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A new generic plant growth model framework (PMF): Simulating distributed dynamic interaction of biomass production and its interaction with water and nutrients fluxes

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Today, crop models have a widespread application in natural sciences, because plant growth interacts and modifies the environment. Transport processes involve water and nutrient uptake from the saturated and unsaturated zone in the pedosphere. Turnover processes include the conversion of dead root biomass into organic matter. Transpiration and the interception of radiation influence the energy exchange between atmosphere and biosphere. But many more feedback mechanisms might be of interest, including erosion, soil compaction or trace gas exchanges. Most of the existing crop models have a closed structure and do not provide interfaces or code design elements for easy data transfer or process exchange with other models during runtime. Changes in the model structure, the inclusion of alternative process descriptions or the implementation of additional functionalities requires a lot of coding. The same is true if models are being upscaled from field to landscape or catchment scale. We therefore conclude that future integrated model developments would benefit from a model structure that has the following requirements: replaceability, expandability and independency. In addition to these requirements we also propose the interactivity of models, which means that models that are being coupled are highly interacting and depending on each other, i.e. the model should be open for influences from other independent models and react on influences directly.

Hence, a model which consists of building blocks seems to be reasonable. The aim of the study is the presentation of the new crop model type, the plant growth model framework, PMF. The software concept refers to an object-oriented approach, which is developed with the Unified Modeling Language (UML). The model is implemented with Python, a high level object-oriented programming language. The integration of the models with a setup code enables the data transfer on the computer memory level and direct exchange of information about changing boundary conditions. The crop model concept refers to two main elements. A plant model, which represents an abstract network of plant organs and processes and a process library, which holds mathematical solutions for the growth processes. Growth processes were mainly taken from existing, well known crop models such as SUCROS and CERES. The crop specific properties of root architecture are described based on a maximum rooting depth and a vertical growth rate. The biomass distribution depends on an interactive allocation process due to the soil layers with a daily time step. In order to show the performance and capabilities of PMF, the model is coupled with the Catchment Modeling Framework (CMF) and the simple nitrogen mineralization model DeComp. The main feature of the integrated model set up is the interaction between root growth, water uptake and nitrogen supply of the soil. We show a virtual case study on the hillslope scale and spatially dependence of water and nitrogen stress based on topographic position and seasonal development.