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EFFECTIVE WATER MANAGEMENT FOR OIL PALM IN PEATLAND: FOR PEAT CONSERVATION AND YIELD OPTIMIZATION

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SUMMARY

Oil palm developments in peat land need to emphasize an effective water management in order to have optimum and sustainable oil palm productivity and also peat conservation. The effective water management was conducted by drainage through canals to reduce water level and provide appropriate space for palm roots. The aims of the effective water management were to: 1) maintain an optimum and suitable water level for oil palm growth and productivity; 2) drain the excess water and avoid longer flood periods; 3) minimize peat subsidence; 4) restrict CO_2 emissions; 5) avoid peat drought at upper layer; and 6) avoid the risk of peat burnt. The study was carried out to assess the effect of ground water level on soil moisture variability, CO_2 emission and oil palm growth in an oil palm agro-ecosystem. This study was designed with three treatments of ground water level management, namely: 1) GWL-1 (by setting ground water level at 40-60 cm); 2) GWL-2 (by setting ground water level at 60-70 cm); and 3) GWL-3 (without ground water level control). The research showed that the best water level management was around 40-60 cm from peat surface (measurement with piezometer). This water level will result higher oil palm productivity (about 15%), restricted CO_2 emissions up to 18%, and also maintain the moisture of the upper peat layer. Inappropriate water management usually leads to problems such as dry symptom on lower oil palm fronds, caused by too low ground water levels. The application of an effective water management will prevent drought problems at oil palm fronds, especially in dry seasons.

Keywords: *effective water management, peat land, ground water level, oil palm.*

INTRODUCTION

Total oil palm area in Indonesia by 2015 covered approximately 11.4 million hectares (Mha) (Reference). Due to limited availability of suitable land for oil palm cultivation, the development of oil palm focuses nowadays on marginal lands such as peat. However, the management of oil palm on peat is faced with various problems, mainly in terms of both physical and chemical properties such as: (1) a low level of peat fertility; (2) difficulties in measuring the ground water level between rainy and dry seasons; and (3) high flammability when it is dry (References).

The total tropical peat land of Southeast Asia has been estimated as large as 247,778 km^2 or about 24.8 Mha (Page *et al.,* 2011). Within Southeast Asia, Indonesia has a best estimate of 149,056 km^2 (about 14.9 Mha) of peat land (Ritung *et al.,* 2011).

Under natural conditions, tropical peat land are invariably water-logged with high water tables at or near the surface. Meanwhile, to use tropical peat land for oil palm cultivation, a good water management system is required. This system must be able to remove excess water either at the surface or sub-surface immediately during the rainy season and also must be able to hold water at the predetermined level range as long as possible during dry season. It is important, because excess water can inhibit the development of oil palm roots, while the lack of water will cause the damage of peat land. The aims of an effective water management are to: 1) maintain an optimum and suitable water level to oil palm growth and productivity; 2) drain the excess water and avoid longer flood periods; 3) minimize peat subsidence; 4) restrict CO_2 emissions; 5) avoid peat drought at the upper layer; and 6) avoid the risk of peat burnt. (References missing for this part)

Based on the background, a study was conducted to assess the impact of effective water management to achieve optimum and sustainable oil palm productivity and also peat conservation.

MATERIAL AND METHODS

The study was carried out in Panai Jaya (PAJ) Oil Palm Plantation at district Labuhan Batu, province of North Sumatera-Indonesia. The oil palm block chosen as research plot was 6 years old oil palm (planting year was

2008). The Panai Jaya Estate is cultivated on peat land area with a thickness of peat ranging between 344-503 cm and hemic-sapric maturity degree (Yulianti, 2009; Winarna and Sutarta, 2010).

Plots were treated with three variations of ground water level (GWL), namely: 1) GWL-1 (by setting ground water level at 40-60cm; measured using piezometer); 2) GWL-2 (by setting ground water level at 50-70cm; measured using piezometer); and 3) GWL-3 (without ground water level control). Ground water level management was carried out by setting weirs (water level control structures) at the collection drains, equipped with an over-flow facility. Soil bags were used to construct the weirs. The water level at each plots was observed using piezometer to measure the water level fluctuation during the research. The research observation consists actual soil water content (direct measurement in the field), CO_2 emission, oil palm growth and production.

RESULTS AND DISCUSSION

Peat Characteristics

Physical and chemical characteristics of the peat are presented in Table 1. The soil thickness ranged from 343.65 to 502.92 cm, with sapric maturity level in the upper layer (0 to 10/20 cm) and hemic in the lower layer (10/20 to 50 cm). The fibre content of 44% on upper layer and 68% on lower layer. The peat soil acidity was classified very acid and the bulk density of sapric (at the upper layer) was higher than hemic.

