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SOIL PHYSICAL PROPERTIES OF TROPICAL PEATLAND AT THREE DIFFERENT TYPES OF LAND USE IN KUBU RAYA DISTRICT OF WEST KALIMANTAN, INDONESIA

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SUMMARY

Tropical peatland in West Kalimantan, Indonesia, has become more intensively used not only for agricultural land, but also for other uses. This study is aimed to observe changes in soil physical properties of peatland having been used as secondary forest, temporarily open land, and as oil-palm plantation. Soil samples were collected from study sites in Kubu Raya District of West Kalimantan. Parameters include water table in each site and in secondary canal, field capacity water content, bulk and particle density, porosity, hydraulic conductivity, and soil maturity levels. The results showed that water table was deeper in temporarily open land (66.35 cm) and in oil palm plantation (64.0cm), and shallow in secondary forest (54.26cm). Percentage of field water capacity was highest in secondary forest (79.65%), lower in temporarily open land (77.62%), and lowest in oil palm plantation (75.41%). Water table at secondary canal was also deeper in temporary open land (109cm), higher in oil palm plantation (100.5cm), and highest in secondary forest (99.25cm). Furthermore, bulk density was highest in oil palm plantation (0.46g/cm^3), lower in secondary forest (0.29g/cm^3), and lowest in temporarily open land (0.23g/cm^3). Particle density was also highest in oil palm plantation (1.59g/cm^3), lower in temporarily open land (1.34 g/cm^3), and lowest in secondary forest (1.26g/cm^3). Meanwhile, porosity was lowest in oil palm plantation (70.92%), higher in temporarily open land (78.9%), and highest in secondary forest (81.80%). Hydraulic conductivity was also highest in oil palm plantation (10.61cm/h), lower in temporarily open land (7.88 cm/h), and lowest in secondary forest (5.23cm/h). Finally, there were vary in peat soil maturity levels, namely hemic and fibric in secondary forest, hemic, fibric, and sapric in temporarily open land, and only sapric in oil palm plantation. Conclusion, different management types had caused changes in soil physical properties of tropical peatland in District of Kubu Raya, West Kalimantan, Indonesia.

Keywords*: soil physical properties, tropical peatland, land use*

INTRODUCTION

Tropical peatland in West Kalimantan, Indonesia, has become more intensively used not only for agricultural land, but also for other uses. The shift to other uses, especially for oil palm plantation and for industrial plant forest, has become more concern because it might have caused a destructive impacts to both local and regional environment. Destruction of tropical peatland ecosystem will impact both its in-situ and ex-situ environmental conditions (Noor, 2013). Data from previous study showed that land use change from tropical peat forests into cleared and drained peats used for intensive timber harvesting, oil palm and industrial plantations has greatly degraded major ecological function of tropical peats as carbon storage (Anshari *et.al.*, 2010).

Recently, as newly developed district in West Kalimantan, government of District of Kubu Raya has been actively promoting their tropical peatland to be developed either for agricultural land, oil palm plantation, industrial timber plantation, or other uses. In Rasau Jaya District, in the last few year, oil palm plantation areas has increased about 4.38% per year. In 2011, there was only about 172 ha of oil palm plantation. Then, in the year of 2012 and 2013 oil palm plantation areas increased to 534 and 609 ha, respectively (BPS, 2014). This type of development has greatly increased public concern, especially because it might have a great impact on tropical peatland degradation in Kubu Raya District. This study is aimed to observe changes in soil physical properties of tropical peatland having been used as secondary forest, temporary open land, and as oil-palm plantation. This study only focus on the parameters representing peat soil physical properties as they are too fragile to field management activities. Thus, this paper discuss the impacts of three different types of land use on soil physical properties of tropical peatland.

