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The Effects of Various Water Table Depths on CO_2 Emission at Oil Palm Plantation on West Aceh Peat

Etik Puji Handayani[1], Meine van Noordwijk[2], Kamarudin Idris[3]
Supiandi Sabiham[3] and Sri Djuniwati[3]

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ABSTRACT

The Effects of Various Water Table Depths on CO_2 Emission at Oil Palm Plantation on West Aceh Peat (EP Handayani, M van Noordwijk, K Idris, S Sabiham and S Djuniwati): Changes in the depth of water table influenced carbon cycling in peatlands, and affected the sources and sinks of carbon dioxide. The effects of depth of water tables in oil palm plantations on the emission of CO_2 were studied. CO_2 emissions of peatland were measured in Meulaboh, West Aceh using cylindrical chambers and air samples from the chambers were analyzed by gas chromatography. Five-point transects perpendicular to drainage canals provided variation in the depth of water tables for the samples. Data from oil palm fields were compared to data from an adjacent swamp forest. The data confirmed that the increasing depth of water table was accompanied by the increasing in microbial activity that was measured by CO_2 emission. The CO_2 emissions from chambers with additional root zones were higher than from bulk soil chambers between one to four times.

Keywords: CO_2 emissions, depth of water table, oil palm, peat land

INTRODUCTION

Peatlands worldwide play a vital role in biosphere biogeochemical processes. Peatland constitutes an important biome because of its high soil C content. Turenen *et al.* (2002) estimated that peatlands store 220–460 pg of carbon and hence can significantly influence atmospheric CO_2 concentrations (Hilbert *et al.* 2000).

The total area of peat lands in Indonesia is about 20 million ha (Rieley 1996) and the average oil palm yield on peat land can reach 23 Mg $ha^{-1}y^{-1}$ fresh fruit bunches (Winarna, 2007). Therefore, peat lands have considerable potential for development of oil palm agrobussines in Indonesia. However, peat lands contain one-third of global soil carbon and total stocks represent 70 years of current annual global emission from fossil fuel burning. This carbon store is now being released to the earth's atmosphere through forest fire and respiration, both increased by drainage.

Like many ecosystems, peat land accumulates C under undrained (undisturbed) conditions and emits C (CO_2 by oxidization) under drained (disturbed) conditions (Nykänen *et al.* 1995, Laiho *et al.* 1996, Silvola *et al.* 1996). Peat soil subsidence after drainage is often seen as a rough measure for CO_2 emissions, though little agreement exists on the fraction of the subsidence that can be attributed to oxidization.

Carbon dioxide gas is part of the greenhouse effect on global warming. CO_2 gas emissions vary with stages of plant growth, depending on management practices for soil and plants (such as drainage and fertilization) and characteristics of peat land, including water level, and the thickness and maturity of the peat deposits.

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[1] STIPER Dharma Wacana Metro, Lampung, Indonesia, email etik_ph@yahoo.com;
[2] World Agroforestry Centre, South East Asia Office, Bogor, Indonesia;
[3] Bogor Agricultural University, Bogor, Indonesia.

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This research was aimed to be assessing the influence of depth of water tables on CO_2 emissions on the areas with roots and without roots.

MATERIALS AND METHODS

Study Site

This research was conducted in the peat domes of Aceh Barat District, Nanggroe Aceh Darussalam (NAD) Province of Indonesia in 2008. The emitted CO_2 gas was captured using closed chambers from the rooted (R) and non-rooted (NR) chambers or zone. The observation was conducted at smallholder oil palm plantations with 10 and 5 year old plant stands. For each of the age groups, three to five pairs of observation points were made one transect which have the same depth of peat, each point with R and NR treatment.

Analysis of CO_2

The closed chambers of 30 cm diameter and 30 cm tall were made of PVC tubes. The bottom brim of the chamber was sharpened to minimize soil compaction during their insertion into the ground. For each chamber designed for rooted zone emission, a hole of 5 cm diameter at a point 20 cm from its top was made for channelling three pieces of oil palm roots in such a way that the roots can still grow and develop inside the chambers. These chambers were installed at a distance of 2.5 m from the trunk of oil palms aged 10 years, and 1 m from the trunk of oil palm aged 5 years according to the distribution of the plant roots. The paired R and NR chambers were mounted at a distance of 1 m from each other. Each chamber was equipped with a septum to place the needle puncture. A small (6 cm battery powered) fan was installed inside the chambers to stir the gas. A thermometer was also installed for each chamber to measure the temperature during the gas sampling.