Table 1: Peat soil characteristics of research sites

Peat Properties	Peat Maturity	
	Sapric	Hemic
pH (H_2O)	3.68	3.50
C-organic (%)	55.08	55.26
Ash content (%)	5.05	4.73
Fibre content (%)	44	68
Bulk density (g cm^{-3})	0.18	0.17
Porosity (%)	88.00	90.67
Water content pF2.54 (%, w w^{-1})	354.21	375.93
Water content pF4.2 (%, w w^{-1})	171.48	179.10

Variability of Actual Soil Water Content

The differences in depth of the ground water level at the three treatment plots significantly affected the reduction of soil moisture in the layer of 0 – 10 cm. Soil moisture level at the layers of 0-10 cm in the treatment of GWL-1 showed the highest value compared to GWL-2 and GWL-3. However, the effect of a decrease in ground water level was no longer significantly influential on soil moisture at the layer deeper than 10 cm.

Based on the observations of the soil water content during the wet seasons (rainfall > 100 mm), variability of soil moisture on the all GWL was relatively small. This is because the ground water level of all GWL is relatively shallow and has quite similar fluctuations. While in the dry months, all GWL treatments decreased the ground water level. The largest decrease occurred in the GWL-3, i.e., deeper than 70 cm.

There was a considerably great variability of soil moisture content in the field, mainly in the upper layer of peat due to ground water fluctuation. The relatively large decrease of soil moisture occured during the dry seasons and the ground water level became deeper. When the condition of ground water level was too deep (>70 cm from soil surface), the soil layer of 0 – 10 cm were very vulnerable to hydrophobicity.

Carbon Dioxide (CO_2) Emission

CO_2 emissions were 49.99; 37.67; and 25.64 tons ha^{-1} $year^{-1}$ from GWL-1, GWL-2, and GWL-3, respectively. The GWL up to >70 cm from soil surface significantly increased the CO_2 emissions. Figure 1 shows that the CO_2 emission on GWL-3 is higher than GWL-2 and GWL-1, respectively by 49.99; 37.67; and 25.64 tons ha^{-1} $year^{-1}$.

Figure 2 showed the relationship between CO_2 fluxes with ground water level. The figure shows that any reduction in the depth of ground water as deep as 10 cm will increase the flux CO_2 of 30.6 mg m^{-2} $hour^{-1}$ or the CO_2 emissions of 2.7 tons ha^{-1} $year^{-1}$. Setyanto *et al.* (2010) stated that there will be an increase about 5.73 tons of CO_2 ha^{-1} $year^{-1}$ on each 10 cm decrease in the depth of ground water level.

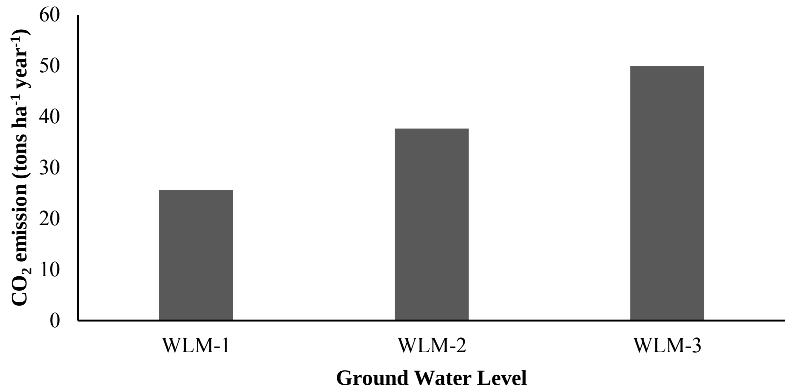

Figure 1: CO_2 emission at three different water level treatments (GWL)

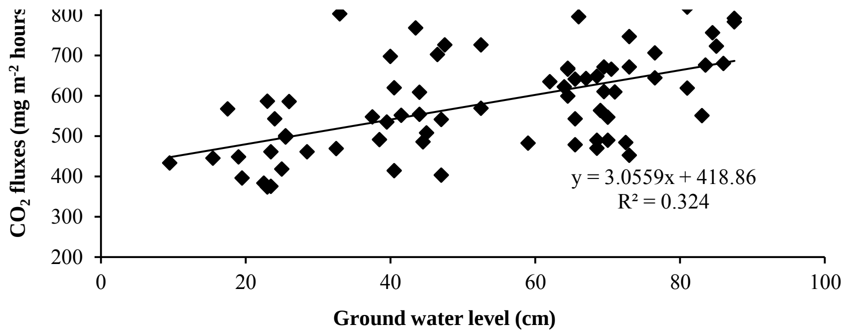

Figure 2: The relationship between CO_2 fluxes with ground water level (GWL-1; GWL-2 and GWL-3)

Oil Palm Growth and Productivity

Oil palm growth parameters observed were petiole cross-section (PCS), leaves dry biomass at 17th frond, and leaf area index (LAI). The GWL-1and GWL-2 treatments significantly increased PCS, leaves dry biomass and LAI compared to GWL-3, whereas comparisons between GWL-1 and GWL-2 showed no significant effect on oil palm growth (Table 2).

