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CHANGES IN PHYSICAL AND CHEMICAL PROPERTIES OF PEAT IN VARIOUS AGES OF OIL PALM PLANT IN EAST KOTAWARINGIN DISTRICT

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KEYWORDS
natural forest, peat, oil palm, physical, chemical, change.

ABSTRACT

The purpose of this study was to examine changes in the physical and chemical properties of natural peat forests and peatlands designated for oil palm plantations at various ages of oil palm planting. The research was carried out in 4 (four) locations in East Kotawaringin Regency, namely: (1) Natural peat swamp forest in Kota Besi District (2) Peat land designated for oil palm plantations planting age less than 4 years in Parenggean District; (3) Peat land designated for oil palm plantations with a planting age of 4-10 years in Cempaga District; and (4) peat land designated for oil palm plantations with a planting age of more than 10 years in Mentawa Baru District, Ketapang. The results showed that the peat land designated for oil palm plantations caused changes in the physical and chemical properties of the peat soil. Changes in the physical properties of peat soil are indicated by the color of the peat soil which changes from very dull red in natural peat forests to reddish black in oil palm plantations. Peat maturity changes from fibric in natural peat forest to hemic and sapric on peatland designated for oil palm plantations. The water content has decreased significantly, the older the age of the oil palm plant, the water content will decrease. In terms of bulk density, the older the age of oil palm plantations, the higher the density of peat soils. The water level in oil palm plantations has increased when compared to natural peat forests. Changes in chemical properties were indicated by an increase in peat soil pH, total N, and available P, while a decrease occurred in the C-Organic content. An increase also occurred in the content of K-dd, Ca-dd, Mg-dd, Na-dd, and CEC with increasing age of oil palm plants. When viewed from the relationship pattern of each physical characteristic, water content has a positive relationship with fiber content, the higher the water content will be followed by the higher fiber content or vice versa. Bulk density has a negative relationship with fiber content and moisture content, which means that an increase in the bulk density of peat soil will be followed by a decrease in fiber content and moisture content. The relationship pattern of chemical properties shows that the pH (H2O) of peat soil has a positive relationship with organic C, total N, available P, and Cation Exchange Capacity (CEC). High or low peat acidity will be proportional to the high or low -organic, N-total, P-available, and Cation Exchange Capacity (CEC).

INTRODUCTION

Peatlands are unique ecosystems that have a high role in providing environmental services. Peat has production functions, water storage, biodiversity habitat, protection and economic functions. However, peatland is a very unique land and very vulnerable to land use change. The slightest change occurs in the natural balance between water, soil, and vegetation, it will cause peat damage which will later experience difficulties in its recovery. Peatlands which in their natural state have low fertility can be converted into highly productive lands that can provide a level of profit equal to that of mineral soils. Harmonization between these various functions requires governance that utilizes appropriate and environmentally friendly technology to maintain the existence of peatland ecosystems so that they are able to meet human needs in a sustainable manner.

The use of peatlands is undergoing rapid changes in the form of management transfers in the form of agricultural development. Until the last few years, efforts to develop agriculture on peatlands on the island of Sumatra are still running rapidly, even in Kalimantan its development has accelerated. One of them is the conversion of peatland management into oil palm plantations. This is more because mineral land is limited, so that peatlands including natural peat forests are one of the options for developing oil palm plantations. Oil palm plantations are one of the important plantations in Indonesia.

Indonesia's oil palm plantation area in 2010 reached 8.43 million and in 2015 it reached 11.3 million hectares (Ministry of Agriculture, 2016). The area of peatlands in Indonesia reaches 20.6 million hectares, which is dominantly spread over the islands of Sumatra, Kalimantan and Papua. Specifically for the Province of South Sumatra, peatlands including peat mineral soils covering an area of 1.48 million hectares and 8.31 percent or 120,400 ha are used for oil palm plantations (Heryanto, 2005) and (Miettinen, Shi, & Liew, 2012).

Changes in the use of peatlands, especially from peat forests to oil palm plantations, of course have a negative influence on the diversity of living things, especially plants (Fitzherbert et al., 2008; Sodhi, Koh, Brook, & Ng, 2004; Wilcove, Giam, Edwards, Fisher, & Koh, 2013) and affect biological processes in ecosystems such as production and litter decomposition through changes in plant composition (Hättenschwiler, Coq, Barantal, & Handa, 2011) is a major function in the carbon cycle and ecosystem function (Dixon, Harrison, & Lamb, 1994), (Houghton, 2005), (Del Grosso et al., 2008) (Pan, 2011). The conversion of forest land into oil palm plantations is the dominant factor in the peat ecosystem that causes peatland degradation (Riwandi, 2003). Moreover, the development of oil palm on peatlands is also faced with the problem of potential CO2 emissions as a greenhouse gas (GHG) (Hooijer et al., 2006), and the loss of biodiversity (Riwandi, 2003). Land clearing activities that do not pay attention to environmental biophysical characteristics will cause peatlands to degrade and become abandoned land (Noor, 2001)

Peat soil characteristics are very different from mineral soils (Staff, 2003). The difference lies in the chemical, physical, and biological properties of the soil. The characteristics of natural peat can change after land clearing or use, so it is called fragile. Therefore, the use of peatlands for agriculture will cause various problems when compared to mineral soils, so that the use of peatlands requires more inputs and the management model is more complex.