METHODS

The three study sites are located in the Village of Rasau Jaya 3 and in the Village of Rasau Jaya Umum, Kubu Raya District of West Kalimantan. They represent three types of land use; secondary forest, temporarily open land, and oil palm plantation. The secondary forest is belong to local people. This secondary forest is the natural forest that previously had been logged by local peoples. At the moment, the forest now is left uncultivated for its natural resources stocks. Temporarily open land is a site belong to PT. Mitsubishi that formerly prepared for industrial timber plantation. It was mechanically opened in 2006, however, up to now it is not yet planted and left opened. Some part of it is naturally inhabitated by acasia trees and shrubs. Oil palm plantation site is belong to PT. Sumatera Unggul Makmur. It was mechanically opened and drained in 2010, and planted in 2011. The planting density was 160 palms per hectar. Total planted areas is about 196 ha.

Soil samples were collected using ring sample to collect undisturbed soil samples from each site. Undisturbed soil samples were used for its physical properties analyses, while disturbed samples were used for its chemical properties analyses. Soil samples were analysed in both Soil physical Lab, and Soil Chemistry and Fertility Laboratories of Faculty of Agriculture, Tanjungpura University. Parameters observed include water table depth in each site and in secondary canal, bulk density, particle density, porosity, hydraulic conductivity, field water capacity, and soil maturity levels.

RESULTS

Water Table Depth

Data on water table depth presented in figure 1 shows that average data in each observation site is higher in temporarily open land (66.35 cm) and lower in oil palm plantation (64.0cm), and lowest in secondary forest (54.26cm). Similar trend is also showed for average water table data in secondary canal.

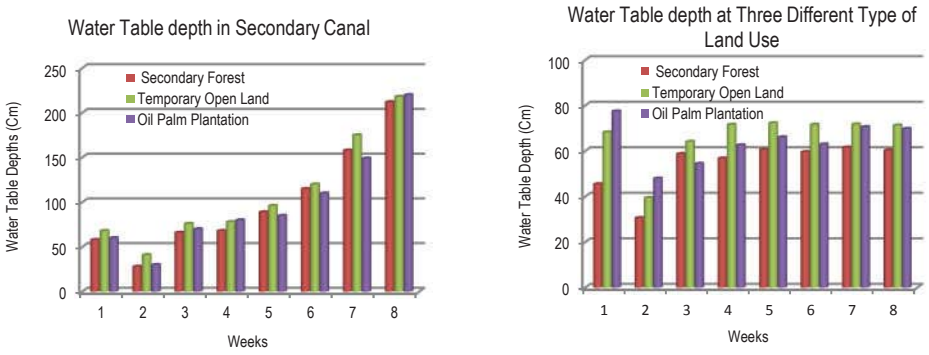

Figure 1: Water Table in Secondary Canal (left) and Water Table Depth of Tropical Peatland at Three Different Types of Land Use (right).

During eight weeks observation, water table at secondary canal was also higher in temporary open land (109cm), slightly lower in oil palm plantation (100.5cm), and lowest in secondary forest (99.25cm). Week 8 of observation was the peak of dry season of this year. This data shows that secondary forest dominated by young trees has more capacity to retain water compared to that of either in temporary open land and in oil palm plantation.

Soil Bulk and Soil Particle Density, Hydraulic Conductivity, and Porosity

Data on soil bulk density is highest in oil palm plantation (0.46g/cm^3), lower in secondary forest (0.29g/cm^3), and lowest in temporarily open land (0.23g/cm^3) (Figure2). Similar trend for data on soil particle density which is also highest in oil palm plantation (1.59g/cm^3), lower in temporarily open land (1.34 g/cm^3), and lowest in secondary forest (1.26g/cm^3). This trend is also occured for data on hydraulic conductivity, it is highest in oil palm plantation (10.61cm/h), lower in temporarily open land (7.88 cm/h), and lowest in secondary forest (5.23cm/h). On the other hand, data for porosity was lowest in oil palm plantation (70.92%), higher in temporarily open land (78.9%), and highest in secondary forest (81.80%).

