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Water Management "Tabat System" in Carbon Dioxide Mitigation and Vulnerability to Fire On Peatland

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ABSTRACT

The conservation measures of peat or peat maintain under natural conditions many proposed to address the increase in carbon emissions from land use change and efforts to minimize of fire, but it can not entirely implemented due to peat land has the potential for development of the agricultural commodities is supported by extensive area. Peatlands can be productive agricultural land with appropriate methods. Water management is required to regulate groundwater levels which is suitable for plants, nature conservation and restore hydrological conditions, such as reducing the vulnerability to fire. The percentage of water content vertically and functional groups of organic materials that have both hydrophilic and hydro phobic properties can be an indicator of vulner ability to fire. This research was conducted by survey method and then field sampling on land use rubber. Water management carried out with the installation of water-gate in the drainage channels (*Tabat System*). There are two experimental units in peatland, namely: 1) the drainage channel is equipped with the water-gate/*Tabat* (KST), *Tabat* size adjusted to the channel dimensions, and 2) there are no water-gate on the drainage channel (KNT). The parameters are observed of CO_2 fluxes, ground water levels, water content and functional groups of organic matter. The purpose of this study was to determine the role of "tabat system" in mitigating CO_2 emission sand vulner ability tofire. The results showed that the water management "tabat system" can reduce CO_2 emissions by 47.6%, reducing hydrophobic properties of peat (0-50 cm soil depth) of 6.6% and is able to prevent loss of water-holding ability of fibric peat by 26.6%. This indicates that water management measures is required as one effort to maintain of peat to remain moist condition, so that changes in peat properties of hydrophilic become hydrophobic can be prevented, and reduce peat vulnerability to fire.

Keywords: Carbon dioxide emissions, Peatland, Vulner ability to fire, Water management

ABSTRAK

Tindakan konservasi gambut atau mempertahankan gambut dalam kondisi alami banyak diusulkan untuk mengatasi peningkatan emisi karbon akibat perubahan penggunaan lahan dan upaya untuk meminimalkan kebakaran. Namun hal tersebut tidak dapat sepenuhnya dilaksanakan karena lahan gambut mempunyai potensi untuk pengembangan komoditas pertanian. Lahan gambut dapat menjadi lahan pertanian produktif dengan metode yang tepat. Pengelolaan air diperlukan untuk mengatur tinggi muka air tanah agar sesuai dengan keperluan tanaman dan untuk konservasi alam dan mengembalikan kondisi hidrologis, seperti mengurangi kerentanan lahan gambutterhadapkebakaran. Besaran kadar air secara vertikal dan gugus fungsional bahan organik yang mempunyai sifat hidrofilik dan hidrofobik dapat menjadi indikator kerentanan terhadap kebakaran. Penelitian ini dilakukan dengan metode survey pada penggunaan lahan karet. Pengelolaan air dilakukan dengan pemasangan pintu-pintu air pada saluran drainase (SistemTabat). Terdapat dua unit penelitian, yaitu : 1) lahan gambut yang saluran drainasenya dilengkapi dengan pintu air/Tabat (KST), ukuran tabat disesuaikan dengan dimensi saluran, dan 2) lahan gambut yang saluran drainasenya belum dilengkapi dengan Tabat (KNT). Parameter yang diamati adalah fluks CO_2, tinggi muka air tanah, kadar air dan gugus fungsional bahan organik. Tujuan penelitian ini adalah untuk mengetahui peran sistem tabat dalam mitigasi emisi CO_2 dan kerentanan terhadap kebakaran. Hasil penelitian menunjukan bahwa pengelolaan air dengan sistem tabat dapat mereduksi emisi CO_2 sebesar 47.6%, mengurangi sifat hidrofobik gambut (kedalaman tanah 0-50 cm) sebesar 6.6% dan mencegah berkurangnya kemampuan gambut dalam menyimpan air sebesar 26.6%. Hal ini mengindikasikan bahwa tindakan pengelolaan air sangat diperlukan sebagai salah satu upaya mempertahankan gambut tetap dalam kondisi lembab agar perubahan sifat gambut dari hidrofilik menjadi hidrofobik dapat dicegah dan mengurangi kerentanan gambut terhadap kebakaran.

