1.30. The water content and total peat soil pore space the rawer the decomposition rate will be greater the value of water content >304.81% and the total peat soil pore space > 81%. Efforts in the use of peatlands for plantation should pay close attention to the condition of drainage canals such as build canal blocking. Size of drainage canals, and the treatment of drainage canals should be more considered because excessive drainage will affect the characteristics and physical properties of peat soils.

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