Extended Abstract No. 331

REGULATORY FACTORS OF SOIL CH_4 FLUXES IN DIFFERENT AGES OF OIL PALM ON TROPICAL PEATLAND, SARAWAK, MALAYSIA

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SUMMARY

The objectives of this study were to quantify soil methane (CH_4) fluxes and determine the regulatory factors affecting them in different ages of oil palm on tropical peatland in Sarawak, Malaysia. Monthly soil CH_4 fluxes were measured using a closed chamber method. Soil CH_4 fluxes decreased with palm age with values of 53.8, 23.1 and 17.5 µg C m^{-2} h^{-1} for 1, 5 and 7 year old palms, respectively. This may due to the release of trapped CH_4 in the peat vacuoles upon drainage and the increasing degree of CH_4 oxidation in the drained anoxic peat layers of older plantings. The significant correlations between rainfall, water table and water-filled pore space (WFPS) with soil CH_4 fluxes emphasized the importance of moisture in soil CH_4 fluxes in tropical peatland.

KEY WORDS: Oil palm, tropical peatland, soil CH_4 flux

INTRODUCTION

Reclamation of tropical peatland for any agricultural activity, particularly oil palm cultivation, will require drainage and compaction to reduce the excess water and create an anoxic zone for better root respiration and also to increase the soil bulk density. Drainage and compaction have been suggested to affect the soil methane (CH_4) flux in tropical peatland (Couwenberg, 2009).

Soil CH_4 flux could also be controlled by soil temperature (Couwenberg, 2009), precipitation (Inubushi *et al*., 2003) and water-filled pore space (%WFPS) (Melling *et al*., 2005). While the quantification of soil CH_4 fluxes and the factors that control them are well understood in the case of both temperate and boreal peat, there is still a lack of such studies for tropical peatlands. Therefore, the aims of this study were to quantify soil CH_4 fluxes and determine the regulatory factors affecting them in different ages of oil palm on tropical peatland.

MATERIAL AND METHODS

This study was conducted in an oil palm plantation at Mukah, Sarawak, Malaysia (2° 51'N, 112° 13'E). The location has an equatorial climate with temperatures between 30.6 to 33.7˚ C and annual rainfall of more than 3000 mm. Drainage, with controlled water management and compaction, had been carried out during the establishment of the oil palm plantation. Three sites, with oil palms of 1, 5 and 7 years old respectively, were selected. The peat soils at the site with 1 year old palms have been classified as *Typic Haplofibrists* whereas the sites with 5 and 7 year old palm had *Typic Haplohemists* peat soils. Detailed descriptions of each site are shown in Table 1.

Measurements of monthly soil CH_4 fluxes were conducted using a closed-chamber method from July 2006 until June 2008. Three random plots were set-up in each site for sampling of soil CH_4 gas. Environmental variables such as air temperature, relative humidity (RH) and soil temperature at 5 and 10 cm deep, depth of water table and rainfall were measured simultaneously with soil CH_4 flux measurement. The gas concentrations were determined in the laboratory using a gas chromatograph (Agilent 7890A).

Core soil samples were taken after gas sampling at each chamber point to determine soil bulk density and water-filled pore space (%WFPS). Core sample volumes were measured with a soil volume analyser (model Dik-1130, Daiki Rika Kogyo Co. Ltd) after which the samples were oven dried at 105 °C for 48 hours. The soil was also sampled using a peat auger in each chamber point at depths of 0-25 cm and 25-50 cm and analysed for selected chemical properties as shown in Table 1.

Cross correlation analysis was used to determine any correlation between soil CH_4 fluxes and rainfall, water table and WFPS. The significance of the cross correlation coefficient r at lag k can be assessed by the approximate test

$$t = r_k \sqrt{\frac{n-2}{1-r_k^2}},$$

with $(n - 2)$ degrees of freedom. A significance level of 0.05 was used for statistical significance, and a significance level of 0.10 was used for weak statistical significance in this study.

Table 1. Site description of oil palm plantation.