Presidential Decree No. 32 of 1990 confirms that peat with a thickness of >3 m is designated as a conservation area. This is because the thicker the peat layer, the more fragile the peat is

By maintaining it as a conservation area, its function as a hydrological buffer is maintained. Peat with a depth of < 3 m can be used for agriculture provided that the mineral layer under the peat is not quartz sand or pyrite clay, and the maturity level is not fibric. Furthermore, the Ministry of Agriculture recommends for food crops and horticulture directed at shallow peat (< 100 cm) and for annual crops on peat with a thickness of 2–3 m (Sabiham & Pramudya, 2010). The basis for consideration is that shallow peat has a relatively higher fertility rate and lower environmental risk than deep peat.

The nature of Indonesian peatlands varies greatly in terms of physical, chemical and biological properties as well as environmental conditions. The condition of the variation in the nature of the peat indicates the existence of peatlands that can be used for agricultural development and some that need to be maintained to preserve the environment (Masganti, 2013). Peatland is one type of ecosystem that is formed under anaerobic conditions (poor drainage) in tidal swamps or lebak and contains organic matter (>50%) from the accumulation of plant residues. Peatlands provide several ecological, economic, and social services that have the potential to be developed as a life support system (Galbraith, 2005); (Egoh et al., 2007).

Tropical peatlands have a large diversity of physical and chemical properties, both spatially and vertically. Its characteristics are largely determined by the thickness of the peat, substratum or mineral soil under the peat, maturity, and the presence or absence of enrichment from overflowing rivers in the vicinity. These characteristics of peatlands should be used as a reference in the use of peatlands, especially for oil palm plantations so that high and sustainable productivity is achieved. The purpose of this study was to examine changes in the physical and chemical properties of natural peat forests and peatlands that have been converted into oil palm plantations at various ages of oil palm planting.

METHOD RESEARCH

Research Location and Time

The research was conducted in East Kotawaringin Regency, Central Kalimantan Province with the determination of 4 (four) research locations , each of which is: (1) Natural peat swamp forest in Kota Besi District (112 ^{0} 41' 35.73" east longitude, 2 ^{0} 22' 0.57" LS) , (2) peat land designated for oil palm plantations with less than 4 years of planting age in Parenggean District (112 ^{0} 42' 27.53" east longitude 2 ^{0} 6' 28.54" south latitude) ; (3) Peat land designated for oil palm plantations between 4-10 years of age in Cempaga District (112 ^{0} 54' 42.58" east longitude 2 ^{0} 16' 10.71" south latitude) ; and (4) peat land designated for oil palm plantations with planting age above 10 years in Mentawa Baru District, Ketapang (112 ^{0} 42' 27.53" east longitude 2 ^{0} 6' 28.54" south latitude). Peat soil analysis to measure the physical and chemical properties of peat was carried out at the Soil Laboratory of the Faculty of Agriculture, Brawijaya University and Palangka Raya University. The research time from preparation to data processing was carried out for 10 (ten) months, starting from June 2017 to March 2018.

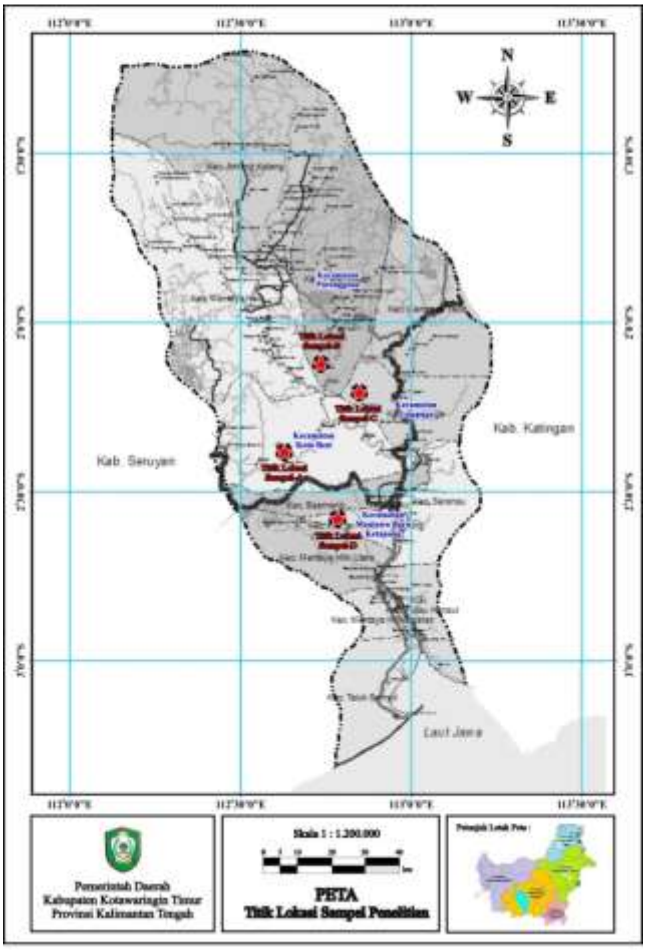


Figure 1. Research Location Map

Research procedure

Plot Creation

Observation plots were made measuring 20 mx 20 m with the determination of observation plots carried out randomly as many as 3 (three) plots and 5 (five) soil sampling points at each research location. The total sampling of soil is 60 points.

Soil Sampling

Composite sampling of peat soil at 5 (five) points as replicates in each plot at a depth of 20 cm. The weight of the soil taken at each point is 500 grams, so that each observation plot is 2. 500 gr. Soil samples from each point in one plot were mixed in one place until homogeneous to represent one observed plot, then 100 g per point or 500 g were taken for each plot.

