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Relationship between Sampling Distance and Carbon Dioxide Emission under Oil Palm Plantation

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ABSTRACT

A carbon dioxide emission on peatland under oil palm plantation was highly varied due to many factors involved. The objectives of the research were to evaluate the effect of sampling distance from center of oil palm tree on Carbon dioxide flux, and to study the factors that cause variability of carbon dioxide flux on peatland under oil palm plantation. The study was conducted on peatland at Arang-Arang Village, Kumpek Ulu Sub-District, Muaro Jambi District, Jambi Province, on six-years old oil palm plantation. The study was conducted in the form of observational exploratory. Emission measurements were performed on 5 selected oil palm trees at points within 100, 150, 200, 250, 300, 350, and 400 cm from the center of trunk. Carbon dioxide flux was measured using (IRGA), Li-COR 820. The results showed that there was significant correlation between the distance of sampling from center of oil palm tree and Carbon dioxide flux. The farther distance from the tree, the more decreased of Carbon dioxide flux . Before applying fertilizer, variability of soil fertility was not significantly correlated with the flux of Carbon dioxide, so the difference of Carbon dioxide flux based on distance sampling can be caused by root distribution factor. After fertilizer application, variability of Carbon dioxide flux under the oil palm tree were not only affected by differences in root distribution but also greatly influenced by fertilization.

Keywords: Carbon dioxide flux, distance sampling, oil palm, peat, root-related respiration

INTRODUCTION

Carbon dioxide emission which is estimated from soil respiration measurement is not only derived from peat decomposition (heterotrophic respiration) but it may also come from plant root respiration (autotrophic respiration). Some studies showed that in density of oil palm root decreased when the distance from the tree were wider (Martoyo 1992, Law *et al.* 2001, Khalid *et al.* 1999, Henson and Chai 1997). Therefore, distance of the observation point from the tree may affect the results of measurements of Carbon dioxide fluxes. Thus it is necessary to determine the appropriate sampling point so that the measurement results can accurately depict the level of emissions from peatlands. It is important to consider because of the Carbon dioxide emissions from autotrophic (root respiration) can be compensated with a Carbon dioxide sequestration from photosynthesis (Murdiyarso *et al*. 2010).

Various studies resulted in a wide range of root-related emission contributions were relative to the total emissions; between 10 and 90% depending on vegetation type and season (Silvoa *et al.* 1996b, Hanson *et al.* 2000). The contribution of root respiration in humid temperate peatlands was between 55-65% of total soil respiration (Knorr *et al.* 2008). This suggests a significant contribution of root-related respiration to the total soil respiration. Types of plant and plant growth stage also affects the root respiration that contribute to total soil respiration. Research conducted by Jauhiainen *et al*. (2012) in peatland under Acacia plantations (aged 31-46 months) in Kampar Peninsula, Riau Province, reported an average contribution of root-related respiration was 21% of the total soil respiration. For oil palm plantation on peatlands the root-related respiration ranged from 26 to 38% (Melling *et al*. 2007, Murdiyarso *et al*. 2010; Hergoualc'h and Verchot 2011; Agus *et al.* 2010).

Variability of carbon dioxide emissions based on distance from trees on peatland also can be caused by management factors, such as application of fertilizer in a circle with a certain distance from the tree. The effects of fertilization on green house gas emission are varied according to some researchers. Carbon dioxide flux increased from non fertile to fertile soil (Mikkinen *et al*. 2007, Silvora *et al*. 1996a). Silvora *et al*. (1985) also reported that P and K fertilization on peatland increased total soil respiration. In oligotropic peat which is unfertile, CH_4 production is extremely low. Amador and Jones (1993) showed that ammonium inhibit decomposition if there are high concentrations of phosphate, whereas the results of Howarth and Fisher (1976) showed a positive effect of nitrate on C fragmentation, mean while the effect of phosphate is not very visible. In the forest of dryland, N fertilization (Olson *et al*. 2005) and PK fertilization (Franklin *et al*. 2003) decreased soil respiration.

The objectives of the research were: (1) to evaluate the effect of distance sampling from center of oil palm tree on Carbon dioxide flux, (2) to study the factors that cause variability of Carbon dioxide flux on peatland under oil palm plantation.

