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Characteristics of peat in the oil palm plantation environment

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Abstract

Peat's characteristics research helps the farmers to map out the sites that will be planted with different treatments. Particularly, the changes that lead to degradation of peat lands are characterized by: decreased water holding capacity, increased soil acidity, decreased organic C-and N-total. This study aims to examine the change of peat characteristics in the area of oil palm plantations of generation I and generation II with observations on *Piringan, Gawangan mati and Pasar pikul*. A survey method was conducted in the Peat Palm Oil Plantation of *Aek Korsik* Village, *Aek Kuo* Sub-district, North *Labuhan batu* Regency with geographic position 2°22'36" - 2°26'04" North Latitude (NL) and 99°50'18" - 99°54'36" East Longitude (EL), altitude place 25 - 33 m above sea level. The sampling is site of the soil on the *Piringan* (a circle area under a certain diameter of palm oil), *Gawangan mati* (area that is used as the area of wood and shrubs) and *Pasar pikul* (roads used to deliver the harvested fruit palm) with a depth of 0-20 cm and 40 -60 cm. The results showed in second generation plants: lower pH, higher organic C-, lower N-total, lower CEC, lower BD and higher maximum water content. The result of t-test of the research showed that the C / N ratio was significantly different in *Pasar pikul* and very different in the *Gawangan mati* and the 0-20 cm depth of *Piringan*.

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Introduction

Peat swamp land in Indonesia is quite wide, which is about 20.9 million ha or 10.8% of the land area of Indonesia. The peat swamp land is mostly located in three large islands, they are Sumatra 35%, Kalimantan 32%, Papua 30%, and 3% are scattered partially in narrow areas (Wahyunto and Mulyani, 2011). Peatlands including marginal and fragile, among others, flammable in the dry season, easily subsided (subsidence), so that in its utilization must be done carefully. Planning should refer to the results of in-depth study of local peatland and environmental characteristics and subsequent impacts (Agus and Subiksa, 2008).

Utilization of peatlands for oil palm plantations has been done for a long time and become a source of life. The peat land used for the largest oil palm plantation in Riau Province is 788,491 ha, then the Province of Kalimantan 288,136 ha and North Sumatra area of 217,305 ha. The Government has restricted the use of peatlands for the development of plantations, especially oil palm with the Ministry of Agriculture Regulation (PERMENTAN No. 14/2009) and the suspension of new permits for peatland clearing with Presidential Instruction (INPRES No. 10/2011).

Peatland degradation can occur when land management is not well implemented, degraded peat has characteristics such as: decreased water holding capacity (hydrophobic) due to irreversible drying peat, increased soil acidity, decreased total organic carbon and N-total (Anshari, *et al.* 2010). The present inventory of peat swamps and analysis of changes in a given period of time is critical and a key source of information for supporting environmental conservation, biodiversity and conservation of water resources, calculating greenhouse gas emissions to address the threat of climate change, and flood control. Information on the characteristics of peat swamp land, conditions and land use existing landuse in oil palm plantations can be used to develop more accurate planning for optimum utilization and conservation efforts. The objective of the study was to examine the differences of peat characteristics in the area of oil palm plantations of the first generation (old plant) and second generation replanting on the *Piringan, Gawangan mati* and *Pasar pikul.*

Materials and methods

The research was carried out on peat land at the Palm Plantation Companies, located in *Aek Korsik* Village, *Aek Kuo* Subdistrict, North *Labuhan Batu,* Regency of North Sumatera Province (about 315 km southeast of Medan). The location of the study lies in the geographical position of 2°22'36" - 2°26'04" North Latitude (NL) and 99°50'18" - 99°54'36" East Longitude (EL) with a height of 25-33 m from sea level (Fig. 1).

Based on the Sumatra Agroclimate Map Scale 2: 500,000 study areas are included in the D1 agroclimate zone, ie areas with wet months (monthly rainfall > 200 mm) sequentially 3 - 4 months and dry months (monthly rainfall < 100 mm) respectively for < 2 months.