Age of palm (year)	1 2° 50'N, 112° 13' E	5 2° 51'N, 112° 13'E	7 2° 53'N, 112° 12'E
Peat thickness (cm)	520	475	375
Bulk density (g cm^{-3})	0.23	0.21	0.22
WFPS* (%)	74.2	81.2	78.5
Water table (cm)	-56.4	-66.6	-55.6
Soil pH	3.6	3.8	3.9
Loss on ignition (%)	94.4	93.9	94.2
Total C (%)	55.6	55	56.1
Total N (%)	2.1	1.9	1.9
CEC* (cmol kg^{-1})	45.4	42.5	41.8
Base saturation (%)	40.7	60.4	61.8

RESULTS

Mean monthly soil CH_4 fluxes decreased with palm age, with values of 53.8, 23.1 and 17.5 µg C m^{-2} h^{-1} for sites with 1, 5 and 7 year old palms, respectively. The corresponding cumulative soil CH_4 fluxes for the three sites were 465.5, 203.3 and 168.0 mg C m^{-2} yr^{-1} (Table 2).

Table 2. Mean monthly soil CH_4 flux and cumulative flux for oil palm plantation.

Age of palm (year)	Mean soil CH_4 flux (µg C m^{-2} h^{-1})	Cumulative soil CH_4 flux (mg C m^{-2} yr^{-1})
1	53.8	465.5
5	23.1	203.3
7	17.5	168.0

Soil CH_4 fluxes and rainfall showed positive correlations for all lag months in all sites. The highest correlation was recorded in 1 lagged month at the site with 1 year old palms but 2 lagged months in the sites with the older plantings. For the site with 1 year old palms, the correlation between soil CH_4 fluxes and rainfall at 1 lagged month was significant ($p = 0.02$) whereas weakly significant correlations were observed in the other sites ($p < 0.10$) (Fig. 1a). Depth of water table and soil CH_4 fluxes were found to be negatively correlated for all lags in all sites. Significant ($p < 0.05$) peaks were observed in each site but in different lagged month (Fig. 1b). The correlation between soil CH_4 fluxes and WFPS were generally positive except in the case of the 1 year old palms, where they were inconsistent. Significant correlations ($p < 0.05$) occurred in each site whereas a weakly significant correlation ($p = 0.07$) was found at 0 lagged month at the site with 5 year old palms (Fig. 1c).

DISCUSSION

The conversion of tropical peatland to oil palm initially increases soil CH_4 emissions probably due to the release of CH_4 trapped in the peat vacuoles prior to drainage. Furthermore, the compaction of peat for the planting of oil palm would improve gaseous diffusion. The decline in soil CH_4 emission with palm age might be attributed to the oxidation of soil CH_4 in the upper drained layers of peat and the decreasing production of CH_4 upon drainage.
Higher rainfall enhances soil CH_4 flux (Inubushi *et al*., 2003) by increasing the water table and WFPS, which in turn improves methanogenic activity. The positive correlations found between soil CH_4 fluxes and rainfall, water table and WFPS bear this out particularly in older palms (Fig. 1). Relatively constant monthly air and soil temperatures throughout the year may probably cause the lack of effect between soil CH_4 fluxes and soil temperatures for all palm ages (Davidson *et al*., 2000). However, the indirect effect of temperature on soil CH_4 fluxes was a plausible reason for the inconsistent correlation between soil CH_4 fluxes and WFPS in 1 year old palms due to the disruption of methanogens activities in unshaded sunlight on soil