MATERIALS AND METHODS

Study Site

The study was conducted in oil palm plantation at Arang-Arang Village, Kumpek Ulu Sub-District, Muaro Jambi District, Jambi Province, on six year old of smallholder oil palm plantation. The peat depth was <3 m, the maturity of peat in the surface layer was sapric. Figure 1 shows the characteristics of peat at the research site. Oil palm fertilizer was applied to the circle within 200 cm from the center of the tree. The fertilizer doses were based on fertilizer recommendation for oil palm plantations on peat soil, which were 2.5 kg urea, 2.75 kg SP-36, and 1.25 kg KCl tree^{-1} yr^{-1} that were is given twice a year or every six months, so the total doses of six months were 1.25 kg urea; 1.375 kg SP-36; and 1.125 kg KCl tree^{-1}. Application of fertilizer should be noted because it would affect the emission rate.

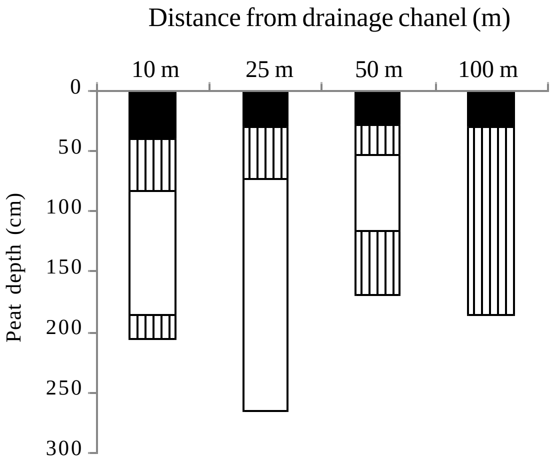

Figure 1. The characteristics of peat (the depth and maturity) at the site research. ■ = sapric, ▥ = hemic, and □ = fibric.

Field Setting and Measurements

The study was conducted in the observational exploratory. Determination of point observations were made using a purposive sampling method, i.e. the determination of observation point is done intentionally, which is considered representative. Measurements of emission were performed on 5 selected oil palm trees at points within 100, 150, 200, 250, 300, 350, and 400 cm from the center of trunk. The measurements of Carbon dioxide flux were was a day before fertilizer application, two days respectively after one week fertilization, and 2 (two) consecutive days every month for 4 months, and at seven months after fertilization.

Carbon dioxide gas that comes out through the surface of the peat soil was captured with the closed lid (closed chamber) made from PVC with diameter of 25 cm and height of 23 cm. The closed lid chamber was buried about 3 cm from the soil surface and the effective to capture Carbon dioxide gas was about 20 cm. The gas from the closed chamber is circulated into the IRGA unit using a pressure pump and its Carbon dioxide concentration is read immediately in the field every second for 2 minutes using Infra Red Carbon dioxide Gas Analyzer (IRGA), Li-COR 820 model. The linear relationship between time and Carbon dioxide concentration will be used for Carbon dioxide flux calculation using the following equation (Madsen *et al*. 2009):

$$f_c = \frac{Ph}{RT}\frac{dC}{dt}$$

Where :
f_c = Carbon dioxide Flux (ìmol m^{-2} sec^{-1})
P = atmospheric pressure based on the average reading *of* IRGA (kPa)
H = height of chamber (cm)
R = gas constant (8,314 Pa m^{-3} ^{o}K^{-1} mole^{-1})
T = temperature
dC/dt = the change in Carbon dioxide concentration over the change of time, which is the slope of the linear relationship of of concentration and time (ppm sec^{-1}).

Some of additional parameters were observed at each Carbon dioxide flux measurement such as water table depth, air, soil, and chamber temperatures, soil water content (% vol) at 20 cm depth. Soil chemical properties were measured at

0-20 cm soil depths at each observations point before fertilizer application.

RESULTS AND DISCUSSION

The results of Carbon dioxide flux measurements on the selected oil palm trees before fertilizer application in June 2011 showed that the highest average of Carbon dioxide flux was occurred at <150 cm distance from the tree. The Carbon dioxide flux decreased after 150 cm distance. The average of Carbon dioxide flux before fertilizer application at <250 cm (100, 150 and 200 cm) was 27% higher than the average of > 250 cm (300, 350, and 400 cm) distance from the tree (Figure 1). The higher value of Carbon dioxide flux at the nearer distance from tree was due to the root density that highly spread in the zone, so contribution of root respiration was relatively dominant in determining Carbon dioxide flux. Some research indicated that closer to the tree, root density was higher (Law *et al*. 2001; Khalid *et al.* 1999; Henson and Chai 1997; Martoyo 1992), and the contribution of roots respiration to total soil respiration was likely to be higher than average (Wang *et al.* 2005).