Observation Variables

The observed variables consisted of the physical and chemical properties of the peat soil. The physical properties include soil temperature, peat color, *bulk density*, water content, peat thickness, peat maturity (fiber content), and water table height (*water table*), while the chemical properties consist of pH (H_2O), C-Organic, N-total, P-available, K-dd, Ca-dd, Mg-dd, Na-dd, and CEC.

Table 1
Description of Materials, Tools, and Testing Procedures

Parameter	Ingredient	Tool	Testing Procedure
Physical Properties			
Soil Temperature	Peat	soil thermometer	Digital thermometer
Peat Color	Peat	Measuring cup, beaker, 100 m sieve, MSCC Color Manual	*Munsell Soil Color Charts*
Filling Weight (*Bulk density*)	Peat	Rings, Scales, desiccators, petridis and goblets, rulers.	Ring (Core) sample
Soil Water Content	Peat	Rings (Core) Peat soil samples	Gravimetric (Blakermore *et al* ., 1987).
To the thickness of Peat	Peat	Peat Drill	Boring Method
MaturityPeat	Peat	Peat Drill	Mckinzie method
Water Level (*Water table*)	Peat	Hobo U20 Digital *Water table* pipe , Onset, Bourne, USA	Digital *water table* electric sensor
Chemical Properties			
pH (H_2O)	Peatland and aquades	Bottles, shakers, scales, pH meters	PH meter
C-Organic (%)	Peat, H_2O, H_2SO_4, NHCl, NaOH, HCl, H_3BO_3	Scales, tubes, erlenmeyer, pipettes	Kjeldahl
N-total (%)	Peat soil, K2Cr2O7, H_2SO_4, H_2O, diphelamine, H3PO4, $FeSO_4$	Sieve, scale, erlenmeyer, pipette,	*Walkley and Black*
P-available (ppm)	Peat soil, Bray I solution, filtrate, phosphate B	Spectrophotometer, balance, shaker, erlenmeyer, filter paper, pipette, tube	P-Bray I
Interchangeable Bases (K-dd , Ca-dd , Mg-dd , Na-dd)	Peat soil, NH_4OAc	Scales, centrifuge tube, glass stirrer, strainer	Extraction of ammonium acetate, 1 *N* pH 7.0
CEC (me/100 g)	Peat soil, ammonium acetate (NH_4OAc)	Scales, centrifuge tube, glass stirrer, strainer	Extraction of ammonium acetate, 1 N pH 7.0

Data analysis method

Data analysis of physical and chemical properties of peat soil was carried out descriptively with the help of tables and graphs. Regression and correlation methods were used to determine the pattern of correlation between several physical and chemical properties of peat soil with the help of the Ms. Excel 2016

RESULTS AND DISCUSSION

Physical Properties of Peat

The physical properties of peat soils are a very important factor in determining the level of productivity of plants cultivated on peatlands, because they determine the conditions of aeration, drainage, load-bearing capacity, and the level or potential for degradation of peatlands. In the use of peatland for agriculture, the characteristics or physical properties of peat that are important to study are peat maturity, water content, *bulk density*, *bearing capacity*, *subsidence, and irreversible* dryness. *drying*) ((Agus & Subiksa, 2008).

Table 2

Physical properties of natural peat forest and peatland designated for oil palm plantations in East Kotawaringin Regency

Parameter	Secondary natural forest	Oil Palm Planting Age		
		<4 years	4-10 years	>10 years
Soil Temperature (^{0}C)	29.39	27.61	26.58	28.32
Peat Thickness (m)	1.34	0.98	0.76	0.42
Peat Color	10 R/2.5/2	10 R/2.5/1	5 YR/2.5/1	10 R/2.5/1
	Chocolate	Dark brown	Dark chocolate	Black
Peat Maturity	Fibric	Hemic	Hemic	Saprik
Fiber Content (%)	76.86%	29.41%	27.36%	14.32%
Water content (%)	711.36	668.22	625.08	354.98
Filling Weight (g/cm ^{3})	0.16	0.27	0.34	1.28
Water Level(cm)	58.15	58,30	59.39	58,19

Peat Soil Temperature

Soil temperature in natural peat forest is 29.39 ^{0} C, while the temperature of peat soil in oil palm plantations less than 4 years old is 27.61 ^{0} C, oil palm planting age is between 4-10 years 26.58 ^{0} C, and coconut oil palm planting age over 10 years is 28.32 ^{0} C. The temperature of the peat soil is still included in meeting the requirements for oil palm growth. Oil palm requires an optimum average annual air temperature for oil palm of 25 ^{o} C-28 ^{0} C, but can still produce at an average annual air temperature of 240 $^{C.}$ The combination of rainfall and air temperature is very likely to play a role in the mechanism opening and closing of leaf stomata which leads to the process of photosynthesis (Risza, 2008).

Making drainage causes a decrease in groundwater, then changes in temperature and humidity in the peat layer near the surface, thus accelerating the weathering process and decreasing the peat surface. Changes in temperature that occur are caused by the condition of the oil palm plantations at each planting age. Oil palm plants require a high enough intensity of sunlight to carry out photosynthesis in carrying out their life activities that are useful for growth. Photosynthesis in oil palm leaves increases in line with the condition of the leaf area and the amount of chlorophyll that can receive light.