The ground water level (GWL) treatment significantly affected fresh fruit bunches (FFB) production (6 years old). The FFB production was in the following order: GWL-1 > GWL-2 > GWL-3. The decrease of GWL deeper than 70 cm significantly reduced the production of FFB up to 11% toward the treatment of GWL in the range of 30-70 cm. The implication of this research was that the application of good water management on the peat soil in the oil palm plantations by regulating the ground water level in the range of 30-70 cm that was adequate of keeping the soil moist until the top layer of peat soil could prevent hydrophobicity, reduce CO_2 emissions, and improve the growth and production of oil palm.

Table 2: Growth and productivity of oil palm in three ground water level

Ground Water Level	PCS (m^2)	Dry Leaves Biomass (kg)	LAI	Ton FFB ha^{-1} year^{-1}	Bunch tree^{-1}	kg bunch^{-1}
GWL-1	20.45 ^{a}	1.98 ^{a}	3.83 ^{a}	20.40^a	17.12^a	7.12^b
GWL-2	18.82 ^{a}	2.13 ^{a}	3.88 ^{a}	19.82^a	16.91^{ab}	7.41^a
GWL-3	15.55 ^{b}	1.80 ^{b}	3.23 ^{b}	18.44^b	15.19^b	6.82^c

Note: different letters denoted the significant differences (α = 0.05)

DISCUSSION

Bulk density at the upper layer (sapric) was higher than the deeper layer (hemic). Increased bulk density occurred in the higher decomposition degree (Andriesse, 1988; Verry *et al.,* 2001), besides the presence of compacted soil at the upper layer as the result of cultivation. Decomposition degree and compaction of soil also affected the water retention capacity of peat. Based on the percentage of water content at pF 2.54 (strongly retained-water), sapric showed higher retention capacity than hemic. Peat characteristics such as bulk density, hydraulic conductivity, and total porosity are closely related to the water retention capability of peat.

Water level in peat fluctuated rapidly during rain or dry seasons. Decrease in ground water levels affect the distribution of soil moisture to the entire peat soil profile in upper layer (Kurnain *et al.,* 2006). Changes of ground water level resulted in the release of a number of volumes of soil water from the upper layer. The soil water content has a considerable influence on the actual hydrophobicity of peat in the field. The peat hydrophobicity can occur if the soil moisture is lower than the critical water content. A critical water content value is issued to determine the actual hydrophobicity of the studied peat soil, which compares the actual water content with critical water content in the corresponding layers. The actual water content above the transition zone which a peat is wettable and below which a peat is hydrophobicity. Soil sample can be either wettable or hydrophobic within the transition zone (Dekker *et al.,* 2001). Differences in critical soil water content at each layer of peat in the field is mainly influenced by the peat properties.

There are significant differences of CO_2 emission rates between GWL-1, GWL-2, and GWL-3 treatments. The results showed that the GWL-1 and GWL-2 treatments the CO_2 emissions are lower than GWL-3. From these result it appears that there is a linear correlation between the depth of ground water level to the rates of CO_2 emission, meaning the CO_2 emission increased as ground water level decreased. This study also showed that at ground water level less than 70 cm (GWL-1 and GWL-2), the CO_2 emission are still lower than the minimum emission constants defined by the Intergovernmental Panel on Climate Change (IPCC) at 40 tonnes of CO_2 ha^{-1} $year^{-1}$. This means that with management of ground water level at about 30-70cm, the requirements of IPCC can be met.

Management of ground water level in peat land for oil palm cultivation should increase water retention and keep it as long as possible until the peat surface, especially during dry seasons (Melling and Hatano, 2010). During rainy seasons, the ground water should be controlled at a lower level to reduce excessive water, whereas in the dry season, the ground water level should be controlled at a higher level for the preservation of peat (Ambak and Melling, 2000; Wosten *et al.,* 2008; Lim *et al.,* 2012).

At the GWL-3 treatment, when the ground water level was set deeper than 70cm, this lead the upper layer of peat to become dry and this caused the plant growth to be disrupted. The analysis of actual water content results showed that the actual water content has decreased by 255% (w w-1) at the GWL-3 treatment. The soil water content on permanent wilting point conditions (pF 4.2) ranged from 231-248%, which means the available water that can be absorbed by plants is only about 7-24%. Since oil palm needs water in adequate volumes to maintain the continuity of physiological functions, this will certainly give a negative impact on oil palm growth.

CONCLUSION

The maintenance of water levels in the range of 40-70 cm significantly increased the ability of the peat soil to retain water at the layer of 0-10 cm. Excessive soil drainage (depth of ground water level > 70 cm) causes soil hydrophobicity (irreversible drying) at the upper layer, especially in dry season. Although drainage is important for oil palm cultivated on peat land, over-drainage should be strongly avoided. For implementation on the ground, it is important to manage ground water levels at 40-60 cm from peat surface by installing water barriers (stop-log) and other water control structures. Since ground water levels in peat can fluctuate rapidly during rainy or dry seasons, it is important to control ground water levels regularly. The implication of this research was that the application of effective water management on the peat soil in the oil palm plantations by regulating the ground water level in the range of 40-60 cm proved an adequate approach to keep the soil moist until the top layer, prevent hydrophobicity, reduce CO_2 emissions, and improve the growth and production of oil palm.

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