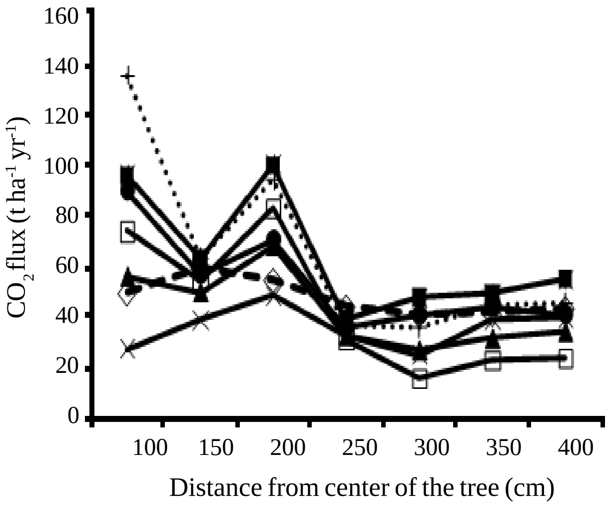

Figure 1. Carbon dioxide flux before fertilization (BF) , 1 week and 1, 2, 3, 4 and 7 months after fertilization (AF) at several site points with a variation of the distance from the center of palm trees. = BF (Jun 2011), = 1 week AF (Jun 2011), = 1 month AF (Jul 2011), = 2 month AF (Aug 2011), = 3 month AF (Sep 2011), = 4 month AF (Oct 2011), and 7 month AF (Jan 2012).

Higher Carbon dioxide flux at the relatively near from the tree before fertilization may also be caused by variability of soil fertility (Table 1). However, there were no significant correlation between soil chemical properties (pH and content of some nutrients) before fertilization and Carbon dioxide flux (Table 2). This could be due to the concentration of chemical properties were not high enough to cause the difference in Carbon dioxide flux.

After fertilization, a drastic change of Carbon dioxide flux was occured. There was also a change in variability based on the distance from the tree, especially for the site point with the highest flux (Figure 1). One week after fertilization, the highest Carbon dioxide flux was on 200 cm from the tree, the average Carbon dioxide flux was 82.23 Mg ha^{-1} yr^{-1}. The average magnitude of Carbon dioxide flux in one week after fertilization increased 52% compared to before fertilization. Water table depth as one of factor influenced to Carbon dioxide flux was relatively similar, it was about 42-43 cm (Figure 2). After one and two months from fertilization, Carbon dioxide flux continued to decrease with magnitude of 67.36 Mg ha^{-1} yr^{-1} and 48.16 Mg ha^{-1} yr^{-1}, respectively. The highest flux still occurred at a point 200 cm, this indicated that the Carbon dioxide fluxes variation were still influenced by fertilization zoning.

At three months after fertilization (September 2011), the flux of Carbon dioxide at all points of return had increased dramatically, the highest flux still occurred at site point of 200 cm distance from the center of tree, which was 99.27 Mg ha^{-1} yr^{-1} (Figure 1). The increasing of Carbon dioxide flux was very rapidly due to the deeper of water table

Table 1. Correlation between the distance of observation points from the center of tree and the chemical properties of peat at the 20 cm depth.

Parameter	pH-KCl	C	N	P_2O_5	K_2O	Ca	Mg	K	Na	Fe	Mn	Cu	Zn
Corr.	-0.55	0.21	-0.14	-0.57	-0.35	-0.58	0.11	-0.33	-0.36	-0.00	-0.29	-0.45	-0.21
P-Value*	0.001	0.220	0.426	0.000	0.038	0.000	0.529	0.056	0.033	0.997	0.089	0.006	0.228

*P values < 0.05 are significantly different at 5 % level.

Table 2. The correlation between the chemical properties of soil and Carbon dioxide flux before fertilization.

Parameter	pH-KCl	C	N	P_2O_5	K_2O	Ca	Mg	K	Na	Fe	Mn	Cu	Zn
Corr.	0.005	-0.11	0.152	-0.097	0.037	0.006	-0.257	0.042	-0.056	-0.234	-0.189	0.00	-0.2
P-Value*	0.731	0.529	0.383	0.581	0.834	0.972	0.136	0.811	0.751	0.176	0.277	0.99	0.248

*P values < 0.05 are significantly different at 5 % level.

depth. This month in which the peak of dry season, the average of water table depth was more than 100 cm (112 ± 14 cm), whereas in other months were <50 cm (Figure 2). Therefore, the establishment of a permanent water table below 75 cm or more on peatlands shall be reconsidered because it is very risky in terms of increasing Carbon dioxide flux.