Time of Observation

Gas samples were taken by using syringes of 5 and 10 ml capacity, with a sampling frequency of 0, 5, 10, 15, 25 and 35 minutes after closing of the chambers. All sampling was conducted during the morning hours from 07:00 to 10:00 *a.m.* for best consistency. Samples were analyzed within 24 hours after sampling using a portable gas chromatography instrument. Measurements were conducted from October to November 2008 to represent early rainy season. For each gas emission measurement point, the depth of the water table was also measured from a hole as deep as 1 m made with a soil auger at the midpoint between the R and NR.

RESULTS AND DISCUSSION

The rate of CO_2 emissions in the peat soils was in the range of 10 - 40 Mg ha^{-1} yr^{-1}. The CO_2 emissions from each transect is shown in Figures 1 - 7.

Carbon dioxide emission in rhizosphere zones (the chamber with roots) were higher than non rhizosphere zones (the chamber without roots). However, the effect of water table depth on CO_2 emissions was rather inconsistent. Other researchers demonstrated a positive correlation between CO_2

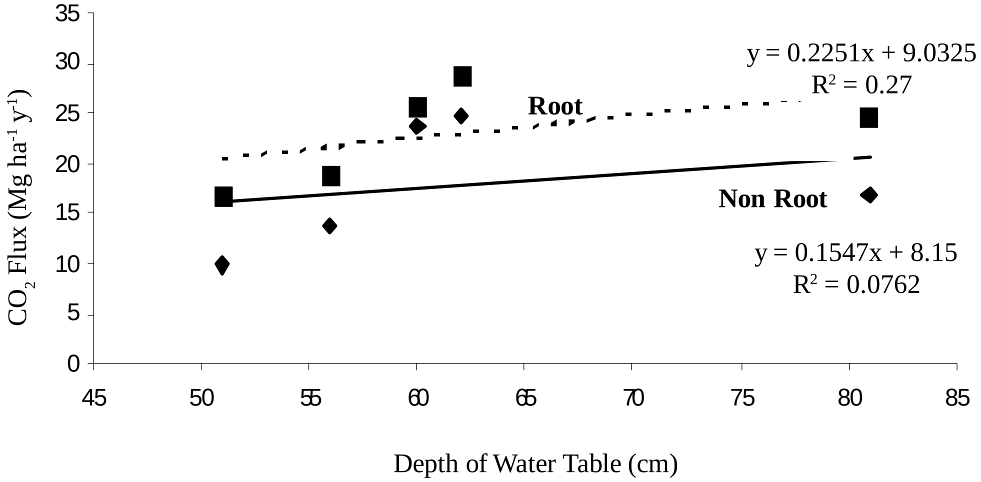

Figure 1. CO_2 emission under a smallholder oil palm plantation in Suak Puntong, Transect 1.

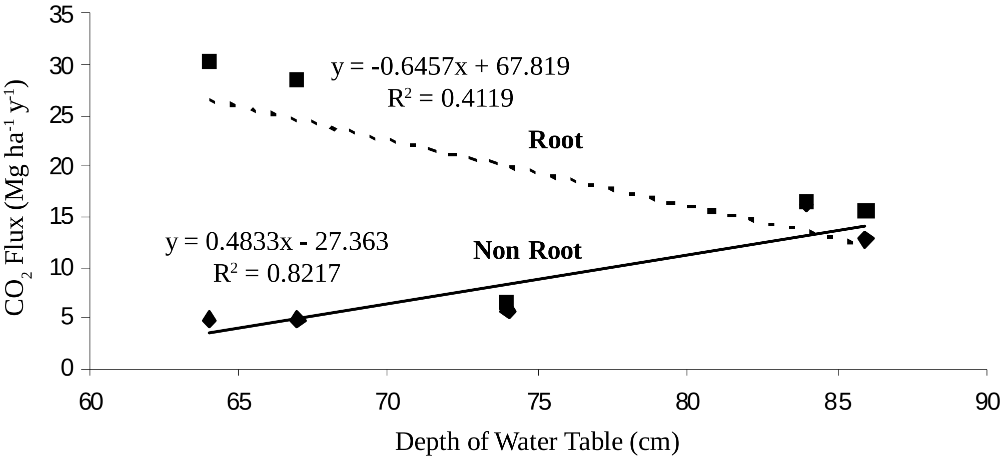

Figure 2. CO_2 emission under a smallholder oil palm plantation in Suak Puntong, Transect 2.