Thickness peat

The peat thickness ranges from 0.42 m in oil palm plantations with a planting age above 10 years and 0.98 m in oil palm plantations with planting age of less than 4 years. Natural peat forest has a thickness of 1.34 m. This peat thickness meets the required criteria to ensure the sustainability of peatland functions, namely the thickness of the peat layer is less than 3 (three) meters (Ministry of Agriculture No. 14 of 2009), because the thickness of peat > 3 m is designated as a conservation area (Presidential Decree No. 32 of 1990). The thicker the peat, the more important its function is in providing protection to the environment and conversely the environmental conditions of thick peatlands are more fragile when converted into agricultural land.

Agriculture on thick peatlands is more difficult to manage and requires expensive costs due to low fertility and carrying capacity, making it difficult for vehicles to transport agricultural facilities and crops to pass (Agus & Subiksa, 2008). difficult to reach the mineral layer that is below it. This results in disrupted plant growth, and causes plants to easily tilt and collapse, especially in annual plants or plantation crops (Suswati, Hendro, Shiddieq, & Indradewa, 2011).

Peat soil color

Soil color is the most obvious and easily determined soil property. Although color has little effect on the usability of the soil, it can sometimes be used as an indication of the existence of special properties of the soil. The color of the peat soil changes from brown in natural peat forest to dark brown in oil palm plantations at planting age less than 4 years, blackish brown in oil palm plantations between 4-10 years and black in oil palm plantations above planting age. 10 years. The color of the peat soil changes from brown, dark brown, blackish brown to black. Differences in soil color are generally caused by differences in organic matter content, the higher the organic matter, the darker the soil color (Suswati et al., 2011).

Peat maturity (fiber content)

Peat maturity is defined as the level of weathering of organic matter which is the main component of peat soil. Peat maturity greatly determines the level of peatland productivity, because it greatly affects the level of peat soil fertility, and nutrient availability. Peat maturity level is one of the permanent limiting factors that cannot be corrected through technical cultural measures. Thus, if these two limiting factors are in the heavy category, then the decision to cultivate oil palm in tidal swamp land should be reviewed. Peat maturity level which is a weight limiting factor is at the fibric level (raw peat), while peat depth >3 m can be classified as a weight limiting factor for oil palm cultivation.

The conversion of natural peat forests into oil palm plantations causes changes in peat maturity. Natural peat forest has a Fibric maturity level with a fiber content of 76.86%, the maturity level of peat in oil palm plantations at planting age is less than 4 years and oil palms at planting age between 4-10 years is hemic, each has a fiber content of 29.41% and 27.36%. Oil palm plantations over the age of 10 years have a sapric maturity level with a fiber content of 14.32%.

Peat soil has various maturity levels because it is formed from different materials, environmental conditions and time. Ripe peat (sapric) tends to be finer and more fertile. In contrast, the immature (fibric) contains a lot of crude fiber and is less fertile (Najiyati, Muslihat, & Suryadiputra, 2005). The level of ripeness of saprik has a high content of organic matter and is in a state that has been completely weathered. Peat soil with a hemic maturity level has a high content of organic matter, but the organic matter has not decomposed completely so that it cannot provide sufficient nutrients for plants. Fibric peat is peat with a young maturity level so it is not suitable for oil palm cultivation.

Water content

Peat water content is water held by peat or water that fills part or all of the soil pores or the amount of water that can be absorbed by the soil (Andriesse, 2003). The water contained in peat soils can reach 300-3000% dry weight, much higher than mineral soils whose ability to absorb water is only around 20-35% dry weight (Elon, 2011). Peatlands have the ability to absorb and store water much higher than mineral soils. The dominant composition of organic matter causes peat to be able to absorb relatively high amounts of water.

The highest peat soil moisture content occurs in natural peat forests (711.36%), while in oil palm plantations, the lowest water content occurs in oil palm plantations with planting age above 10 years (354.98%), oil palm plantations at planting age between 4-10 years (625.08%), and water content in oil palm plantations at planting age less than 4 years (668.22%). The longer the age of oil palm planting, the lower the water content. This condition is caused by changes in the level of maturity (decomposition) of peat that occurs in oil palm plantations.

The availability of peat groundwater is not only based on maturity, but is also influenced by rainfall or irrigation water, the ability of the soil to hold water, evapotranspiration, and groundwater level. The ability of peat soil to absorb and bind water in fibric peat is greater than hemic and sapric peat, while hemic peat is greater than sapric peat (Suwondo, Sabiham, Sumardjo, & Paramudya, 2012).

Fill Weight

Bulk density or often referred to as volume weight is a physical property of the soil that indicates the mass of solids in a certain volume. The lowest density of peat soils occurred in natural peat forest (0.16 g/cm^3), while in oil palm plantations, respectively, for oil palm plantations, the planting age was less than 4 years (0.27 g/cm^3), oil palm plantations were between 4-10 years old (0.34 g/cm^3), and the highest was in oil palm plantations over 10 years old (1.28 g/cm^3).

The low density of peat results in low soil carrying capacity so that plants experience difficulties in anchoring their roots, as a result many annual plants that grow lean and fall (Noor, 2001).

Water Level (*Water table*)

Peatlands are also often known as wetlands due to the condition of the groundwater (*water table*) which is close to or above the peat surface throughout the year and fluctuates with the intensity and frequency of rainfall. The optimal water level varies with the depth of the root zone of the plant. It also has needs that vary temporally depending on the phase of plant growth and also tillage activities such as cultivating and harvesting.

