Methane balances of tropical peat ecosystems in Sarawak, Malaysia

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Tropical peatlands of Southeast Asia, widely distributed in Indonesia and Malaysia, are a globally important carbon reservoir, storing an enormous amount of soil organic carbon as peat. In recent decades, however, the peatlands have been threatened with rapid land cover changes, predominantly into industrial plantations of oil palm and pulpwood. Owing to the huge soil carbon stock, high groundwater level (GWL) and high temperature, tropical peatlands potentially function as a significant source of methane (CH_4) to the atmosphere. However, chamber studies of soil CH_4 flux have reported that CH_4 emissions from tropical peat swamp ecosystems were negligible. On the other hand, recently, it was reported that some tree species growing in peat swamp forest emit considerable CH_4 from their stems. Thus, ecosystem-scale flux measurement is essential to quantify the CH_4 balance of tropical peat ecosystems.

In this study, we measured ecosystem-scale CH_4 flux continuously above three different tropical peat ecosystems in Sarawak, Malaysia for three years from February 2014 to January 2017. This is the first study applying the eddy covariance technique in tropical peat ecosystems. The three sites were different in disturbance; namely an undrained peat swamp forest (UF), a relatively disturbed secondary peat swamp forest (DF) and an oil palm plantation (OP) established on peat after deforestation. The objectives of this study were to: (1) quantify the net ecosystem exchange of CH_4 (F_{CH4}) of each site; (2) examine the responses of F_{CH4} to environmental factors; and (3) compare F_{CH4} among the three ecosystems and discuss the inter-site difference of CH_4 balance.

The F_{CH4} was determined half-hourly as the sum of eddy CH_4 flux and CH_4 storage change and summed up annually after gap filling. Daily mean F_{CH4} was positively correlated to GWL in UF and DF, in which GWL governed the production and oxidation of CH_4 in peat. On the other hand, F_{CH4} was almost independent of GWL in OP, in which GWL was lowered by drainage. Monthly mean F_{CH4} was always positive even in drained OP, meaning CH_4 sources. Mean annual CH_4 emissions (± 1 SD) were 8.46 ± 0.51, 4.17 ± 0.69 and 2.19 ± 0.21 g C m^{-2} yr^{-1}, respectively, in UF, DF and OP. There was a significant difference ($P < 0.001$) among the sites. The annual CH_4 emission was highest in UF with the highest GWL and lowest in water-managed OP. The inter-site difference was explained considerably by GWL from a significant positive exponential relationship ($P < 0.001$). The ecosystem-scale CH_4 emission from UF was lower than those from mid-latitude peat ecosystems, though it was much higher than soil CH_4 emissions measured by the chamber technique in tropical peat swamp forests. The difference was probably due to CH_4 emissions from tree stems, which were not measured in the soil chamber studies.

A significant positive relationship was found between F_{CH4} and GWL on monthly and annual bases, including all data from the three sites. The positive relationship indicates that the conversion of a peat swamp forest to an oil palm plantation decreases CH_4 emissions, because the land conversion accompanies drainage. However, the decrease of CH_4 emissions would be insufficient to offset the increase of carbon dioxide emissions through oxidative peat decomposition. The oil palm plantation drained deep to –62 cm on average still functioned as a small CH_4 source probably because of high CH_4 emissions from ditches.