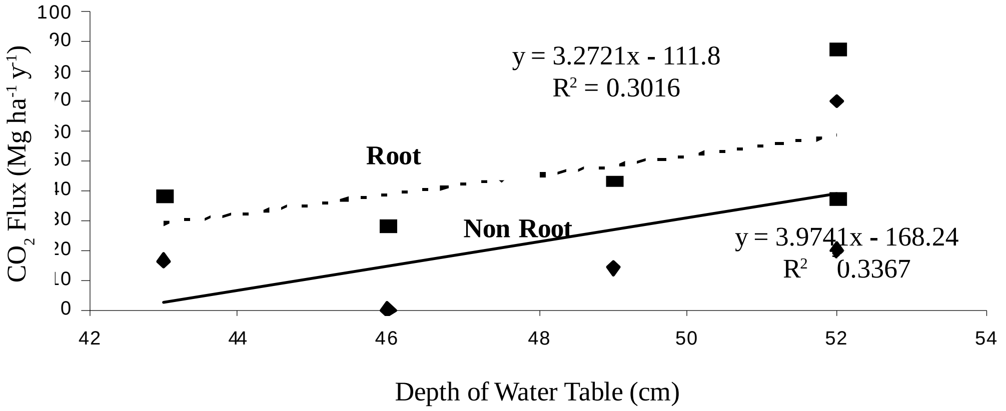

Figure 3. CO_2 emission under a smallholder oil palm plantation in Suak Raya, Transect 3.

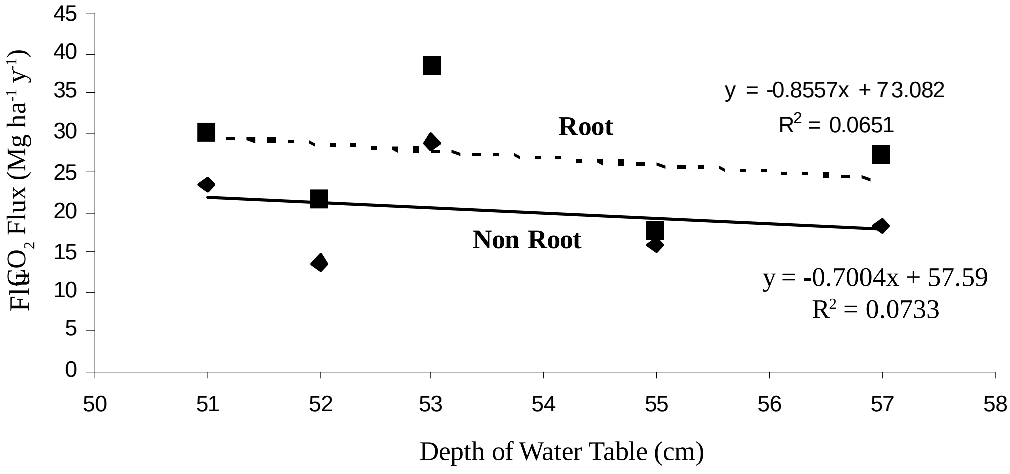

Figure 4. CO_2 emission under a smallholder oil palm plantation in Suak Raya, Transect 4.

