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Contributions of methane and nitrous oxide to peat greenhouse gas emissions from forests and oil palm plantations in an Indonesian peatland

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Land-use change in tropical peatlands substantially impacts emissions of methane (CH_4) and nitrous oxide (N_2O) in addition to emissions of carbon dioxide (CO_2). However, assessments of peat GHG budgets are scarce and the contributions of CH_4 and N_2O remain highly uncertain. The objective of our research was to assess changes in peat GHG flux and budget associated with peat swamp forest disturbance and conversion to oil palm plantation and to evaluate drivers of variation in trace gas fluxes. Over a period of one and a half year, we monitored monthly CH_4 and N_2O fluxes together with environmental variables in three undrained peat swamp forests and three oil palm plantations on peat in Central Kalimantan. The forests included two primary forests and one 30-year-old secondary forest. We calculated the peat GHG budget in both ecosystems using soil respiration and litterfall rates measured concurrently with CH_4 and N_2O fluxes, site-specific soil respiration partitioning ratios, and literature-based values of root inputs and dissolved organic carbon export. Peat CH_4 fluxes (kg CH_4 ha^{-1} yr^{-1}) were insignificant in oil palm (0.3 ± 0.4) while emissions in forest were high (14.0 ± 2.8), and larger in wet than in dry months. N_2O emissions (kg N_2O ha^{-1} yr^{-1}) were highly variable spatially and temporally and similar across land-uses (5.0 ± 3.9 and 5.2 ± 3.7 in oil palm and forest). Temporal variation of CH_4 was controlled by water table level and soil water-filled pore space in forest and oil palm, respectively. Monthly fluctuations of N_2O were linked to water table level in forest. The peat GHG budget (Mg CO_2 equivalent ha^{-1} yr^{-1}) in oil palm (31.7 ± 8.6) was nearly eight times the budget in forest (4.0 ± 4.8) owing mainly to decreased peat C inputs and increased peat C outputs. The GHG budget was also ten times higher in the secondary forest (10.2 ± 4.5) than in the primary forests (0.9 ± 3.9) on the account of a larger peat C budget and N_2O emission rate. In oil palm 96% of emissions were released as CO_2 whereas in forest CH_4 and N_2O together contributed 65% to the budget. Our study highlights the disastrous atmospheric impact associated with forest degradation and conversion to oil palm in tropical peatlands and stresses the need to investigate GHG fluxes in disturbed undrained lands.