(*water table*) occurs in natural peat forest, which is 89.15 cm , while the lowest water table occurs in oil palm plantations with a planting age of more than 10 years (58.19 cm), followed by oil palm plantations of less than 10 years. than 4 years (58.30 cm), and oil palm planting age between 4-10 years (59.39 cm). The water table of peat in natural peat forest shows the groundwater level which is still relatively high (close to the surface), while in coconut plantations oil palm, the groundwater level is relatively better. The condition of the peat soil water table is not only influenced by the opening of drainage channels but also influenced by climatic factors, especially rainfall. The groundwater level will affect the maturity and decomposition of peat soil. The need for water level differs depending on the type of plant being cultivated.

The water *table* for annual plants is recommended to maintain the groundwater level at a depth of 150 cm (Najiyati et al., 2005). The clearing of peatlands for plantations begins with the construction of drainage channels to lower the water table because plantation crops require dry land conditions. The optimum groundwater table depth for oil palm plantations on peatlands is in the range of 60-85 cm. The reality in the field is that it is found that the depth of the groundwater table in oil palm plantations is more than 85 cm (Dariah & Nurida, 2011). This condition occurs because most of the plantation areas do not have control buildings (sluice gates) both at the secondary and tertiary channel levels.

Ground water level will affect peat decomposition (subsidence) and irreversible drying. The rate of decomposition of the peat layer above and above the groundwater table is higher or further than that of the peat layer below the water table. Based on an assessment of changes in peat maturity, ecologically the main factor influencing is the water level (Suwondo et al., 2012).

Peat Soil Chemical Properties

Soil chemical properties can be seen from the level of acidity and composition of mineral nutrient content. Soil chemical properties have an important meaning in determining the dose of fertilization and soil fertility class. Oil palm plants do not require soil with special chemical properties because the lack of a nutrient can be overcome by fertilization. However, soil containing large amounts of nutrients is very good for vegetative and generative growth of plants, while soil acidity determines the availability and balance of nutrients in the soil. Peat soil has a low fertility level characterized by a low pH (acidic), the availability of a number of macro (Ca, K, Mg, P) and micro (Cu, Zn, Mn, and B) nutrients that are low, containing organic acids that poisonous.

Table 3
Characteristics of chemical properties of peatlands designated for oil palm plantations in East Kotawaringin Regency

Parameter	Natural Peat Forest	Oil Palm Planting Age		
		< 4 years	4-10 years	> 10 years
pH (H_2O)	2.09	3.54	4.15	3.17
	So sour	So sour	So sour	So sour
C-Organic (%)	38.63	34.51	39.94	31.71
	Very high	Very high	Very high	Very high
N-total (%)	0.88	1.02	1.37	1.47
	Very high	Very high	Very high	Very high
P-available (ppm)	46.44	59.36	65.72	49.47
	Very high	Very high	Very high	Very high
K-dd (ppm)	0.39	0.77	1.29	0.88
	Very high	Very high	Very high	Very high
Ca-dd (ppm)	24.74	34.35	35.69	26.24
	Very high	Very high	Very high	Very high

Mg-dd (ppm)	49.8	24.65	24.27	23.62
	Very high	Very high	Very high	Very high
Na-dd (ppm)	0.26	0.18	0.16	0.08
	Low	Low	Low	Very low
CEC (me/100 g)	106.08	134.37	143.03	125,17
	Very high	Very high	Very high	Very high

pH (H_2O)

One of the chemical properties of peat that becomes an obstacle to its utilization is the high level of acidity. The high level of acidity is caused by poor drainage conditions and hydrolysis of organic acids. The conversion of natural peat forest into oil palm plantations causes an increase in soil pH even though it is still in the very acidic category (3.08-4.15). An increase in peat soil pH of 1.45% occurred in oil palm plantations under 4 years of age and in oil palm plantations between 4 - 10 years of age an increase of 2.06%. Peat soil pH also increased by 1.08% for oil palm plantations over 10 years of age. The increase in pH in oil palm plantations is thought to be due to the activity of overhauling soil organic matter and opening drainage channels in oil palm plantations.

The increase in the pH value of the soil which is still classified as very acidic is thought to be due to the ongoing decomposition process in peatlands. The decomposition process that is taking place on peatlands produces acidic organic acids. The very high level of acidity is a natural constraint for plant development due to the limited supply of nutrients for peat soils. The high acidity of peat soils is partly due to poor drainage conditions and hydrolysis of organic acids (Agus & Subiksa, 2008). Transitional peat converted to oil palm plantations for more than 10 years has increased soil pH but is still classified as very acidic (Suwondo et al., 2012).

The addition of organic matter will increase soil pH and at the same time reduce Al-dd and Fe-dd. Soil organic matter is considered as an electron donor that contributes to metal-metal reduction reactions at low pH (Olafisoye, Fatoki, Oguntibeju, & Osibote, 2020). pH is still included in the very low category (3.08-4.15). The low pH is caused by the leaching of alkaline cations that occur from the top layer to a deeper layer, leaving H^+ and Al^{3+} cations in the top layer which plays a very important role in soil acidity (Hong, 2008). The low pH of the soil will cause a decrease in the availability of plant nutrients which in turn will reduce the production of Fresh Fruit Bunches (FFB).