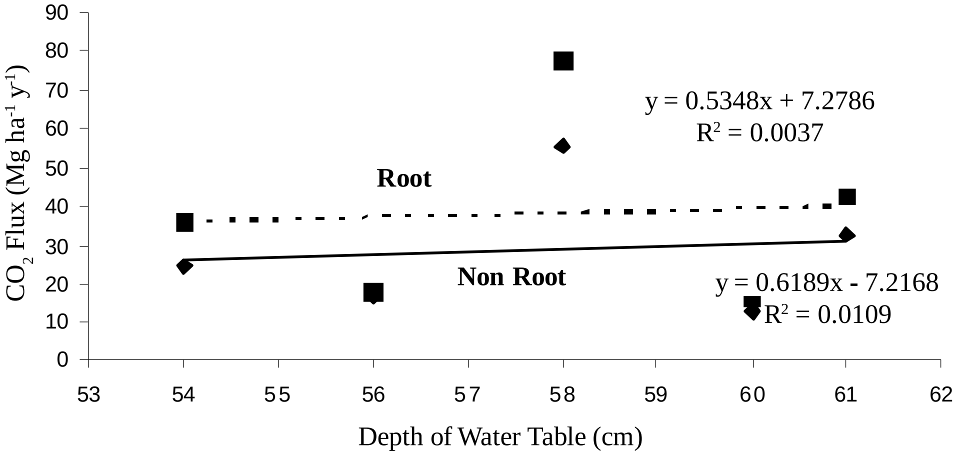

Figure 5. CO_2 emission under a smallholder oil palm plantation in Suak Raya, Transect 5.

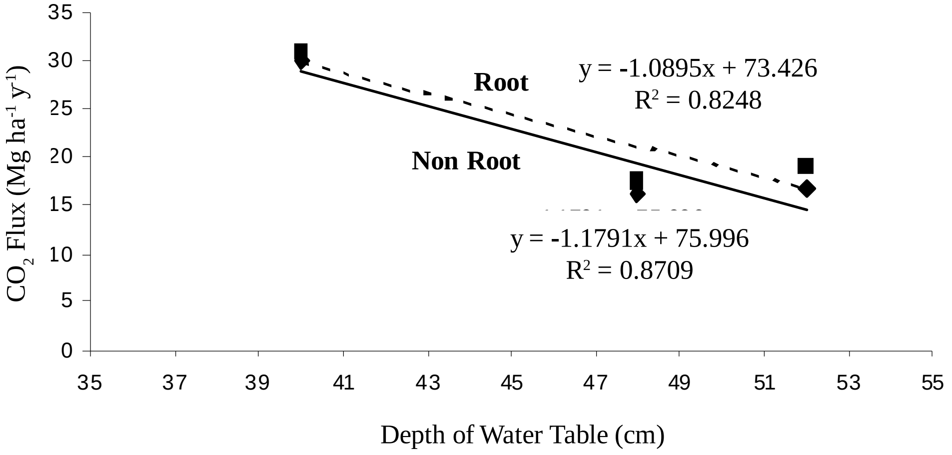

Figure 6. CO_2 emission under a smallholder oil palm plantation in Suak Raya, Transect 6.

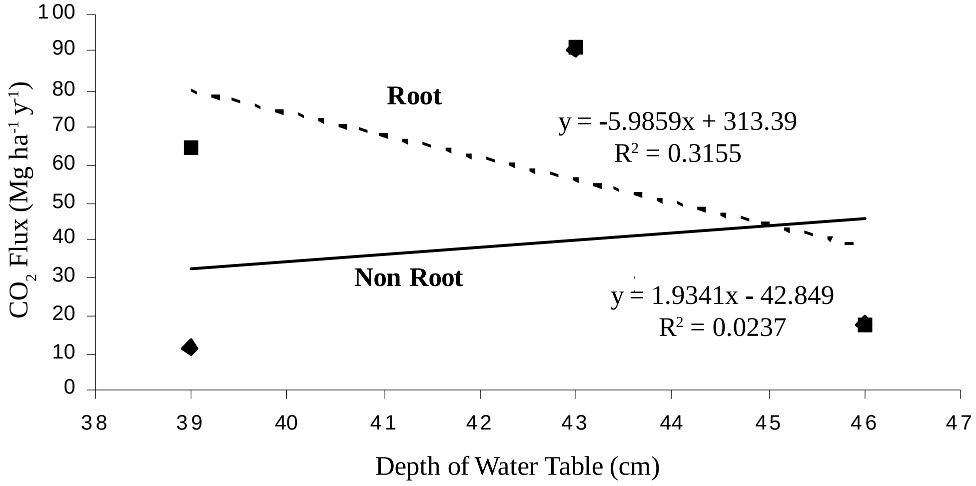

Figure 7. CO_2 emission under a smallholder oil palm plantation in Suak Raya, Transect 7.

emissions and water table depth (Hooijer *et al*. 2006; Jauahiainen *et al*. 2001). The high variation in our data may have contributed to these inconsistencies. At transect 1, 2, 3, 5 and 7 the phenomenon of CO_2 emission increased with increasing depth of water table, while at transect 4 and 6 would be decreased. CO_2 emission decreased with increasing depth of water table at transect 4 and 6 due to the peat thickness only 142-170 cm than the other transect. Yulianti (2009) reported that the reserved of C peat had a positive correlation to thickness of peat ($r = 0.93$).

