学 位 論 文 内 容 の 要 旨

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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 CH_4, CO_2 and N_2O. 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 CH_4 production. In addition, drying and rewetting processes can stimulate nitrification and denitrification in soil, which are both major processes of N_2O production. Meanwhile in natural conditions, wetland vegetation has usually developed specific organs which can supply atmospheric oxygen (O_2) to the rhizosphere, where a part of the O_2 may be consumed for CH_4 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 CH_4 produced in water saturated tropical peat soil, and 2) CH_4 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 CO_2 and a rapid equilibration method for CH_4 and N_2O. 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 (NH_4^+ and NO_3^-) 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) CH_4 fluxes and dissolved CH_4 concentrations were significantly influenced by land use and drainage. CH_4 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±SD) mgC m^{-2} h^{-1}, respectively). Dissolved CH_4 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 μmol L^{-1}, respectively). Dissolved CH_4 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 μmol L^{-1}) than in the burnt sites (4.0±2.9 μmol L^{-1}). These results suggested that CH_4 produced in the peat might be oxidized by plant-mediated oxygen supply in the forest sites. CH_4 is produced by methanogenic bacteria under anaerobic conditions. The high dissolved CH_4 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 O_2 to the soil profiles.

2) The land use significantly influenced CO_2 fluxes. The CO_2 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 CO_2 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 CO_2 emission by aerobic peat decomposition and plant respiration in the drained forest site.

3) N_2O fluxes ranged from −2.4 to −8.7 μgN m^{-2} h^{-1} in the flooded sites and from 3.4 to 8.1 μgN m^{-2} h^{-1} in the drained sites. However, there were no significant differences in N_2O fluxes among the sites based on either land use or drainage. The negative N_2O fluxes might be caused by N_2O consumption by denitrification under flooded conditions, which involved the reduction of N_2O to N_2. Meanwhile the dissolved N_2O concentrations were 0.005 to 0.22 μmol L^{-1} but <0.01 μmol L^{-1} in most cases. The dissolved N_2O 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 N_2O production (nitrification) as well as aerobic CO_2 production. Considering soil N processes including nitrification and denitrification, NO_3^- concentration is one of the important controlling factors. In this study, however, the total content of NO_3^- (0.05±0.03 to 0.26±0.25 mg L^{-1}) was probably too small to influence the N_2O emissions.

4) GWP was mainly determined by CO_2 flux, with highest levels in the drained forest site. In spite of almost the same CO_2 flux, GWP in the flooded burnt sites was 20% higher than that in the flooded forest sites due to the large CH_4 emission, although it was not significant. N_2O fluxes made little contribution to GWP.

Conclusions

The first hypothesis was supported given that 1) CH_4 emissions in the flooded burnt sites were significantly larger than those in the flooded forest sites, 2) Dissolved CH_4 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 CH_4 flux and the dissolved CH_4 concentration at a depth of 20 cm in the drained burnt site were similar to values observed in the forest sites, suggesting that CH_4 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 CO_2 flux. Consequently, GWP and CO_2 flux in the drained forest site were the highest for all study sites, and N_2O flux made little contribution to GWP.