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Towards a full greenhouse gas balance of managed tropical peatlands in northern Borneo

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Oil palm is the largest agricultural crop in the tropics, accounting for over 13% of current tropical land area. Biosphere-atmosphere exchange of radiatively important trace gases (e.g. CO_2, CH_4, N_2O) from oil palm ecosystems therefore have potentially important implications for global climate because of the large area of land under oil palm production. Understanding the contribution of plantations on peat is of particular interest because of the large C stocks held by tropical peat soils and the sensitivity of these C stocks to human perturbation. Here we report preliminary data on net ecosystem CO_2, CH_4 and N_2O fluxes from a mature oil palm plantation (7-10 years old) grown on peat soils in Sarawak, Malaysian Borneo. Fluxes of CO_2, CH_4 and N_2O were determined using a combination of top-down and bottom-up approaches that included eddy covariance, intensive C plot measurements, chamber-based flux measurements, and quantification of aquatic exchange. Eddy covariance, intensive C plot, and fluvial measurements suggest that these ecosystems are atmospheric sources of CO_2 or approaching net atmospheric balance. Using both eddy covariance and a bottom-up source-sink inventory, we calculated that these ecosystems were emitting no more than 3 ± 4 Mg C ha^{-1} yr^{-1}. Net ecosystem exchange was strongly linked to water table position, with reduced CO_2 loss at higher water table levels. This plantation was also a net atmospheric source of CH_4 and N_2O. Eddy covariance measurements of CH_4 suggest a net flux of approximately 37 kg C ha^{-1} yr^{-1}; broadly in agreement with bottom-up chamber measurements, where we estimated an area-weighted mean annual flux of 62 ± 88 kg C ha^{-1} yr^{-1}. In contrast, while both top-down and bottom-up measurements of N_2O flux agree that this ecosystem is a net atmospheric source of N_2O, the two methods differed in terms of the estimated magnitude of the flux. Eddy covariance measurements of N_2O suggest a net flux of 11 kg N ha^{-1} yr^{-1}, while chamber-based flux measurements suggest an area-weighted annual flux of 591 ± 843 kg N ha^{-1} yr^{-1} to 4782 ± 8522 kg N ha^{-1} yr^{-1}. This discrepancy between top-down and bottom-up methods probably stems from differences in the periods over which the observations were collected; eddy covariance measurements integrated fluxes between fertilization events, while the chamber-based fluxes tracked the response of N_2O flux to fertilizer application. Fluxes of CH_4 and N_2O were spatially and temporally heterogeneous. However, CH_4 showed more spatial rather than temporal heterogeneity, while N_2O flux showed relatively weak spatial heterogeneity and high temporal variability. For example, CH_4 fluxes were greatest from water-logged microforms (e.g. drainage ditches) and lowest from non-vegetated microforms. In contrast, N_2O flux was relatively evenly distributed among different microforms, but displayed very high temporal variability, linked to periodic applications of fertilizer. These findings suggest that important mitigation strategies for reducing greenhouse gas emissions from these peatland plantations include improved water table management to reduce peat oxidation, more efficient fertilizer practices to suppress N_2O flux, and innovative methods of reducing CH_4 flux from emission hotspots.