Field Water Capacity and Soil Maturity

Field water capacity is the amount of water remaining in a soil after the free water has been allowed to drain away after it is saturated. Findings data show that field water capacity percentage was highest in secondary forest (79.65%), lower in temporary open land (77.62%), and lowest in oil palm plantation (75.41%) (**Figure** 3).

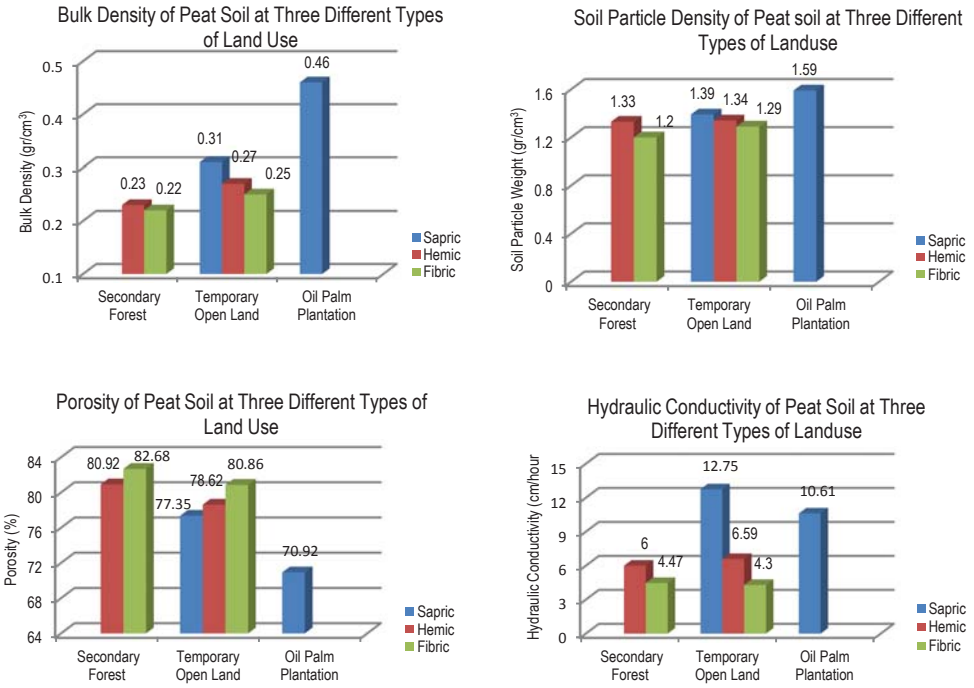

Figure 2: Soil Bulk Density, Particle Density, Porosity, and Hydraulic Conductivity of Peat Soil at Different Types of Land Use.

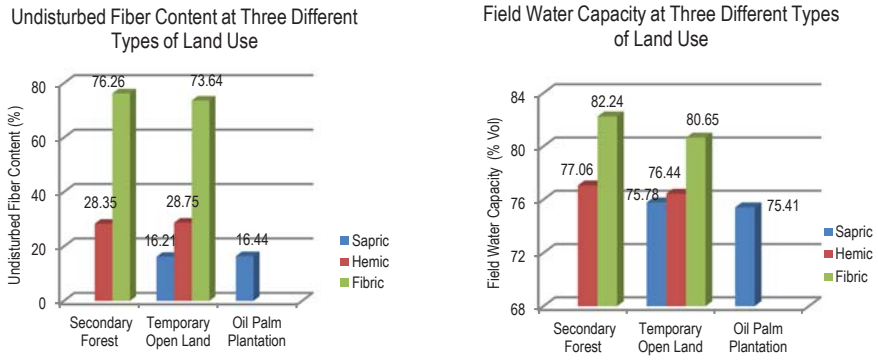

Figure 3: Percentage of Undisturbed Fiber Content (left) and Field Water Capacity (Right) in Peat Soil at Different Types of Land Use.