Determination of research location was done by purposive with consideration of old plantation of 22 year old oil palm that will be replanted and plant which have done by replanting 2 years old. Soil sample analysis was conducted at Central Laboratory of Faculty of Agriculture, University of North Sumatra. The implementation of the research includes: survey and sampling of soil, soil analysis, data processing and report writing. Peat land sampling consists of undisturbed soil samples and disturbed soil samples.

The area of oil palm plantation is not equipped with water gates to regulate groundwater depth. Soil sampling was conducted in two locations, 1) in Generation I palm oil area which is a plant produces Afdeling IV planting in 1993 to be replanted; 2) Generation II area which is the unimpeded plant of Afdeling I which is re-planted in 2013 (Fig. 2). Soil sampling positions are: 1) *Piringan*, 2) *Gawangan Panen*, 3) *Gawangan mati*.

Fig. 1. Map of research locations.

The sample depth is: 0 - 20 cm, and 40 - 60 cm. Observation of 1 sample tree = 3 x 2 = 6 observations.

Taking in each area was done with 6 sample trees.
The total sample size is: 6 x 6 x 2 = 72 sample observations. The observation parameters were: pH (H_2O) (Electrometric method), C-organic (Walkley and Black method), N-total (Kejdhal method), C/N ratio, CEC, Volume Weight (g/cm^3) Thermogravimetry, Water content (%) is measured by gravimetric method. Water content observed is water content in water saturated condition, Color using Munsell Soil Color Chart.

Fig. 2. Location of sampling areas.

Results and discussion

The pH values for the peat area of the first generation plant ranged from 4.17 to 4.56 and the second generation ranged from 4.20 to 4.38 was considered very acid (Table 1), based on the criteria of Soil Research Institute (2005).

This is a characteristic of tropical peat, the high acidity of peat soil is caused by the high acid organic acid formed in the process of weathering organic matter, especially carboxyl group (-COOH) and hydroxyl group of phenolate (-OH) which acts as colloids.

Tabel 1. Characteristics of peat area plant of generation I and generation II.

Characteristic		Piringan		Gawangan Mati		Pasar Pikul	
		0-20 cm	40-60 cm	0-20 cm	40-60 cm	0-20 cm	40-60 cm
pH (H_2O)	I	4,51	4,37	4,17	4,38	4,46	4,56
	II	4,28	4,28	4,26	4,20	4,28	4,38
C-organik (%)	I	38,91	44,63	38,91	47,63	36,42	42,73
	II	39,53	44,95	40,88	46,33	39,33	46,52
N-total (%)	I	1,30	1,24	1,26	1,20	1,23	1,16
	II	1,23	1,14	1,17	1,05	1,20	1,14
C/N	I	30,03	36,12	30,89	39,68	29,69	36,78
	II	32,23	39,49	34,92	44,02	32,71	41,16
KTK	I	65,31	63,80	67,84	65,87	64,36	64,92
(me/100 g)	II	61,55	67,31	67,08	63,04	64,84	65,63
BD (g/cm^3)	I	0,32	0,30	0,30	0,29	0,39	0,38
	II	0,30	0,26	0,29	0,25	0,32	0,29
K. Water Max (%)	I	508,87	715,01	556,25	622,81	436,51	433,43
	II	667,84	884,29	632,99	884,11	637,99	731,95
Colour	I	2,5YR2,5/2	2,5YR2,5/2	2,5YR3/2	2,5YR3/2	2,5YR2,5/2	2,5YR3/2
	II	2,5YR2.5/2	2,5YR2,5/4	2,5YR3/4	2,5YR2,5/2	2,5YR2,5/4	2,5YR2,5/2

The value of pH can be lower than 3.0 if there is an oxidized sulfur layer (MARDI, 2009). In general, peat pH values are higher at a depth of 40-60 cm than compared to a depth of 0-20 cm, this is in accordance with research Muttalib *et al.* (1991) suggests that soil acidity decreases with the deeper peat.