Kata Kunci : Emisi CO_2, kerentanan terhadap kebakaran, lahan gambut, pengelolaan air

INTRODUCTION

Peatlands have significant potential for agricultural development. Land use changes, including peat forest conservation will alter the rate of emission and sequestration. Currently, the land conversion is considered as something a natural in terms of the economy because of the increasing number of population, so it is unlikely be stopped but must be controlled by means of considering peat characteristics of physical-chemical properties related to the peat stability. The conversion of natural forests to agriculture led to changes in peat hydrological conditions due to the manufacture of drainage channels. The depth of the drainage channel/decrease in groundwater level can be used as an indication of the potential emissions.Based on that, Hooijer *et al.* (2010) stated emission factor of 0.91 Mg ha^{-1} yr^{-1} for each increase 1 cm depth drainage. The data resulted in overestimated. Therefore, Agus *et al.* (2010) suggested that CO_2 emission factors presented by Hooijer *et al.* (2010) corrected to become 0.7 Mg ha^{-1} yr^{-1}. The correction is based on the mixing of the CO_2 gas flow from peat decomposition and root respiration of plants at the time of measurement of CO_2 flux from the chamber. Besides that, the data used by Hooijer *et al.* (2010) comes from several studies, thus allowing the presence of measurement uncertainty. The measurement uncertainties are among the thickness and maturity of peat, bulk density, carbon content and a decrease in groundwater level. Peatlands in Indonesia has a thickness variability and maturity and peat-forming materials of different origin. Nurzakiah *et al.* (2014 a; b) reported that the peat with a degree of maturity hemicand sapric, soil carbon stockwas 658.68 ± 22.99 MgC $ha^{-1}$and groundwater level between 49.6 to 109 cm below soil surface, CO_2 emissions occur at 0.37 Mg $ha^{-1}yr^{-1}$ of each1 cm decrease in groundwater level. The litter in peat surface can also increase the flux of CO_2 by supplying labile carbon and nutrient input (Hirano *et al*. 2009;. Williams and Yavitt 2010).

Carbon emissions can be reduced with ameliorant and water management in a hydrological region of peat. Water management can be done by using canal blocking on a drainage channel, one of them with a "tabat system" that serves to regulate groundwater levels in accordance with the purposes of plants and water conservation. Therefore, the development of peatlands that will be done by the government, private sector/plantation companies and community must consider peat function as a carbon storage and as a water catchment area. Installation of water-gate in conjunction with manufacture of the drainage channel needs to be done and is an important component in water management. Water management begins by holding water during land clearing before it created drainage channels to avoid the excessive drainage that can be caused irreversible drying of peat (Furukawa 2005).These conditions caused of peat combustible. The burning of peat will impact on the environment that is global warming due to CO_2 release into the atmosphere.The percentage of water content vertically and functional groups of organic materials that have hydrophilic and hydrophobic properties can be an indicator of vulnerability to fire. The purpose of this study was to determine the role of the "tabat system" in mitigating CO_2 emissions and vulnerability to fires in peatlands.

MATERIALS AND METHODS

This research was conducted by survey method and then field sampling on land use rubber that has incident of fire, in Jabiren Village, Central Kalimantan Province in 2014. Water management carried out with the installation of water-gate in the drainage channels (*Tabat System*). There are two experimental units in peatland, namely: 1) the drainage channel is equipped with the water-gate/ *tabat* (KST), *tabat* size adjusted to the channel dimensions, and 2) there are no water-gate on the drainage channel (KNT).Soil sampling and CO_2 carried out three times on the land condition that represents of wet condition (rainy season), moderate (intermediate) and dry (dry season), so that known CO_2 emissions in a year. The sampling of CO_2 was conducted in the morning (from 6 am to 8 am). Gas chamber is block-shaped made of polycarbonate material (length 50 cm; width 15 cm; height 30 cm). The top chamber is equipped with a hole covered with a septum for gas sampling and the hole for the thermometer. Gas sample was taken using a syringe with the size of 10 mL. The time inter valused for gas sample collection was the 5th, 10th, 15th, 20st, and 25th minute. The sample was then analyzed using micro GC type 4900. The concentration of CO_2 gas from the gas samples analyzed will be simultaneously released. The measurement of CO_2 fluxes was carried out using the method of closed chamber technique adopted from the International Atomic Energy Agency (IAEA 1992). The calculation of fluxes at each observation point was performed using the following equation:

$$E = \frac{Bm}{Vm} \; x \; \frac{¢\, Csp}{¢\, t} \; x \; \frac{V}{A} \; x \; \frac{273.2}{T + 273.2}$$

