Assessing Methane and Nitrous Oxide Fluxes in Soil and Stems of Malaysian Tropical Peat Swamp Forests

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Tropical peat swamp forests are crucial global carbon (C) reserves. Prevailing waterlogged conditions in peat soils prevent the complete decomposition of dead plant material. As a result, more organic matter is produced than decomposed, leading to the gradual accumulation of peat. However, the destabilisation of tropical peatlands through climate warming, droughts, and changes in land use threaten this C sink capacity. Anaerobic conditions in peat soils lead to methane (CH_4) production through decomposition and nitrous oxide (N_2O) production under moderate levels of soil oxygen content. Earlier evidence suggests that tree stems in tropical peat swamp forests are significant sources of CH_4; however, little information is available on their exchange of N_2O.

This study investigated CH_4 and N_2O exchange of soil and stems of *Combretocarpus rotunditus* and *Shorea albida* trees in a peat swamp forest in Sarawak, Malaysia, from September 2022 to September 2023. To describe the temporal dynamics of greenhouse gas (GHG) exchange, we measured gas fluxes from the soil and stems at different heights (10, 80 and 170 cm from the tree's base) using the manual static chamber method and spectroscopic gas analysis. The chemical composition of the soil was analysed and several environmental parameters, including groundwater level, soil moisture content, soil and air temperature, were simultaneously measured with the GHG fluxes to determine the relationships between the fluxes and environmental factors.

Soil CH_4 emissions varied between 52.3 and 807 μg C m^{-2} h^{-1}, with higher values observed during the wet season in conjunction with higher groundwater levels. On the other hand, the soil N_2O fluxes were relatively low and did not show a distinct seasonal pattern, ranging from -1.33 to 3.54 μg N m^{-2} h^{-1}. Annual average soil CH_4 and N_2O emissions were 392 μg C m^{-2} h^{-1} and 0.65 μg N m^{-2} h^{-1}, respectively. The highest average stem CH_4 emissions (1.48 μg C m^{-2} h^{-1}) were recorded at the lowest parts of trees, with a vertical decrease in emissions and an overall uptake observed at the highest measurement point. In contrast, stem N_2O emissions were small, with no clear trend with measurement height.

In summary, we observed moderate and variable soil CH_4 emissions with limited generalisable relation to measured environmental parameters. Soil and stem N_2O emissions were relatively small. These results indicate the need for further comprehensive soil and stem GHG analyses in tropical peat swamp systems to better understand the GHG dynamics of this critical ecosystem.