From the t-test, it was found that the peat pH was not significantly different between the old crop area and the re-planted peat area on the *Gawangan mati, Pasar pikul* and *Gawangan* with 40-60 cm of depth (Table 2), except for the significantly different 0-20 cm depth of *Piringan* ($p \leq 0{,}05$). This is due to the technical culture factor of fertilization and liming which tend to increase the pH and stimulate the microbe activity of the remodel or mineralization of nitrogen in peat. The addition of dolomite in ameliorant material can decrease soil acidity, improve nutrient balance so that nutrients can be absorbed by plants (Brown *et al.*, 2007).

The intensity of the technical culture such as the dolomite fertilization of higher doses in old crops has an effect on the increase of pH (Muniandy *et al.*, 2009). Calcification can also contribute Ca^{2+} ions so that complexity will be formed with humic acid. According to Jeong *et al.* (2005), the magnitude of the complexation is highly dependent on the level of proton in the soil solution.

The C-organic content ranges from 36.42 to 47.63% in the peat area of first generation crops and 39.33 - 46.52% in the second generation peat plant area, is very high. The thickness of the peat is strongly related to the C-organic content, where the greater the depth of the peat will be the higher C-organic (Suwondo *et al.*, 2010).

Tabel 2. Result of t-test comparison of peat characteristics between generation I plant area and generation I plant are.

Characteristics	Piringan		Gawangan Mati		Pasar Pikul	
	0-20 cm	40-60 cm	0-20 cm	40-60 cm	0-20 cm	40-60 cm
pH (H_2O)	N	tn	tn	tn	tn	tn
C-organik (%)	tn	tn	tn	tn	tn	sn
N-total (%)	sn	sn	sn	sn	tn	tn
C/N	sn	tn	sn	sn	n	tn
KTK (me/100 g)	N	n	tn	tn	tn	tn
BD (g/cm3)	tn	n	tn	n	sn	sn
Water (%)	N	n	tn	n	tn	sn

Information of Independent T-test Result: tn = Not Real   n= Real   sn= Very Real.

In addition, the remaining crops from older plants that are contaminated are also C-organic sources that make higher organic C-levels in re-planting areas. The C-organic content of peat soils is very high at 12-60%[9]. The results of Muniandy *et al.* (2009) obtained by C-organic content of palm oil peat area ranged from 40-50%. In general, the C-organic content of the research peat is lower at a depth of 0-20 cm which means a higher decomposition than in a depth of 40-60 cm.