C-organic

The conversion of natural peat forest to oil palm plantations causes a decrease in organic C content in oil palm plantations less than 4 years old (4.12%) and oil palm plantations over 10 years old (6.92%). The increase in C-organic content occurred in oil palm plantations between 4-10 years old (1.31%) when compared to natural peat forests. Overall the C-organic content is still included in the very high category. This decrease is thought to occur due to decomposition activities by soil microorganisms, erosion of organic matter that occurs due to peatland processing activities for oil palm plantations. The condition of drained peatlands changes the peat conditions from anaerobic to aerobic. This results in increased activity of microorganisms that break down organic matter in peat soil.

Changes in anaerobic to aerobic conditions on peatlands encourage the activity of microorganisms to decompose soil organic matter (Subandar, 2011). Soil organic matter has an important role in the carbon and nutrient cycle and changes in soil pH (Wang et al., 2013). The C-organic and organic matter content in forest soils tends to be high. This is because in the forest soil there is a lot of accumulation of litter and plant residues that accumulate on the soil surface, the cover of the soil surface by the plant canopy and there are many soil macroorganisms (worms) and soil microorganisms (decomposers) that help break down the litter found in forest soil.

N-total

The conversion of natural peat forests into oil palm plantations has resulted in an increase in total N as the age of oil palm plantations, although it is still in the very high category. When compared with natural peat forest, the N-total content increased by 0.14% in oil palm plantations less than 4 years old, an increase of 0.49% in oil palm plantations between 4-10 years, and an increase of 0.59 % in oil palm plantations over 10 years of age. The increase in total N that occurs in oil palm plantations is thought to occur due to treatment with NPK fertilizer every 6 months. Fertilization treatment given to oil palm plantations greatly affects the availability of total soil N content (Oksana, Irfan, & Huda, 2012), NPK 15-15-15 application can increase root development, biomass production (Barros, Baptista, & Ferreira, 2007) and nutrient content network (Costa, 2012).

P-available

The conversion of natural peat forest to oil palm plantations causes an increase in the available P content and is still in the very high category. When compared to natural peat forest, the available P content has an increase of 12.92% in oil palm plantations less than 4 years old, while the increase is 19.28% occurred in oil palm plantations with planting age between 4-10 years, and an increase of 3.03% in oil palm plantations over 10 years of age. The increase in available P in oil palm plantations was thought to be only due to P fertilization treatment and had not been affected. by the activity of P-fixing micro-organisms, this happens because the soil pH is still very acidic (extreme).

P in the dominant soil comes from weathering rocks, while P in peat soil comes from organic P extract (Istomo, 2006)

The main nutrient problem in peat soils is the availability of P and low P storage. The cause of the low P storage in peat soil is because P is bound by organic compounds with weak bond strength. P ions bound to the adsorption site are easily released and carried by *leachate* . In order to strengthen the bond, it is necessary to use tips such as using compounds that are effective in absorbing P, using natural phosphates and adjusting the timing of ameliorant application and P fertilization (Masganti, 2013).

K-dd

The conversion of natural peat forests into oil palm plantations results in changes in the K-dd content as the plants age. When compared with natural peat forests, the Ka-dd content in oil palm plantations under 4 years of age increased by 0.38%, oil palm plantations at 4-10 years of age increased by 0.90%, and oil palm plantations at planting age in over 10 years experienced an increase of 0.49%. The K-dd content of natural peat forests was in the medium category, the K-dd content of oil palm plantations under 4 years of age and above 10 years was in the high category, while in oil palm plantations of between 4-10 years in the very high category.

The increase in Potassium (K) in oil palm plantations is caused by periodic K fertilizer application. Fertilizer application can restore nutrients in the soil transported by plants. Pawesti *et al* . (2013) stated that the increase in N, P, and K of plants could be by applying NPK fertilizer to plants.

Ca-dd

The conversion of natural peat forests into oil palm plantations resulted in an increase in the Ca-dd content as the plants age. When compared with natural peat forests, the Ca-dd content in oil palm plantations under 4 years of age increased by 9.61%, Oil palm plantations at planting age of 4-10 years increased by 10.95%, and in oil palm plantations at planting age above 10 years experienced an increase of 1.50%. However, all Ca-dd content was still in the very high category. The increase in Ca-dd that occurred in oil palm plantations at various plant ages was thought to be caused by periodic calcium fertilization treatment. This can be seen from the decrease in Ca-dd in oil palm plantations over the age of 10 years.

Calcium is the most important nutrient after the essential elements (N, P, and K) as a supply of plant nutrients. The function of calcium in plants is used as a builder of cell walls. Calcium is also mostly used as a control of soil pH and helps the formation of soil aggregates. Calcium also has a role in the formation of proteins and the movement of carbohydrates.

Mg-dd

The conversion of natural peat forest into oil palm plantations results in changes in the Mg-dd content as the plant ages, even though the Mg-dd content is still in the very high category. When compared to natural peat forest, the Mg-dd content in oil palm plantations is under 4 years old decreased by 25.15%, oil palm plantations at planting age of 4-10 years decreased by 25.53%, and oil palm plantations at planting age over 10 years decreased by 26.18%. This is presumably due to fertilization treatment as an effort to restore transported nutrients. by plants at harvest.

(Ghufron & Risnawita, 2010) stated that fertilization efforts can improve the nutrient content in the soil carried or used by plants. (AR, Junedi, & Farni, 2012) stated that the antagonistic properties of K and Mg greatly affect their availability in the soil. The high value of Mg in the soil affects the availability of K in the soil.

