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Ecosystem-based greenhouse budgets in oil palm plantations differ with plantation age

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Global increase in demand of palm oil is leading to the expansion of oil palm plantations, particularly in SE Asia. Oil palm plantations in Sumatra, Indonesia, together with those in Kalimantan, are responsible for half of the world's palm oil production. Available studies point to plantations being large carbon dioxide (CO_2) sinks due to the high photosynthetic rates of oil palm as a result of high fertilizer inputs, especially in large-scale plantations. However, methane (CH4) uptake in the soil of oil palm plantations is reduced and soil nitrous oxide (N2O) emissions increased right after nitrogen (N) fertilization. Greenhouse gas (GHG) budgets at the ecosystem level are still missing, and the few available information was derived from mature plantations, pointing to a lack of knowledge on the changes of these GHG budgets with plantation age.

With the aim of quantifying CO_2, CH4 and N2O fluxes during the non-productive and productive phases of oil palm cultivation, an eddy covariance (EC) tower was installed in a 2-year old (non-productive) oil palm plantation and was subsequently moved to a 12-year old (productive) plantation. Both sites were on Acrisol soils and were located in Jambi province, Sumatra. Chamber-based measurements of soil GHG fluxes were also carried out along the EC footprint.

Net ecosystem exchange (NEE), based on EC measurement, showed that the non-productive plantation was a strong CO_2 source (990 g C m-2 yr-1) whereas the productive plantation was a CO_2 sink (-790 g C m-2 yr-1). For CH4 fluxes, both plantations showed similar soil CH4 uptake that led to a small carbon sink of ($\sim$1.3 g C m-2 yr-1). Soil N2O fluxes were high in the productive plantation (3.26 $\pm$ 1.73 kg N ha-1 yr-1), as measurements were carried out in a plantation with high fertilization rates. In the non-productive plantation, soil N2O fluxes were lower and were associated with fertilization events. Our results show that the global warming potential of a non-productive oil palm plantation was dominated by CO_2 fluxes, whereas in a productive plantation N2O contribution to the global warming could be significant due to high N fertilizer input. Our results also highlight the need of evaluating various stages of development of oil palm cultivation when assessing their GHG budgets at a regional scale in order to support quantitative-based mitigation strategies.