Where:

E : CO_2 emission (mg m^{-2}minute^{-1})

V : chamber volume (m^3)

A : width of chamber base (m^2)

T : average temperature inside the chamber (°C)

äCsp/dt : change rate of concentration of CO_2 gas (mg.kg^{-1} minute^{-1})

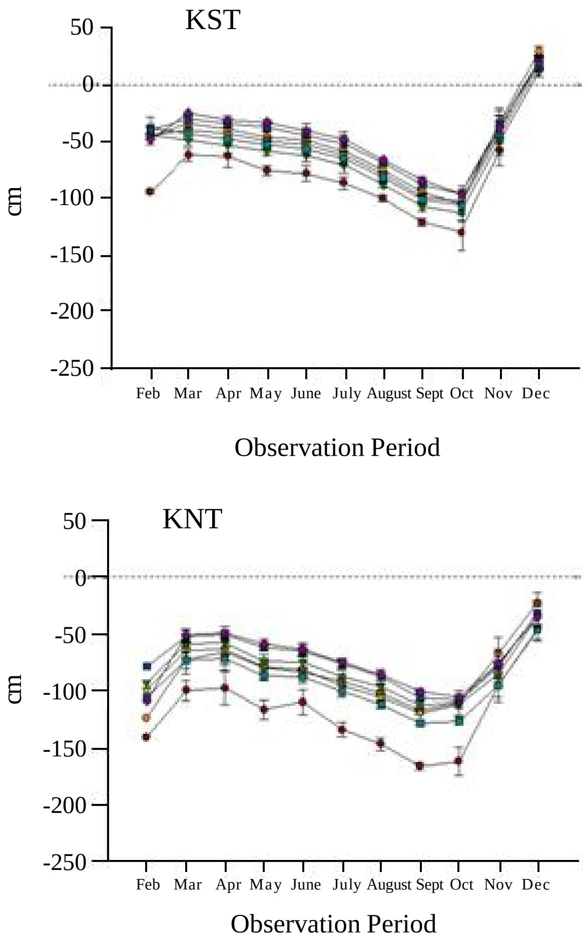

Figure 1. Groundwater levels in research sites. : Drainage Canal, : 16 m, : 24 m, : 32 m, : 40 m, : 100 m, : 150 m.

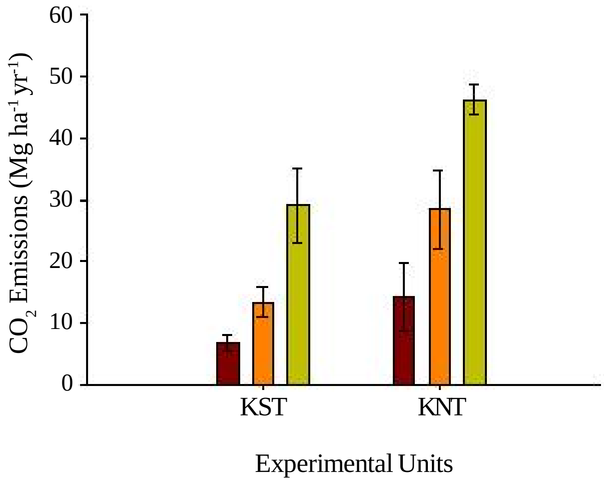

Figure 2. Carbon dioxide emissions in the research sites. : Rainy Season, : Intermediate, : Dry Season.

Bm : molecule weight of CO_2 gases in a standar condition

Vm : gas volume at the stp condition *(standar temperature and pressure)* i.e. 22.41 liters at 23°K

The soil samples were taken at a depth of 0-50 cm, 50-100 cm and 100-150 cm for the analysis of water content (gravimetric) and the functional group in organic matter (FTIR spectrophotometer and its interpretation by Flaig *et al*. 1975). Functional groups can be identified based on the different of infrared absorption intensity on the specific wave number (cm^{-1}) (Artz *et al*. 2008; Krumins *et al*. 2012). The functional groups intensity determine by peak area calculation from each functional groups curve. In addition it also conducted observations of groundwater levels. Observation of groundwater levels is done once a week and starts from February to December 2014. The determination of groundwater levels in piezometers are made of PVC q 1.5"length of 2 m. Piezometers installed at a distance of 16 m, 24 m, 32 m, 40 m, 100 m and 150 m of drainage channels. Variation data were analyzed with standard error and illustrated with Sigma Plot program.

