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Soil and tree-stem N2O and CH4 fluxes from rainforest and cacao agroforest on highly weathered Ferralsol soils in the Congo Basin, Cameroon

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Although tree stems have been found to act as conduits for greenhouse gases (GHG) produced in the soil, it remains unknown whether trees in tropical lowland forests on Ferralsol soils, developed on tropical shield area, are large contributors to N_2O and CH_4 emissions. Moreover, soil GHG fluxes remain understudied across various African ecosystems, and the effect of land-use change on these gases is identified as an important research gap in the GHG budget of Africa. Only one study has reported on soil GHG fluxes (with only a 3-month measuring period) from the Congo Basin. Our study aimed to (1) quantify changes in soil-atmosphere N_2O and CH_4 fluxes with forest conversion to cacao agroforestry, (2) to identify whether trees in lowland forests and cacao trees in cacao agroforestry are important conduits of soil GHG, and (3) to determine their controlling factors.

We conducted whole-year measurements at monthly interval of soil and stem N_2O and CH_4 fluxes at three sites (villages) in central and southern Cameroon, each site with natural forest and mature cacao agroforestry. At each site, we selected four replicate plots (2,500 m^2 each) for each land use. Soil and stem GHG fluxes were measured monthly using vented static chambers (4 chambers per plot) and stem chambers (6 trees per plot), respectively, from April 2017 to April 2018. On each measurement period, we also measured known soil and climatic controlling factors.

We observed no effect of forest-to-cacao agroforestry conversion on both soil and stem GHG across all sites ($p = 0.46$ to 0.94). Annual soil N_2O fluxes (in kg N ha^{-1} yr^{-1}) ranged from 0.87 ± 0.27 (mean $\pm$ standard error) to 1.46 ± 0.46 for the forests and from 0.80 ± 0.39 to 1.25 ± 0.27 for the cacao agroforestry. Stem N_2O fluxes accounted for 7.3-11.6% of the total (soil + stem) N_2O fluxes in the forests and 13.6-18.3% of the total N_2O fluxes in the cacao agroforestry. Across the three sites and two land uses, the temporal pattern of stem N_2O fluxes was influenced by soil and air temperature, vapor pressure deficit and soil N_2O concentration, while soil N_2O fluxes was controlled by soil mineral N and water content. Soil mineral ^{15}N-tracing to stem N_2O emission indicated that stem-emitted N_2O originated partly from soil-produced N_2O. Annual soil CH_4 fluxes (in kg C ha^{-1} yr^{-1}) ranged from -1.72 ± 1.27 to -3.19 ± 1.32 for the forests and -2.17 ± 1.96 to -4.80 ± 0.79 for cacao agroforestry. Across sites and land uses, the temporal pattern of soil CH_4 fluxes was controlled by an integrated index of soil fertility. The balance between the soil and stem CH_4 fluxes indicated that there was a net CH_4 sink in all the sites for both land uses.

Our study provides the first spatially replicated quantification with a full year of measurements of soil and stem GHG fluxes in the Congo Basin, and contributes to the much-needed information on GHG budget from these important ecosystems.