To study peat maturity levels we observed it through its undisturbed fiber content as proposed by Mc Kenzie (19.). Beside that we also used quick field method of Von Post. Both methods showed relatively similiar results that there were vary in soil maturity levels among observation sites, namely hemic and fibric in secondary forest, hemic, fibric, and sapric in temporarily open land, and only sapric in oil palm plantation (Figure 3). Method of Mc Kenzi resulted the data for average undisturbed fiber content as presented in Figure 3 (left). The higest percentage for average undisturbed fiber content was found in secondary forest (52.30%), followed by percentage in temporary open land 39.53%), and the lowest is found in oil palm plantation site (16.44%).

C-Organic and C/N Ratio

Soil organic matter is a complex and varied mixtured of organic substance. The results on avergae C-organic content and C/N ratios presented in Figure 4 below showing that the highest C-organic percentage is found in secondary forest (57.09%), followed by in temporary open land (55.0%), and lowest in oil palm plantation (32,09%). Similar trend occured for average data of C/N ratios, the highest also found in secondary forest (24.09), followed by in temporary open land (19.27), and lowest in oil palm plantation (17.73).

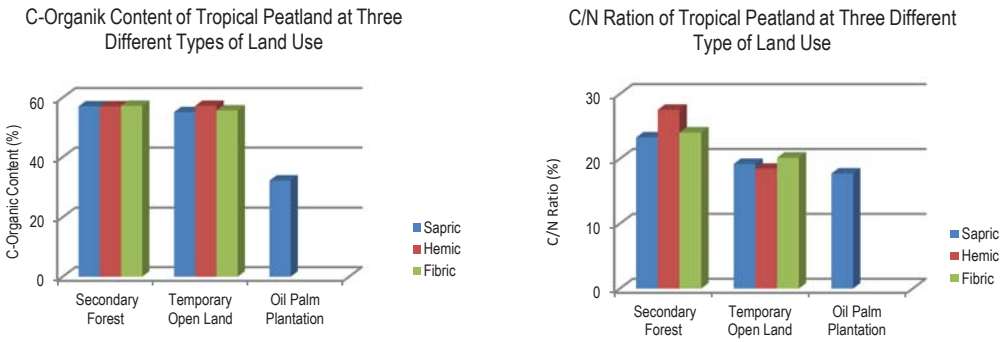

Figure 4: C-Organic content (left) and C/N Ratio (Right) of Tropical Peatland at Different Types of Land Use.

DISCUSSION

Water Table Depth

This study found that the type of land use has affected water table dept in each observation site. The average data for water table depth in each observation site is higher in temporarily open land and lower in oil palm plantation, and lowest in secondary forest. Similar trend is also showed for average water table data in secondary canal (Figure1). Since there are different in management strategy and also in dominating vegetation species within each site, it was predictable that water table will be higher in temporarily open land and lower in oil palm plantation. These data on water table depth have similar trend to that of Soewandita (2008) where in reclaimed plantation water table was higher than that of in forest. A significant decrease of water table, either in secondary canal or in each study site (Figure1), during eight weeks observation is mainly due to climate condition. During measurement period, from July to September 2015, it was a long dry season accompanied with heavy smoke covered most part of West Kalimantan Province. The fluctuation in water table depth is parallel with seasonal change, it increases during rainy season and decreases regularly when dry season (Asdak, 1995).

Bulk and Particle Density, and Hydraulic Conductivity,

Average data of bulk density, particle density, and hydraulic conductivity have similar trend, highest in oil palm plantation and lower in temporary open land and secondary forest. Bulk density which is higher in oil palm plantation than that of in secondary forest was similar to the data found by Melling et.al. (2005). Bulk and particle densities represent the soil characteristics of the mass per unit volume (Miller and Donahue, 1990). Therefore, the higher the values mean the denser the soil. Furthermore, hydraulic conductivity shows the readiness with which a liquid, such as water, flow through a solid, such as soil, in response to given potential gradient (Brady and Weil, 2008). Therefore, denser soil may result in higher soil hydraulic conductivity, as it is the proportionality factor in Darcy's Law (Miller and Donahue, 1990). These findings show that different type of land use has resulted different effects on bulk and particle densities so that its hydraulic conductivity.

