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Modeling greenhouse gas emissions and nutrient transport in managed arable soils with a fully coupled hydrology-biogeochemical modeling system

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The use of mineral nitrogen fertilizer sustains the global food production and therefore the livelihood of human kind. The rise in world population will put pressure on the global agricultural system to increase its productivity leading most likely to an intensification of mineral nitrogen fertilizer use. The fate of excess nitrogen and its distribution within landscapes is manifold. Process knowledge on the site scale has rapidly grown in recent years and models have been developed to simulate carbon and nitrogen cycling in managed ecosystems on the site scale. Despite first regional studies, the carbon and nitrogen cycling on the landscape or catchment scale is not fully understood.

In this study we present a newly developed modelling approach by coupling the fully distributed hydrology model CMF (catchment modelling framework) to the process based regional ecosystem model LandscapeDNDC for the investigation of hydrological processes and carbon and nitrogen transport and cycling, with a focus on nutrient displacement and resulting greenhouse gas emissions in various virtual landscapes / catchment to demonstrate the capabilities of the modelling system.

The modelling system was applied to simulate water and nutrient transport at the at the Yanting Agro-ecological Experimental Station of Purple Soil, Sichuan province, China. The catchment hosts cypress forests on the outer regions, arable fields on the sloping croplands cultivated with wheat-maize rotations and paddy rice fields in the lowland. The catchment consists of 300 polygons vertically stratified into 10 soil layers. Ecosystem states (soil water content and nutrients) and fluxes (evapotranspiration) are exchanged between the models at high temporal scales (hourly to daily) forming a 3-dimensional model application.

The water flux and nutrients transport in the soil is modelled using a 3D Richards/Darcy approach for subsurface fluxes with a kinematic wave approach for surface water runoff and the evapotranspiration is based on Penman-Monteith. Biogeochemical processes are modelled by LandscapeDNDC, including soil microclimate, plant growth and biomass allocation, organic matter mineralisation, nitrification, denitrification, chemodenitrification and methanogenesis producing and consuming soil based greenhouse gases.

The model application will present first results of the coupled model to simulate soil based greenhouse gas emissions as well as nitrate discharge from the Yanting catchment. The model application will also present the effects of different management practices (fertilization rates and timings, tilling, residues management) on the redistribution of N surplus within the catchment causing biomass productivity gradients and different levels of indirect N2O emissions along topographical gradients.