Geophysical Research Abstracts
Vol. 17, EGU2015-4679, 2015
EGU General Assembly 2015

Losses of soil organic carbon by converting tropical forest to plantations: Assessment of erosion and decomposition by new δ13C approach

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Indonesia lost more tropical forest than all of Brazil in 2012, mainly driven by the rubber, oil palm and timber industries. Nonetheless, the effects of converting forest to oil palm and rubber plantations on soil organic carbon (SOC) stocks remain unclear. We analyzed SOC losses after lowland rainforest conversion to oil palm, intensive rubber and extensive rubber plantations in Jambi province on Sumatra Island. We developed and applied a new δ13C based approach to assess and separate two processes: 1) erosion and 2) decomposition.

Carbon contents in the Ah horizon under oil palm and rubber plantations were strongly reduced: up to 70% and 62%, respectively. The decrease was lower under extensive rubber plantations (41%). The C content in the subsoil was similar in the forest and the plantations. We therefore assumed that a shift to higher δ13C values in the subsoil of the plantations corresponds to the losses of the upper soil layer by erosion. Erosion was estimated by comparing the δ13C profiles in the undisturbed soils under forest with the disturbed soils under plantations. The estimated erosion was the strongest in oil palm (35$\pm$8 cm) and rubber (33$\pm$10 cm) plantations. The 13C enrichment of SOC used as a proxy of its turnover indicates a decrease of SOC decomposition rate in the Ah horizon under oil palm plantations after forest conversion. SOC availability, measured by microbial respiration rate and Fourier Transformed Infrared Spectroscopy, was lower under oil palm plantations.

Despite similar trends in C losses and erosion in intensive plantations, our results indicate that microorganisms in oil palm plantations mineralized mainly the old C stabilized prior to conversion, whereas microorganisms under rubber plantations mineralized the fresh C from the litter, leaving the old C pool mainly untouched. Based on the lack of C input from litter, we expect further losses of SOC under oil palm plantations, which therefore are a less sustainable land-use compared to rubber plantations. Finally, we discussed the advantages and limitations of the new δ13C based approach to assess erosion and decomposition as well as possibilities for its development and broader application.

The reestablishment of new oil palm plantations has just started in the studied region. We therefore advise 1) to reduce the period without soil protection by planting cover crops at the early stage of the establishment to reduce soil erosion and 2) to leave a maximum of the biomass from the old palm trees on site and/or to keep the land lying fallow for a few years to enable the reconstruction of the SOC pool for the next oil palm generation.