RESULTS AND DISCUSSION

The ecosystems of peatlands is high C stocks, however the carbon stored within it easier emitted when natural peat forest felled and drained. The process of C emissions very rapidly occur when burning peat forests and is one of the serious problems that affect the ecological balance due to loss and destruction of peat forest resources. The

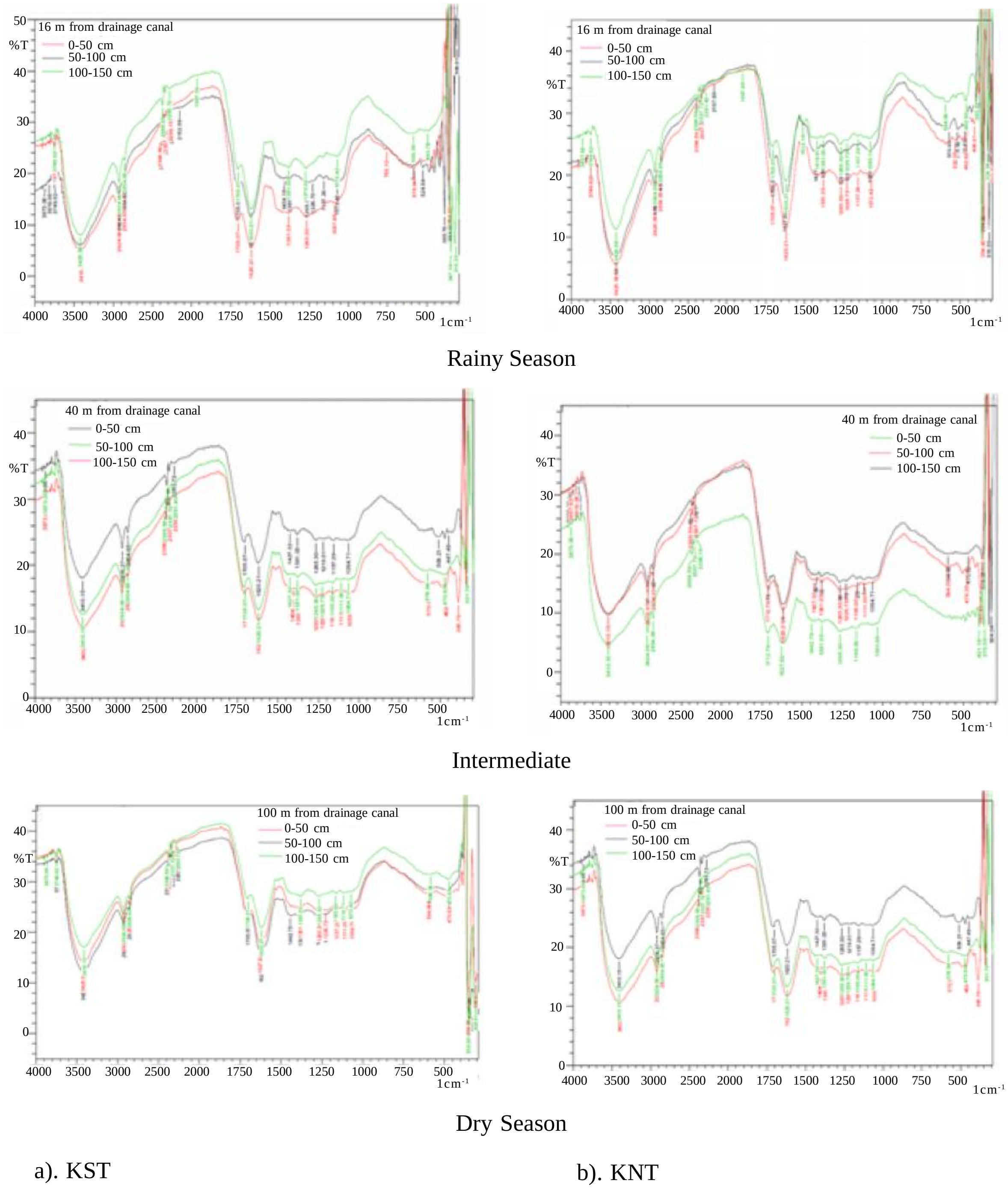

Figure 3. Peat spectrogram FTIR at some point of observation.

research location is peatland affected by tidal activity Kahayan river. Geographically located at 02°29’50 “- 02°30’30" S and 114° 09’30 “- 114°11’20" E. Peat thickness ranged between 437-600 cm (KST) and 420-478 cm (KNT) (Nurzakiah *et al*. 2014).