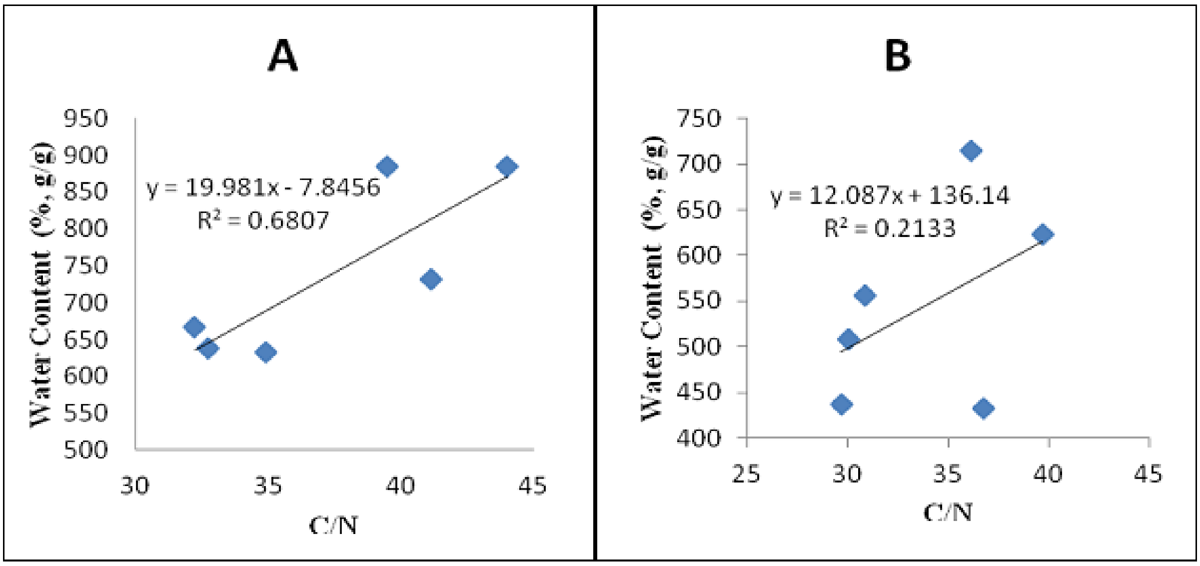

Fig. 3. Relationship of C/N and moisture on saturated water conditions on plant peat generation II (A) and generation I area (B).

The result of t-test of C-organic content showed no significant effect on disc, die weight and picul market at 0-20 cm deep, except on picul market depth 40-60 cm. This is in line with the research of Munandy *et al.* (2009) which states that the organic C content is not significantly different from the depth of the oil palm area until the age of 5 years. Total peat carbon does not differ with age of oil palm plantation.

N-total content ranges from 1.16 to 1.30% in peat area of first generation plant and ranges from 1.05 to 1.23% in second generation peat plant area is classified as very high. Generally, the N-total content in peat soils is higher than that of mineral soils. This is because the mineralization of N results in the decomposition of organic matter, therefore the N content will be higher in the mature peat.

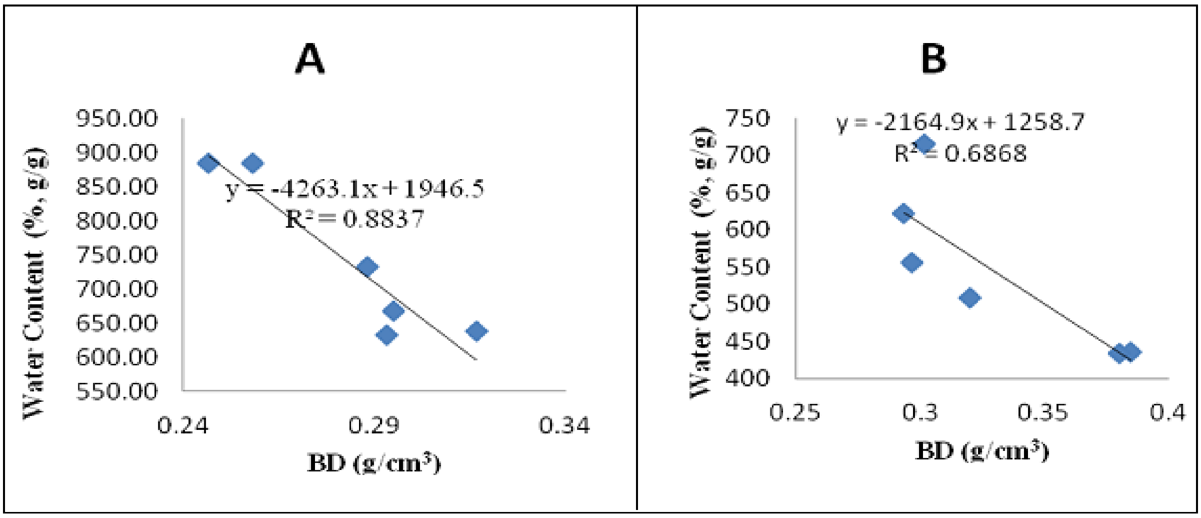

Fig. 4. Relation of BD and Water Content Saturated Peat in Generation II (A) and Generation I (B).