Na-dd

The conversion of natural peat forests into oil palm plantations results in a decrease in Na-dd content as the plants age. The overall Na-dd content is included in the low category, except for oil palm plantations of more than 10 years of age, which are in the very low category. When compared with natural peat forests, the Na-dd content in oil palm plantations under 4 years of age decreased by 0.08%, oil palm plantations aged 4-10 years decreased by 0.10%, and in oil palm plantations of planting age over 10 years decreased by 0.18%.

Cation Exchange Capacity (CEC)

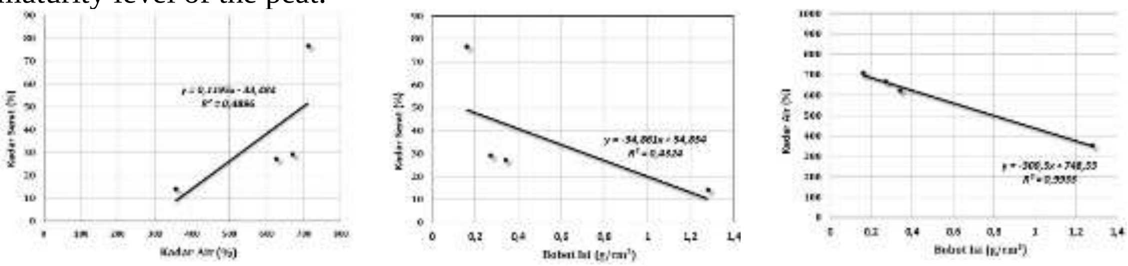
The conversion of natural peat forest into oil palm plantations has resulted in an increase in CEC as the plant ages, even though CEC is still in the very high category. Changes in the value of cation exchange capacity which is still in the very high category is thought to be due to the condition of the soil pH which is still classified as very acidic. When compared to natural peat forests, CEC in oil palm plantations under 4 years of age increased by 28.29%, oil palm plantations at 4-10 years of age increased by 36.95%, and oil palm plantations above 10 years of age. year decreased by 19.09%.

Cation exchange capacity indicates the soil's ability to hold cations and exchange them. The increase in cation exchange capacity occurs along with the increase in pH, the increase in pH value is caused by the cation exchange capacity which is influenced by the negative charge originating from organic matter. Compounds of organic matter are changing charges that are highly dependent on changes in pH. These negative charges retain a number of cations present in the soil solution and in the adsorption complex, so that the cation exchange capacity increases in oil palm plantations of various plant ages as the soil pH increases.

Changes in CEC value along with changes in pH value. The increase in cation exchange capacity in oil palm plantations is thought to be influenced by fertilization treatment and the ongoing decomposition process (Winarno, 2012). Cation exchange capacity is one of many factors related to soil fertility and a good indicator to determine soil quality and productivity. The higher the CEC of the soil, the more alkaline cations the soil can hold, so it is more likely that the soil will have a higher fertility level, on the other hand, if the CEC in the soil is low, the soil cannot hold nutrients properly, so - Nutrients are easily washed off by water.

Relationship of some physical properties of peat soil

Water content has a positive relationship with fiber content (r = 0.70), high water content will be followed by high fiber content (Figure 2a). This condition shows that natural peat forests and plantations with various ages of oil palm plantations experience a water-saturated phase that affects the number and activity of microorganisms to utilize organic fiber as an energy source. The weathering process will run slowly, so that the fiber content is high with a high water content state. The decrease in water level due to drainage will accelerate decomposition and reduce the percentage of fiber content (Noor, 2001) states that the ability to absorb and retain water from peat depends on the maturity level of the peat.



[a] [b] [c]

Figure 2

The graph of the relationship between water content and fiber content (a), bulk weight and fiber content (b), and bulk weight and moisture content (c).

The density of peat soil has a negative relationship with fiber content (r = 0.66). Peat soil has a low density between 0.05-0.25 gr/cm ^{3}, the lower the density value, the weaker the decomposition rate or the lower the maturity of the peat, because it still contains a lot of organic matter (Subagyono, Marwanto, & Kurnia, 2003). The low density of peat soils causes the low bearing capacity of peat soils. In general, the density of the soil the deeper it is, the smaller it will be. The lower the peat maturity, the lower the density value (Andriesse, 2003).

The density of peat soil has a negative relationship with water content (r = 0.99) giving an understanding that the greater the density of peat soil, the lower the water content or vice versa (Figure 2b). *Bulk density* is closely related to *particle density*, if the soil *particle density* is very large, the *bulk density* is also large. If the soil has a high level of water content, then the *particle density* and *bulk density* will be low because if the soil has a high level of water content in absorbing groundwater, then the density of the soil will be low because the pores in the soil become large. Soil that has large pores will more easily enter water in the soil aggregate (Hanafiah, 2004).

Relationship of Several Chemical Properties of Peat Soil

pH (H_2O) of peat soil has a positive relationship with C-organic (r = 0.042) which indicates that high acidity of peat will be accompanied by higher C-organic (Figure 3a). *Peat* soil *organic matter* comes from weathering of the vegetation that grows around it. The decomposition process *of peat soil* has not occurred completely because the dominant peat condition is always saturated. These conditions cause *peat soils to* have low fertility and *pH levels* (Dariah & Nurida, 2011).