Water management is done as one of the mitigation actions of CO_2 emissions. Groundwater levels play an important role in the process of accumulation and decomposition of peat which will affect the amount of CO_2 emissions. As long as observation period, the pattern of groundwater level fluctuations was similar at the two experimental units (Figure 1). Groundwater level decreased with increasing observation time and attain its lowest point in October 2014 was 112.0 ± 7.7 cm (KST) and 125.7 ± 3.7 cm (KNT) below the ground surface. Groundwater level increase at the next observation period. In the December 2014, groundwater level ranged between 11.3 - 29.3 cm above the ground surface (KST).

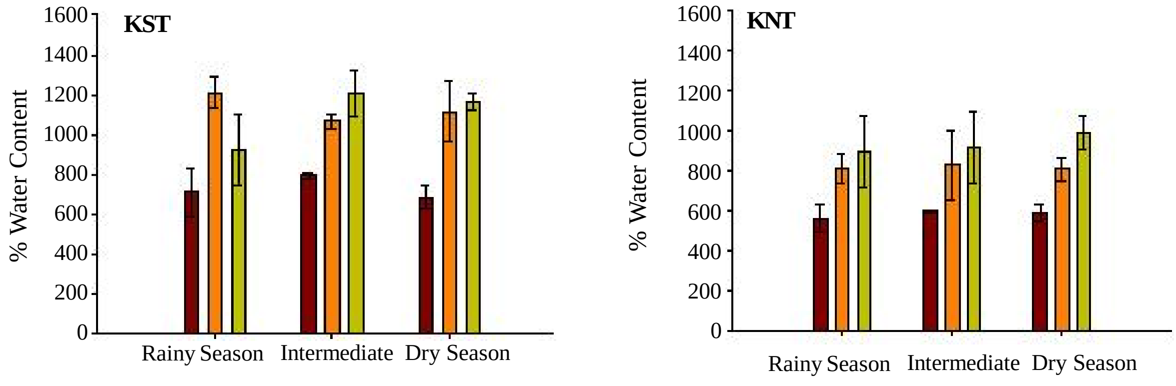

Figure 5. Water content of peat. ▬: 0-50 cm, ▬: 50-100 cm, ▬: 100-150 cm.

Groundwater levels determine oxidative or reductive soil conditions and very influential on hydrophobicity (Szajdak and Szatylowicz 2010). Oxidative conditions can occur when peat drainage. The deeper the ground water level, the oxygen in the soil increased. The presence of oxygen will accelerate the process of mineralization of organic material so that increase of CO_2production and emissions. In addition to the presence of oxygen in the soil, the decomposition rate is also affected by temperature, moisture and nutrient content (Minkkinen *et al.* 2007). Carbon dioxide emissions occur mainly due to the decomposition of organic matter in aerobic and influenced by soil water content. Microbes play a role in the decomposition of organic materials. Fungi are organisms that are the primary decomposers in acid ecosystems such as peatlands (Anderson *et al.* 2006). If there is no fungi, organic matter decomposition under acidic conditions is difficult to occur. From the observations that have been done, CO_2 emissions in the dry season is higher than the rainy season (Figure 2).

In this study, CO_2 gases sampling conducted during the dry season resulted in higher CO_2 emissions and different from the rainy season. This occurs because the groundwater level has decreased up to 125.7 cm from the soil surface (Figure 1). The groundwater level declined, will increase the rate of oxygen diffusion into the soil and increasing aerobic decomposition process that will increase CO_2 emissions. The average CO_2 emissions at two experimental units, namely KST and KNT, respectively was 16.4 Mg ha^{-1} yr^{-1} and 29.6 Mg ha^{-1} yr^{-1}. Overall (of the rainy season until dry season) it can be seen that the water management "*tabat* system" can reduce CO_2 emissions in the amount of 47.6% compared with the peatland there are no water management.