Andriesse (1988) suggests that the increasing age and opening of peat, the N content will increase and correlate with the decomposition rate. The t-test results on the N-total peat of generation I plant area and peat plant area of generation II plant show the total N content is very different on *Piringan* and *Gawangan mati* but not significantly different in *Pasar pikul*. Technical culture such as land clearing, water surface management, calcification and fertilization will increase the activity of microbes that will decompose or mineralize nitrogen in peat (Gandaseca *et al.*, 2014). Higher ammonium content in peat areas of oil palm with different ages can be caused by nitrogen fertilization (Munandy *et al.*, 2009).

The C/N ratio ranges from 29.69 to 39.68 on peat area of first generation plant and ranges from 32.23 to 44.02 on second generation peat plant area, is very high. The C/N ratio is higher at a depth of 40-60 cm in both the old crop area and the re-planting area. This is in line with research Kurnain *et al.* (2001); Takakai *et al.* (2006); Lampela *et al.* (2014) which states that the C/N ratio increases with the depth of ombrotropic peat. Andriesse (1988) argues that the C/N ratio shows the degree of peat humidity and describes the nitrogen consumption by microorganisms when peat is fertilized. The result of t-test of the research shows that the C/N ratio is significantly different in *Pasar Pikul* and very different in the *Gawangan Mati* and the 0-20 cm depth of *Piringan*. This is due to the non-uniform water depth that causes microorganisms to rapidly execute decomposition of carbon and nitrogen in soils on peat oil palm plantations decomposition of nitrogen by soil microorganisms causing high C/N ratios (Muniandy *et al.*, 2009).

CEC value ranges 63.80-67.84 me/100 g in the area of first generation plants and ranges 61.55-67.31 me/100 g in second generation plant area is very high. CERs peat range from 40 to 135 me/100 g. The result of peat tens test of KTK research shows only real difference on the plate. The results of the Aho (1986) study stated that CEC will increase with increasing pH.

BD values ranged from 0.29-0.39 g.cm-3 in peat area of first generation plant and ranged from 0.25-0.32 g.cm-3 in second generation plant area. Increased levels of decomposition with higher fertilization in older plants increase the value of BD, ash content and lower fiber content, total pore space (Firdaus *et al.*, 2015). Based on the value of BD, the peat in the study area included the type of saprik (Wahyunto *et al*, 2004). However, the BD value of ≥ 0.25 g.cm-3 may also be due to heavy machine use during land clearing and drainage trenching. BD peat layer 0-20 cm was higher than layer 40-60 cm. This is related to peat decomposition in the upper layer higher than the bottom layer.

Higher decomposition rates on oil palm peat plantations generally have higher BD (Brady and Weil, 2008). The higher BD also shows that peat becomes denser with fewer totals pore space thus lowering the total pore of the soil. Verry *et al.* (2011) suggests that BD has a positive relationship to the decomposition rate of peat maturity. The result of t-test showed that BD value was significantly different on the depth of *Piringan* 40-60 cm and very different in the *Gawangan Mati* and in the depth of *Pasar Pikul* 40-60 cm. The market has the highest BD due to the use of the picul market as a way for technical culture activities such as harvesting and fertilization (Muniandy *et al.*, 2009).

Water content in water-saturated condition ranges from 433.43-715.01% in peat area of first generation plant and ranges from 632,99-884,29% in second generation peat plant area. The role of cover crops on peatlands is able to increase the water content, where the moisture content in *Gawangan Mati* 0-20 cm depth is higher than *Piringan* and the *Pasar Pikul*. *Piringan* and *Pasar Pikul* are always cleaned both manually and khemis so that the surface is always open faster evaporation. Cover plants play a role in inhibiting evaporation, providing a biomass that has the ability to hold water high. Sabiham (2000) suggests that the decrease in peat ability to absorb water is associated with a decrease in the availability of carboxylic and phenolic groups in the peat material of the decrease in both of organic components due to the drying because of its easy oxidation. Canopy in old plants causes the surface temperature of soil in older plants to be lower than in newly replanted plants (Brady and Weil, 2008).