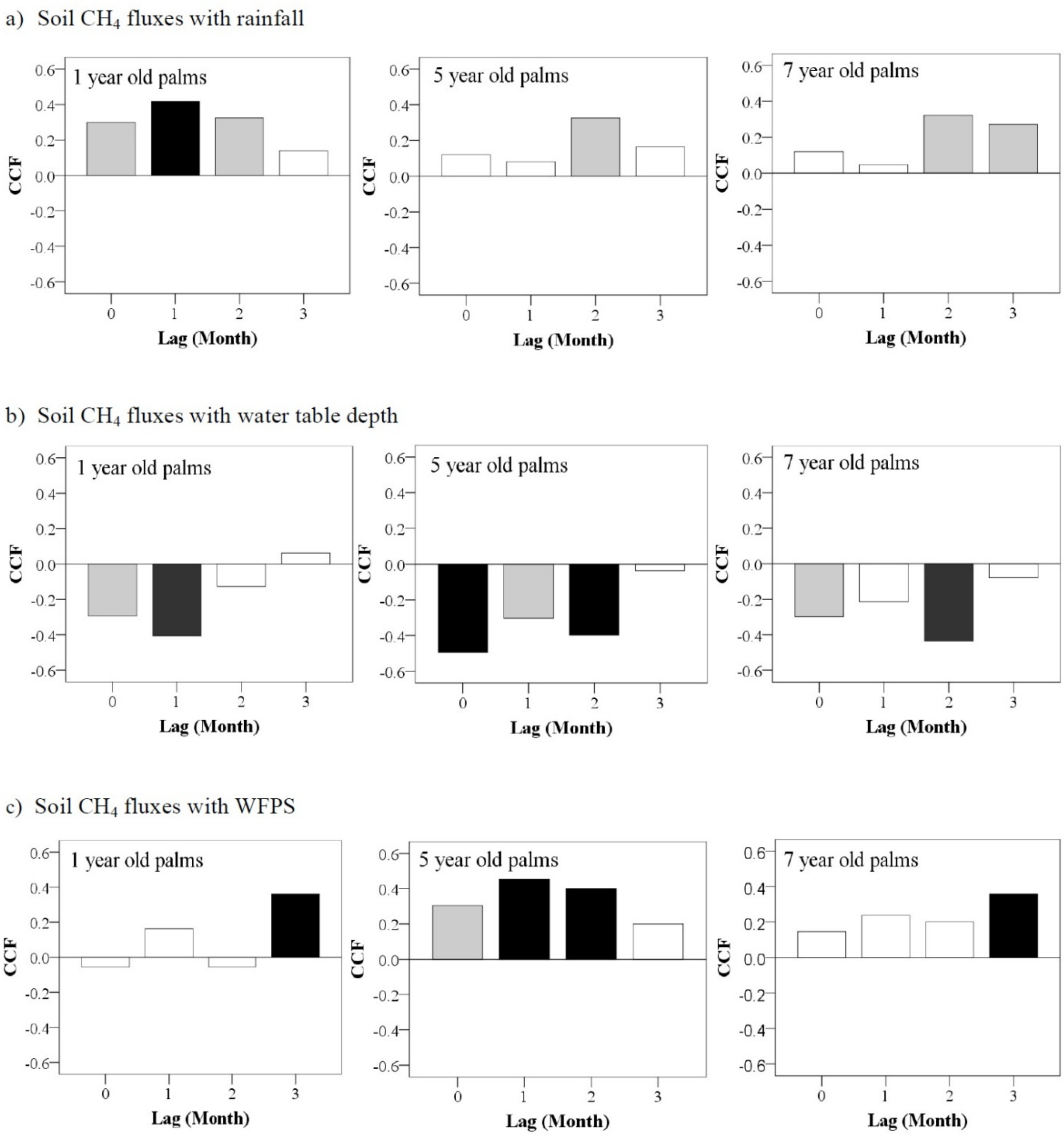

Fig. 1. Cross-correlation functions (CCF) for (a) soil CH_4 fluxes and rainfall, (b) soil CH_4 fluxes and water table depth and (c) soil CH_4 fluxes and water-filled pore space (WFPS) in oil palm plantation. Statistically significant cross-correlation is shown by black bars, weakly significant cross-correlation is shown by grey bars and non-significant cross-correlation is shown by white bars.

surface (Fig. 1c). Hence, higher temperature at the site with the youngest palms may produce high soil CH_4 fluxes through rapid diffusion rate but the effect is hampered by the loss of soil moisture. Soil CH_4 fluxes and cumulative soil CH_4 fluxes in this study were found to be relatively low compared with those reported by Inubushi *et al*. (2003) and Jauhiainen *et al*. (2005) probably due to the higher water tables in their studies.

CONCLUSION

This study clearly showed the importance of soil moisture in soil CH_4 fluxes of tropical peatland under oil palm. Further investigation and attention are imperative for better understanding and accurate interpretation of soil CH_4 flux variability in cultivated tropical peatland.

ACKNOWLEDGEMENT

We thank Department of Agriculture, Sarawak and its staff for their assistance in both the laboratory and field work. We wish to acknowledge Angela Tang Che Ing for her assistance in the statistical analyses. We also like to thank the oil palm plantation for their cooperation. This study was supported by an e-Science grant (no. 06-05-06-SF0004) of Ministry of Science, Technology and Innovation (MOSTI), Malaysia.

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