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Net soil respiration and greenhouse gas balance along a sequence of forest disturbance to smallholder rubber and oil palm plantations in Sumatra

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The rapid increase in demand for land to establish oil palm and rubber plantations has led to the conversion of forests, with potential impacts on greenhouse gas emissions and on climate change. This study evaluates the net greenhouse gas balance following forest change to other land uses, i.e. one year rubber plantation, twenty-year rubber plantation and eight year oil palm plantation on Sumatran mineral soils. None of the plantations had ever been fertilized previously. During this study they were fertilized to provide nitrogen at the recommended rate used by farmers (33.3 kg N ha^{-1} y^{-1}). The ecosystem stores carbon in litterfall, standing litter biomass (undergrowth vegetation, leaves, twigs, litter on the soil surface), soil organic matter, root biomass, and standing tree biomass. It releases carbon to the atmosphere through soil respiration fluxes, negative values indicating that carbon is stored by the land use change and positive values indicating emissions to the atmosphere. Net soil respiration was assessed using a mass balance approach: standing litter and tree biomass were measured once; the rate of carbon accumulation from standing litter and tree biomass was calculated by dividing the stock by the age of plantation or the time since logging started in the disturbed forest. The carbon accumulation in standing litter, tree biomass in the forest and soil organic matter for all land-uses was estimated from available in the literature. Root biomass for each land-use system was calculated using the root:shoot ratio. The net soil respiration of carbon dioxide from the forest, disturbed forest, one year rubber plantation, twenty-year rubber plantation and oil palm plantation were calculated to be -6 ($\pm$ 5), 12 ($\pm$ 6), 11 ($\pm$ 15), 10 ($\pm$ 5), 39 ($\pm$ 7) Mg ha^{-1} y^{-1}, respectively. Soil nitrous oxide, methane and litterfall were measured for 14 months and respiration fluxes were measured for 5 months across land uses and different seasons. The measured emissions of greenhouse gases were similar across land use systems; for nitrous oxide in the forest, disturbed forest, one year rubber plantation, twenty-year rubber plantation and eight year oil palm plantation, respectively, 17.3 ($\pm$ 0.2), 1.2 ($\pm$ 0.1), 1.3 ($\pm$ 0.2), 1.0 ($\pm$ 0.1) and 1.0 ($\pm$ 0.2) kg N ha^{-1} y^{-1}; for methane, -1.4 ($\pm$ 1.0), 0.4 ($\pm$ 0.9), -1.7 ($\pm$ 0.7), -0.2 ($\pm$ 0.3) and 0.2 ($\pm$ 0.7) kg C ha^{-1} y^{-1}; and for carbon dioxide, 13 ($\pm$ 1), 13 ($\pm$ 1), 16 ($\pm$ 2), 14 ($\pm$ 1) and 17 ($\pm$ 2) Mg C ha^{-1} y^{-1}). The overall greenhouse gas balance in carbon dioxide equivalents was significantly lower in the forest (-5 ($\pm$ 5) Mg ha^{-1} y^{-1}) than in the oil palm plantation (40 ($\pm$ 7) Mg ha^{-1} y^{-1}). There was no significant difference in the overall greenhouse gas balance of the disturbed forest, one year rubber plantation and twenty-year rubber plantation (12 ($\pm$ 17) Mg ha^{-1} y^{-1}), but this was also significantly lower than in the oil palm plantation. The overall results support the assertion that the undisturbed forest conserves carbon dioxide and has a negative greenhouse gas balance, while oil palm plantations lead to net emissions.

Keywords: land-use change, global warming potential, carbon flux change, methane, nitrous oxide, carbon dioxide