The longer the planting age of oil palm plantations will be the lower the moisture content in the peatlands. Where this condition occurs in coastal peat and transition. This condition is caused by changes in maturity level (decomposition) of peat that occurs in oil palm plantations. Noor (2001) states that the ability to absorb and hold water from peat depends on the level of maturity.

The ability to absorb and bind water to fibric peat is greater than that of hemic peat and saprik, while hemic peat is larger than saprik. According to Dariah *et al.* (2010) peat with a water content of < 100% by weight generally has undergone no dry process. According to Riwandi (2001) critical water content of fibric peat 300-500%, 300-400% hemik and saprik 200-300%.

The relationship of C/N ratio and water content in water saturated conditions for second generation plantation peat is $y = 19.98x - 7.845$; Correlation coefficient $r = 0.825072$ with $R^2 = 0.680$. In the area of first generation crops before re-planting is $y = 12.08x + 136.1$; Correlation coefficient $r = 0.461816$ with $R^2 = 0{,}213$. Both have a positive correlation which means the higher the C/N ratio the higher the water content (Fig. 3).

Higher correlation coefficient value in re-planted area is $r = 0.825072$ (strong correlation) than old plant area $r = 0.461816$ (weak correlation). According to Noor (2001), the high C/N ratio (C/N> 20) indicates the degree of decomposition that is not yet advanced, the higher the C/N ratio the lower the decomposition rate occurs. Where the total pore space decreases as the decomposition increases.

In water-saturated conditions the total pore space is instrumental to store water, as water fills the entire pore space. The higher total pore space will be able to store higher water. The peat maturity level determines the average peat water level if it is in its natural state (inundated). At a very raw peat maturity level, peat is very nest, so space between peat masses is filled with water. However, since most of the water is in the macro pore, so drained peat water will quickly disappear (Dariah *et al.*, 2010).

The relationship of BD and water content in second generation plant area is $y = -4263.x + 1946$; correlation coefficient $r = -0.9401$ with $R^2 = 0.883$. In the area of first generation crops before re-planting is $y = -2164.x + 1258$; correlation coefficient $r = -0.8287$ with $R^2 = 0.686$ (Fig. 4).

Both have a strong negative correlation coefficient value, this indicates the higher the BD, the lower the water content held vice versa. BD peat depicts decomposition rates and is strongly associated with hydraulic conductivity of peat (Brady and Weil, 2008).

The results of Sasli's research (2011), showed that the greater the BD the smaller the percentage of total pore space. This is because the decomposed peat forms finer granules thus building a pore space with a lower total porosity (Nugroho and Widodo, 2001). Soils with relatively low BD values generally have high porosity, so the potential to absorb and channel water becomes high (Dariah *et al*., 2010).

Conclusion

Characteristics of peat area of the first generation plant and second generation plant was found significantly different, ie, pH only in the depth of *Piringan* 0-20 cm; C-organic only in *Pasar Pikul* depth 40-60 cm; N-total in *Piringan* and *Gawangan Mati*; The ratio of C/N in the depth of *Piringan* 0-20 cm, *Gawangan Mati* and *Pasar Pikul*; CEC only on *Piringan*; BD in *Piringan*, *Gawangan Mati* and *Pasar Pikul* of depth 40-60 cm; Water content in saturated conditions in the depth of *Pasar Pikul* 40-60 cm and in the *Piringan*. In water-saturated conditions the relationship between C/N ratio and water content has a positive correlation in both areas; while for the relationship between BD with water content has a negative correlation coefficient. It concludes that the peat maturity level determines the average peat water level. Thus, at a very raw peat maturity level, it is very nest, because the space between peat masses is filled with water.

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