Porosity and Field Water Capcity

As mentioned above that data for percentage of porosity was lowest in oil palm plantation, higher in temporarily open land and highest in secondary forest. It was in contrast to that of data either on soil bulk and particle densities, or data on hydraulic conductivity. It shows that the denser the soil the lower its soil porosity, as it shows the percentage volume of the total soil bulk not occupied by soil particles (Brady and Weil, 2008). It is clearly explain that pore space is greatly affected by both bulk and particle densities. Similar trend is also found in data on percentage of volume field water capacity (Figure3). The relationship between these porosity and field water capacity data is clear since field water capcity is expressing the amount of water remaining in a soil after the free water has been allowed to drain away after it is saturated (Miller and Donahue, 1990). The more porous the soil, the higher its field water capacity as it is presented in Figure4. In the case of peat soil, it is not unusual when peat soil may hold a mass of water equal to 200 to 400% of its dry weight (Brady and Weil, 2008). However, water content of peatsoil is greatly affected by its maturity level, (Barchia, 2006). Less mature the peat soil (fibric and hemic), the higher its field water capacity (see Figure4).

C-organic, Undisturbed fiber content, C/N Ratios, and Peat Soil Maturity Levels,

Findings on the characters explained above are greatly supported by data on the C-organic content at which the highest C-organic percentage is found in secondary forest, lower in temporary open land, and lowest in oil palm plantation (Figure4). For average data of C/N ratios, the highest is also found in secondary forest, lower in temporary open land, and lowest in oil palm plantation. This ratios is likely showing its rate of decomposition

(Anshari *et.al.*, 2010). This data is also parallel with the data on undisturbed fiber content that is usually used to expres its maturity level (Figure3). Therefore, data for C-organic, C/N ratios, and undisturbed fiber content will be higher in less mature site such as in secondary forest and temporary open land than that of in more mature site such as in oil palm plantation. Figure 3 shows that there is only one maturity level (sapric) in oil palm plantation, two levels (fibric and hemic) in secondary forest, and three maturity levels (fibric, hemic, and sapric) in temporary open land. Bulk and particle density also become higher (denser) in oil palm plantation (sapric material), because they have decreased in pore space, lost their carbon and fiber content due to decomposition process. Porosity, C-organik, undisturbed fiber all are decreased in mature peat soil (Figures. 2, 3 and 4). The cultivation tend to lower pore space compare to that uncultivated soil, and this reduction usually is associated with a decrease in organic mater content (Brady and Weil, 2008). The decomposition process might have been fastened when the land use is changed from peat forest into cleared and drained management (Anshari *et al.*, 2010). On the other hand, average data for bulk density and particle density are lower in both temporary open land and secondary forest sites because they still have higher undisturb fiber and C-organic content (see Figure3 and Figure4). Therefore, in these both temporary open land and secondary forest sites vary in their maturity levels.

CONCLUSION

It is found that different management types had caused changes in soil physical properties of tropical peatland in Kubu Raya District, West Kalimantan, Indonesia. Industrial timber plantation, oil palm plantation and all their field management activities might have greatly fastened peat soil maturity, increased not only its soil bulk density but also its particle density and its hydraulic conductivity. As the results other characteristics such as soil porosity, field water capacity, and water table in oil palm plantation site are lowest compare to that of in secondary forest and that of in temporary open sites. It is recommended to use proper management strategies and choose less destructive impact technologies when using tropical peatland either as agricultural land, industrial timber plantation, oil palm plantation, or another cleared and drained field management practices.

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