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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称 博士（農学）

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学 位 論 文 題 名

Effect of land use change and drainage on peat decomposition and greenhouse gas
emission in a tropical peatland

(熱帯泥炭地における泥炭分解および温室効果ガス放出に及ぼす土地利用変化
と排水の影響)

Introduction

Tropical peatland ecosystems in Southeast Asia cover 24.8 million hectares, comprising 6% of the global peatland area and store 68.5 Pg C, equivalent to 11–14% of the global peat C store (Page *et al.*, 2011), which is comparable to the total fossil fuel C emissions released throughout the world over 9 years. In recent decades, considerable portions of peatland in Southeast Asia have been reclaimed to support agroforestry and rice paddy development. The deforestation and drainage associated with reclamation has increased peat decomposition and peat fire, which have increased the emission of greenhouse gases (GHGs) of CH₄, CO₂ and N₂O. Several trials have been conducted to restore submerged ecosystems in lowland tropical peatlands, however flooded conditions under less vegetation cover after peat fires can increase anaerobic CH₄ production. In addition, drying and rewetting processes can stimulate nitrification and denitrification in soil, which are both major processes of N₂O production. Meanwhile in natural conditions, wetland vegetation has usually developed specific organs which can supply atmospheric oxygen (O₂) to the rhizosphere, where a part of the O₂ may be consumed for CH₄ oxidation. The change of GHG dynamics in tropical peatland soils after artificial drainage, deforestation, peat fires, and re-wetting has not been studied fully. Therefore, this study was conducted to verify the following hypotheses: 1) dissolved oxygen (DO) supplied from plant roots should oxidize CH₄ produced in water saturated tropical peat soil, and 2) CH₄ oxidation should reduce total global warming potential (GWP) in a tropical peat swamp forest.

Materials and Methods

This study was conducted in a tropical peatland near Palangka Raya, Central Kalimantan, Indonesia during the rainy season (Dec. 2011 to May 2012). Six sites were selected from two land uses: three sites were placed in a natural peat swamp forest that was not affected by deforestation or fire (forest sites) and the other three sites were placed in a degraded peatland affected by fire (burnt sites). In each of forest and burnt sites, one site was selected from the area affected by drainage. The GHG fluxes were measured monthly at the ground surface using closed chamber method. At the same time of the flux measurement, air samples equilibrating with gases dissolved in soil pore water were taken at depths of 20, 40, 60, and 80 cm by using an in-situ equilibration chamber for CO₂ and a rapid equilibration method for CH₄ and N₂O. The in-situ equilibration chamber which is a small chamber designed to equilibrate air with the surrounding dissolved gas was developed according to Faulkner *et al.* (1989). Dissolved GHG concentrations were calculated based on the concentrations in the air samples and Henry's law. DO concentration was measured in situ at depths of 10, 20, 40, and 80 cm by extracting soil pore water directly into a closed cell equipped with a DO sensor to avoid contact between the water sample and the atmosphere. Electric conductivity, pH, and dissolved nitrogenous ions (NH₄⁺ and NO₃⁻) were also measured at the same depths of DO measurement. Soil temperature at depths of 5, 10, 30, and 50 cm was monitored by thermocouples and water table level was monitored by pressure loggers placed at a depth of 150 cm.