Water management actions need to be done to maintain peat under moist conditions. If peatland areas disturbed by human activities such as the clearing of natural forests without regard to principles of conservation, there will be subsidence and peat surface becomes dry and vulnerable to fire.When fire consumes vegetation and underlying litter layers, hydrophobic conditions can form (Olorunfemi *et al*. 2014). During combustion hydrophobic organic compounds in litter and topsoil are volatized and released upwards to the atmosphere and downwards into the soil profile along a temperature gradient. This process causes a decrease in affinity for water (Doerr *et al.* 2000). The hydrophobic zone appears as a discreet layer in the soil, at or parallel to the surface. In chemistry, hydrophobic substances have no polarity and therefore do not attract water (De Bano 1981). Drypeat will be lose its function as a soil and hydrophobic, so that it becomes irreversible drying.Peat characteristics associated with irreversible drying, among others arewater content and peat composition.

In this study, the characteristics of peat assessed by analysis groups hydrophilic and hydrophobic with the reading on the FTIR (Fourier Transform Infra Red) spectrophotometers and interpretation by Flaig *et al.* (1975). The FTIR can provide information about the structure of the polymer, the constituent groups, branching, stereoregularity etc. Different functional groups absorb at different frequencies. Groups carrier hydrophilic properties at the peak sorption 3425 cm^{-1} (indicative of the existence of bond H, OH groups and free OH), 2924 cm^{-1} (groups aliphatic CH, C-H_2 and C-H_3), 2854 cm^{-1} (carboxylate ion) and 1381 cm^{-1} (COOH groups in the form of carboxylate salts). While the groups carrying hydrophobic properties are the absorption peaks in 1,712 cm^{-1} (C = C bonds of the ester, ether, phenol and benzene ring), 1627 cm^{-1} (ester, ether, phenol and group C = C in the form of cyclic and benzene) and1265 cm^{-1} (CO esters, ethers and phenols). Figure 3 showing peat spectrogram FTIR at some point of observation. Visible spectrum almost the same pattern at each point of observation (peat depth of 0-150 cm) that distinguishes it is the area of sorption.

The results of peat spectrogram FTIR, obtained a total area sorption in peat hydrophilic or hydrophobic. Hydrophilic peat has an area of sorption between 49.5 - 53.2% (KST) and 50.8 - 51.8% (KNT), while hydrophobic peat has an area of sorption between 11.1 - 14.3% (KST) and 9.3 - 15.3% (KNT) (Figure 4).The peats hydrophilic commonly have almost the similar area of sorption. It indicates that the peat in this study, at depths of 0-150 cm has almost the same vulnerability to drought and fires, especially if there is no water management. When a decline in groundwater level significantly due to the manufacture of drainage channels or due to reduced rainfall will lead to quick dry peat because hydrophilic organic compounds can not perform its function to absorb water. From the data obtained, water management with tabat system can reduce hydrophobic properties of peat (0-50 cm soil depth) of 6.6%. A degree of peat hydrophobicity is important from the viewpoint of maintaining the water balance and the protection of peat against microbial degradation (Bachmann *et al*. 2006).

Hydrophilic and hydrophobic properties associated with water content. Both of these properties are qualitative parametersthat describes the extent of interaction between surface water and soil parti- cles. The maximum ability of peat to store water is very large ranges from 200 to 1,000% on the basis of weight or 50-90% on a volume basis (Andriesse, 1988). The water content peat in KST ranged from 687.7 ± 57.4% until 1210 ± 75.7%, while on KNT ranged from 562.9 ± 72.7% until 919.5 ± 179.4% (Figure 5).

The high levels of water content due to the structure of peat is coarse (fibrous) and the hollow that can accommodate a large amount of water. Additionally, peat has a bulk density and bearing capacity that low as a result of high buoyancy and pore volume. Szajdak and Szatylowicz (2010) stated that the amount of peat's ability to retain water relate to higher humic compounds contained in peat. Water content is influenced by the groundwater level, peat-forming material origin and the degree of peat decomposition. The degree of peat decomposition affects the porosity and the porosity is controlled by the layout of particle size or fiber peat.

In ideal conditions, the hydraulic conductivity of peat that is aerobic/oxidative much higher than anaerobic / reductive. In the oxidative conditions, fibric can hold more water than hemic and sapric but the reductive conditions, its ability to vary according to the distance to the groundwater level. Water management actions can prevent decreasing ability to store water in fibric peat of 26.6%.

CONCLUSIONS

Water management with *Tabat* System can reduce CO_2 emissions by 47.6%, reducing hydrophobic properties of peat (0-50 cm soil depth) of 6.6% and is able to prevent decreasing ability to store water in fibricpeat of 26.6%.

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