In October, when the water table back down to 44 cm average, the Carbon dioxide flux again decreased, with highest Carbon dioxide flux was in site point of 100 cm distance from the tree, and the average of Carbon dioxide flux was 88.9 Mg ha^{-1} yr^{-1}, whereas the average Carbon dioxide flux at site point 200 cm was 69.77 Mg ha^{-1} yr^{-1} (Figure 1). In the seventh month (January 2012), the water table depth was relatively shallow in which 46 cm in average, and then the Carbon dioxide flux increased again. This was probably due to the farmer applied ash on the observation area at one week before measurement.

Table 3 shows correlation between Carbon dioxide flux with three other variables, namely the distance of site point of measurement, water table depth, and soil water content. Significant correlation between the distance and Carbon dioxide flux showed that the farther distance from the tree, the more Carbon dioxide flux decreased. After fertilizer application, Carbon dioxide flux variability under the oil palm trees were not only affected by root

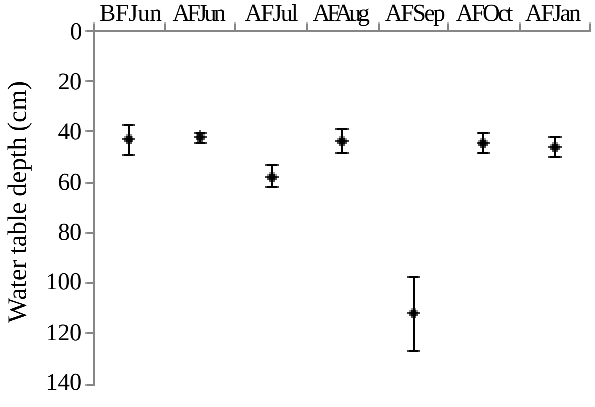

Figure 2. Water table depth at several measurements activity.

Table 3. The correlation between Carbon dioxide fluks and, water table depth, soil water content, the distance of observation site from the center of tree.

Parameter	Distance	Water table depth	Water content
Correlation	-0.386	0.176	-0.163
P-Value	0.000	0.000	0.000

P-Value <0.05 significantly correlated at 5%.

distribution, but also greatly influenced by fertilization zone, because after fertilization (1 week, 1, 2, and 3 months), the average value of the Carbon dioxide fluxes at the site of fertilizer application, were always higher than at another site. Three months after fertilizer application, the highest flux was at the site with the closest distance to the tree, indicating the influence of fertilization zoning began to decrease.

Water table depth was positively correlated with Carbon dioxide fluxes (Table 3), indicating that the deeper of water table depth, the higher Carbon dioxide emissions. Significant correlation between water table depth and Carbon dioxide flux was also demonstrated by Agus *et al.* (2010) who has done research in Klampangan, Central Kalimantan. In the sub tropical peat, Silvola *et al.* (1996a) showed similar results. The water table depth is an indicator in unsaturated conditions (aerobic peat), and one of the factors that regulate heterotrophic respiration processes in peat is aerobic peat thickness (Mikkinen *et al.* 2007). Freeman *et al.* (2001) also stated that in saturated condition, the peat decomposition is lower due to low oxygen levels and toxicity of phenol, the two factors also possibly affected root respiration.

The significant correlation between soil water content and Carbon dioxide flux was also closely related to aerobic peat conditions. In this research, Carbon dioxide flux significantly increased with the decrease of soil water content. However, the relationship between soil moisture content and flux Carbon dioxide flux was not always consistent because the relationship was not linear. Husen *et al.* (2011) showed that Carbon dioxide flux increased with decreasing water content, but after 60 % water content (in volumetric) was reached, Carbon dioxide flux decreased again. It means that there were optimal conditions of water content to reach a maximum Carbon dioxide flux.

CONCLUSIONS

There was significant correlation between the distance of sampling from center of oil palm tree and Carbon dioxide flux. The farther distance from the tree, Carbon dioxide flux more decreased. Before applying fertilizer, variability of soil fertility was not significantly correlated with the flux of Carbon dioxide, so the difference of Carbon dioxide flux based on distance sampling can be caused by root distribution factor. After fertilizer application, variability of Carbon dioxide flux under the oil palm tree were not only affected by differences in root distribution, but also greatly influenced by fertilization.

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