Results and Discussion

1) CH₄ fluxes and dissolved CH₄ concentrations were significantly influenced by land use and drainage. CH₄ fluxes were highest in the flooded burnt sites, followed by the flooded forest sites, the drained burnt site, and the drained forest site (5.75 ± 6.66 , 1.37 ± 2.03 , 0.220 ± 0.143 , and 0.0084 ± 0.0321 (mean $\pm$ SD) mgC m⁻² h⁻¹, respectively). Dissolved CH₄ concentrations were also highest in the flooded burnt sites, followed by the drained burnt site, the flooded forest sites, and the drained forest site (124 ± 84 , 45.2 ± 29.8 , 1.15 ± 1.38 , and 0.860 ± 0.819 μ mol L⁻¹, respectively). Dissolved CH₄ concentrations in the burnt sites were significantly higher than those in the forest sites at all depths under flooded condition and at depths of 40 and 60 cm under drained condition. DO concentrations were influenced by land use only, which were significantly higher in the forest sites (6.9 ± 5.6 μ mol L⁻¹) than in the burnt sites (4.0 ± 2.9 μ mol L⁻¹). These results suggested that CH₄ produced in the peat might be oxidized by plant-mediated oxygen supply in the forest sites. CH₄ is produced by methanogenic bacteria under anaerobic conditions. The high dissolved CH₄ concentrations in the burnt sites were probably due to the lack of large trees which have thick and deep root systems making in the entry of O₂ to the soil profiles.

2) The land use significantly influenced CO₂ fluxes. The CO₂ flux in the drained forest site was highest (340 ± 250 mgC m⁻² h⁻¹ with the water table level of -20 to -60 cm), which was followed by those in the flooded burnt sites and flooded forest sites (198 ± 165 mgC m⁻² h⁻¹ with -5 to +40 cm and 195 ± 199 mgC m⁻² h⁻¹ with -10 to +30 cm, respectively), and was significantly higher than that in the drained burnt site (108 ± 115 mgC m⁻² h⁻¹ with -15 to +10 cm). Dissolved CO₂ concentrations were 0.6 to 3.5 mmol L⁻¹, also highest in the drained forest site, which were significantly higher than other sites at depths of 40, 60, and 80 cm. These results suggested the enhanced CO₂ emission by aerobic peat decomposition and plant respiration in the drained forest site.

3) N₂O fluxes ranged from -2.4 to -8.7 μ gN m⁻² h⁻¹ in the flooded sites and from 3.4 to 8.1 μ gN m⁻² h⁻¹ in the drained sites. However, there were no significant differences in N₂O fluxes among the sites based on either land use or drainage. The negative N₂O fluxes might be caused by N₂O consumption by denitrification under flooded conditions, which involved the reduction of N₂O to N₂. Meanwhile the dissolved N₂O concentrations were 0.005 to 0.22 μ mol L⁻¹ but <0.01 μ mol L⁻¹ in most cases. The dissolved N₂O concentration in the drained forest site was significantly higher at depths of 20 and 40 cm. This can be explained by oxic condition at these depths favorable for N₂O production (nitrification) as well as aerobic CO₂ production. Considering soil N processes including nitrification and denitrification, NO₃⁻ concentration is one of the important controlling factors. In this study, however, the total content of NO₃⁻ (0.05 ± 0.03 to 0.26 ± 0.25 mg L⁻¹) was probably too small to influence the N₂O emissions.

4) GWP was mainly determined by CO₂ flux, with highest levels in the drained forest site. In spite of almost the same CO₂ flux, GWP in the flooded burnt sites was 20% higher than that in the flooded forest sites due to the large CH₄ emission, although it was not significant. N₂O fluxes made little contribution to GWP.

Conclusions

The first hypothesis was supported given that 1) CH₄ emissions in the flooded burnt sites were significantly larger than those in the flooded forest sites, 2) Dissolved CH₄ concentrations in the burnt sites were much higher than those in the forest sites, and 3) DO concentrations in the forest sites were significantly higher than those in the burnt sites. The CH₄ flux and the dissolved CH₄ concentration at a depth of 20 cm in the drained burnt site were similar to values observed in the forest sites, suggesting that CH₄ oxidation in the surface soil layer occurred. The second hypothesis was weakly supported by the observed GWPs in the flooded burnt sites, which were 20% higher than those in the flooded forest sites. In this study, however, GWP was mainly determined by CO₂ flux. Consequently, GWP and CO₂ flux in the drained forest site were the highest for all study sites, and N₂O flux made little contribution to GWP.