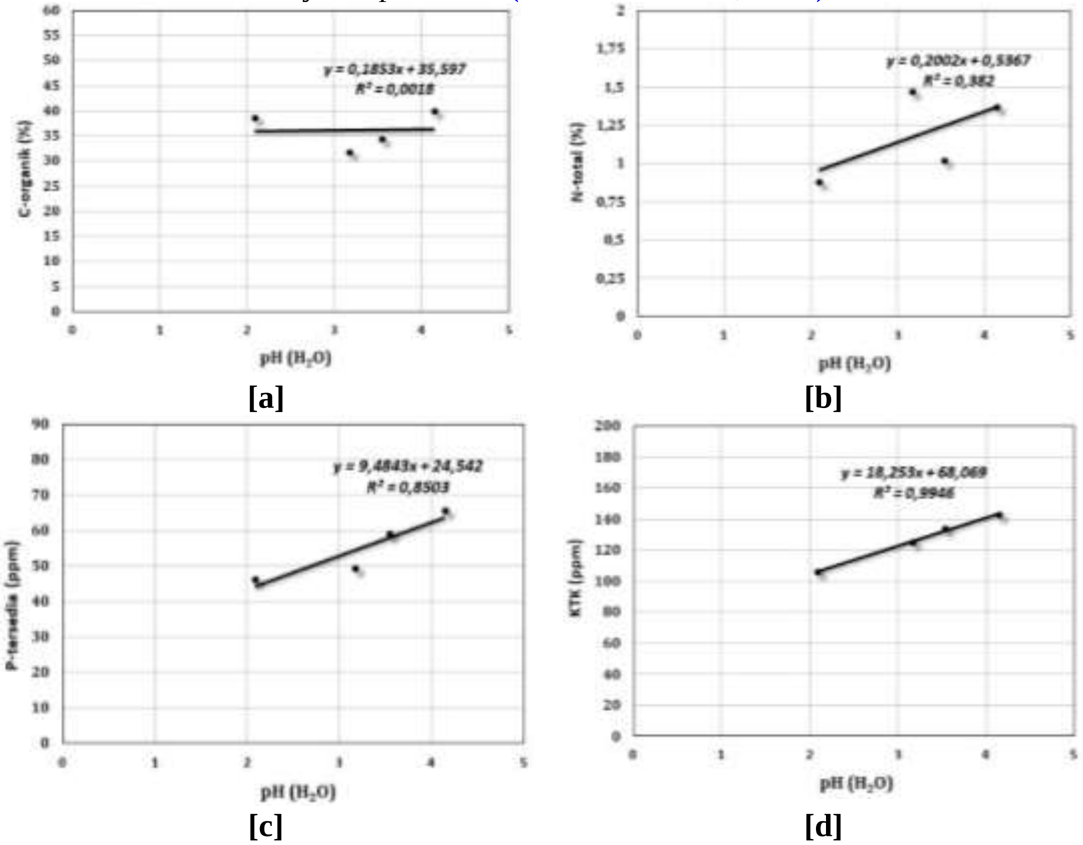


Figure 3

Graph of the effect of peat soil pH (H_2O) on organic C (a), total N (b), available P (c), and CEC (d).

pH (H_2O) of peat soil has a positive relationship with N-total (r = 0.62) (Figure 3b). The decrease in the total N-value of peat soils as oil palm plants age is thought to be due to degradation of organic matter and changes in soil pH which are not significant and are still classified as very acidic. This has resulted in microorganisms that degrade soil organic matter and N fixers have not been able to work optimally (Nugroho, 2017). The pH (H_2O) of peat soil had a positive relationship with available P (r = 0.92) (Figure 3c). The amount of available P in the soil is determined by the amount of P in the adsorption complex (P-total) whose availability mechanism is regulated by pH and the amount of soil organic matter (Winarso, 2005). pH (H_2O) of peat soil has a positive relationship with Cation Exchange Capacity. (r = 99) (Figure 3d). The cation exchange rate in dominant peat soil is very high (90-200 cmol $^{(+)}$ kg $^{-1}$). This negative value is caused because the negative charge depends on the pH which is mostly the carboxyl and hydroxyl groups of phenol. The negative charge of peat completely depends on the pH value. If the pH value is increased, the CEC value will automatically increase (Hartati, Wardoyo, Harjoko, Palembang-prabumulih, & Ilir, 2011)

CONCLUSION

Peatlands designated for oil palm plantations cause changes in the physical and chemical properties of peat soils. Changes in the physical properties of peat soil are indicated by the color of the peat soil which changes from very dull red in natural peat forest to reddish black in oil palm plantations. Peat maturity changes from fibric in natural peat forest to hemic and sapric on peatland designated for oil palm plantations. The water content has decreased significantly, the older the age of the oil palm plant, the water content will decrease. In terms of bulk density, the older the age of oil palm plantations, the higher the density of peat soils. The water level in oil palm plantations has increased when compared to natural peat forests. Changes in chemical properties were indicated by an increase in peat soil pH, N-total, and available P, while a decrease occurred in the C-Organic content. An increase also occurred in the content of K-dd, Ca-dd, Mg-dd, Na-dd, and CEC along with the age of oil palm plantations.

When viewed from the relationship pattern of each physical characteristic, water content has a positive relationship with fiber content, the higher the water content will be followed by the higher fiber content or vice versa. Bulk density has a negative relationship with fiber content and moisture content, which means that an increase in bulk density of peat soil will be followed by a decrease in fiber content and moisture content. The relationship pattern of chemical properties shows that the pH (H2O) of peat soil has a positive relationship with organic C, total N, available P, and Cation Exchange Capacity (CEC). The high or low acidity of peat will be proportional to the high or low -organic, total N, available P, and Cation Exchange Capacity (CEC).

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