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Soil-atmosphere trace gas exchange from tropical oil palm plantations on peat

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Oil palm is the largest agricultural crop in the tropics, accounting for 13 % of all tropical land cover. Due to its large areal extent, oil palm cultivation may have important implications not only for terrestrial stores of C and N, but may also impact regional and global exchanges of material and energy, including fluxes of trace gases and water vapor. In particular, recent expansion of oil palm into tropical peatlands has raised concerns over enhanced soil C emissions from degradation of peat, and elevated N-gas fluxes linked to N fertilizer application.

Here we report our preliminary findings on soil carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) fluxes from a long-term, multi-scale project investigating the C, N and greenhouse gas (GHG) dynamics of oil palm ecosystems established on peat soils in Sarawak, Malaysian Borneo. Flux chamber measurements indicate that soil CO_2, CH_4 and N_2O fluxes averaged 20.0 ± 16.0 Mg CO_2-C ha^{-1} yr^{-1}, 37.4 ± 29.9 kg CH_4-C ha^{-1} yr^{-1} and 4.7 ± 4.2 g N_2O-N ha^{-1} yr^{-1}, respectively. Soil CO_2 fluxes were on par with other drained tropical peatlands; whereas CH_4 fluxes exceeded observations from similar study sites elsewhere. Nitrous oxide fluxes were in a similar range to fluxes from other drained tropical peatlands, but lower than emissions from mineral-soil plantations by up to three orders of magnitude.

Fluxes of soil CO_2 and N_2O were spatially stratified, and contingent upon the distribution of plants, deposited harvest residues, and soil moisture. Soil CO_2 fluxes were most heavily influenced by the distribution of palms and their roots. On average, autotrophic (root) respiration accounted for approximately 78 % of total soil CO_2 flux, and total soil respiration declined steeply away from palms; e.g. soil CO_2 fluxes in the immediate 1 m radius around palms were up to 6 times greater than fluxes in inter-palm spaces due to higher densities of roots. Placement of harvest residues played an important – but secondary – role in modulating soil CO_2 fluxes; soil respiration rates doubled in areas where harvest residues were deposited, reflecting an enhanced input of labile organic matter for decomposition. In contrast, N_2O fluxes were best-predicted by the distribution of harvest residues, and were only weakly related to plant distributions or soil moisture. For example, N_2O fluxes from harvest residue piles were up to twice of the overall plot-average. In contrast, N_2O fluxes showed no clear pattern around palms or in inter-palm spaces; this finding is surprising because N fertilizers are applied within the 1 m radius around palms, and we expected to observe enhanced N_2O fluxes in areas of greater fertilizer input. This suggests that palms may be a strong competitor for N in these ecosystems, and that fertilizer application may more closely match overall plant demand than in mineral-soil plantations. Overall, the spatial patterning of soil CO_2 and N_2O fluxes implies that soil biogeochemical processes are predictably distributed in space, potentially making it easier to model and constrain fluxes of these soil-derived GHGs.