Geophysical Research Abstracts
Vol. 18, EGU2016-6470-1, 2016
EGU General Assembly 2016

How well can we assess impacts of agricultural land management changes on the total greenhouse gas balance (CO_2, CH_4 and N_2O) of tropical rice-cropping systems with biogeochemical models?

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Paddy rice cultivation is increasingly challenged by physical and economic irrigation water scarcity. This already results in the trend of converting paddy rice to upland crop cultivation (e.g., maize, aerobic rice) in large parts of South East Asia. Such land management change from flooded lowland systems to well-aerated upland systems drastically affects soil C and N cycling and related emissions of greenhouse gases. Emissions of methane (CH_4) are expected to decrease, while emissions of nitrous oxide (N_2O) will most likely increase. In addition to such fast evolving 'pollution swapping' it is expected that on longer time scales significant amounts of soil organic carbon (SOC) stocks will be lost in form of carbon dioxide (CO_2).

Within the DFG-funded research unit ICON (Introducing non-flooded crops in rice-dominated landscapes: Impact on carbon, nitrogen and water cycles), we investigated environmental impacts of land management change from historical paddy rice cultivation to the upland crops maize and aerobic rice at experimental sites at the International Rice Research Institute (IRRI), the Philippines. To present, more than three years of continuous measurement data of CH_4 and N_2O emissions under different fertilization regimes have been collected. In addition, measurements of SOC contents and bulk densities in different soil horizons allow for an overall very good characterization of the environmental impacts of mentioned land management change.

In this contribution we will show how well mentioned land management change effects in tropical agricultural systems can be represented and thus better understood by the help of process-based biogeochemical models. Seasonal emissions of CH_4 and N_2O are simulated with r^2 values of 0.85 and 0.78 and average underestimations of 15 and 14 %, respectively. These underestimations predominantly originate from treatments in which no fertilizer is applied (CH_4) as well as uncertainties of soil hydrology (N_2O). Long-term development of SOC stocks is highly influenced by the soil oxygen status as well as the growth of photosynthetic active aquatic biomass. Moreover, simulation results demonstrate that short-term GHG balances may considerably differ from long-term balances. Simulated total GHG emissions 2.5 years after land management change are highest for upland crop – paddy rice rotations due to pronounced losses of soil organic carbon. In contrast, over a longer period of several decades total GHG emissions are highest for double cropping of paddy rice clearly dominated by CH_4 emissions. Simulation results suggest that approx. 2.8 - 3.4 t C ha^{-1} yr^{-1} residue incorporation after harvest is needed in order to sustain stable SOC stocks in mixed upland crop - paddy rice systems.