Results of measurement of depth of water table in each transect indicate that in the same transect, the point of measurement which was close to the drainage channel had the deeper water table, and progressively far from the drainage channel, hence depth of water table decreased. All of the transect except transect SR-4 and SR-6 showed the same correlation that was progressively far from the drainage channel, the water tables were shallow and CO_2 emissions decreased. It was because the nearer point of measurement with the drainage channel, deeper water table caused advance decomposition. Condition aeration would be faster to improve the Oxygen availability in peat substances and could be accelerated the process of C-Organic mineralization. As a results, peat substances produced CO_2, so that CO_2 emissions were higher in the point of measurement near from the drainage canals. Thereby, it could be said that the depth of the water table represents one of factor influencing CO_2 emission. Other researchers reported that decomposition was very influenced by depth of irrigation and water fluctuation irrigation (Belyea and Clymo 2001), so that the content irrigated to influence the emission CO_2 from underground (Smith *et al.* 2003; Liu *et al.* 2008). Silva *et al.* (2008) reported that emission of CO_2 1.2 times bigger at soil which incubation with water holding capacities 40%, 60% and 80% compared to soil with water holding capacities 100%. According to Jia *et al.* (2006), too high water content would pursue the diffusion of CO_2 and microbial activity. However Stark *et al.* (2004) also stated that lowering water content would degrade the microbial activity.

In this research, the value of non root in closed chamber emission, with mean ranging from 18 to 24 Mg $CO_2^{-1}ha^{-1}yr^{-1}$ were less half than the predicted values of Hooijer *et al* (2006) of around 54 Mg CO_2^{-1} ha^{-1} y^{-1} under the depth drainage (in this case, the water table) of around 60 cm and Melling *et al.* (2005) of around 50 Mg CO_2^{-1} ha^{-1} yr^{-1} for oil palms in Sarawak Malaysia and Jauhiainen *et al.* (2001) for stabilized agricultural land. This was because of the limited measurements conducted under the current experiment. Nevertheless the effect of rhizosphere was consistent under the current experiment. Hirano *et al.* (2007) expressed that result of measurement of CO_2 emissions from peat tropic was very high variation depends on time and measurement place, when farms start in conversion, differences microclimate such as temperature of under ground and air temperature, status of nutrient.

Carbon dioxide emissions from rhizosphere zones were 1 up to 4 times bigger than non rhizosphere zones. It was because of the quality of root media capable of changing the nature of physical, chemical and soil biology in an around roots (Darrah 1991; Gregory and Hinsinger 1999). Rhizosphere had the conducive environment expanding a lot of organisms (Bowen and Rovina 1973; Peterson 2003) hence a lot of processes in the rhizosphere directly and also indirectly increased capacities of soil function for the growth of crops and as an environmental buffer (Gregory and Hinsinger 1999). The total of microbial activity as an effect of height of concentration nutrias, C-Labile, and exudates grow on around root area (Kuzyakov *et al.* 2000; Subke *et al.* 2004; Hamer and Marschner 2005). Thereby, produce the CO_2 representing resultants from respiration of microorganism and the value of root respiration on the rhizosphere that were higher than that on the non rhizosphere.

CONCLUSIONS

CO_2 emission increased with increasing the depth of the water table. However, the reverse pattern was also found, and another pattern where CO_2 emission was independent the depth of the water table. It would cause a strong over estimate of peat soil contribution to CO_2 emission when the measurement was conducted in rooted area. Thus when zoning of the measurement was not possible, measurement should be conducted on a relatively root free areas. The CO_2 emissions from chambers with additional root zones were one to four times higher than from bulk soil chambers.

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