Enhancing the simulation of a hydraulic tree-soil system by an interface between the hydraulic models HYDRA for Quercus petraea (Matt.) Liebl. and the hydraulic soil model SilVlow

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Hydraulic processes within trees have long been subject of research activities. Thereby, many empirical research activities base on the assumption of Darcy's law about hydraulic potentials and conductance including the soil space (e.g. Clausnitzer and Hopmans (1994)). These basic principles let Früh and Kurth (1999) create a model about the hydraulic structure within a tree including the relation between hydraulic properties and the architecture of a tree. They implemented the model in form of a simulation software they called 'HYDRA'. HYDRA numerically simulates the water potential structure within a tree and is parametrised for conifers, in particular Pinus sylvestris L. HYDRA simulates the hydraulical structure of the tree over time (usually a single day). The hydraulical structure, thereby, depends also on a conductance model which gives as a result the transpiration rate. The conductance model relies on empirical obtained micro climate information. The numerical simulation of water potentials considering the architecture causes severe numerical problems which are taken care of by a moderate restructuring of tree architecture prior to simulation. HYDRA is a very sophisticated model for the description of the hydraulic situation within a tree crown but does lack a connection to the soil-root layer. In the contrary, the initial potential which is represented at the very bottom of the tree is given by a single parameter and has to be set artificially by the user. The aim of this work was to replace this parameter by an interface to a soil-root simulation system. Here, the model HYDRA was used in a greater project which aimed at the reparameterisation of HYDRA for the tree species Quercus petraea (Matt.) Liebl. Intensive measurements were conducted to get a sufficient amount of information for parameterisation as well as for validation purposes. Hydraulic conductance and potentials are concepts well known in the area of soil sciences. In literature many models exist which describe the concepts of water flow within the soil layer. One approach is that of Blendinger (1995). He describes the hydraulic conditions in the soil layer using the finite element approach well known from physics. Blendinger (1995) created a two dimensional finite element space where the hydraulic potentials are attributed to the finite elements. Furthermore, the model allows to define root elements within these finite elements which then create a sink of hydraulic potential caused by differences of potential at the soil-root boundary. Using these root elements allows studying the impact roots have on the water flow conditions in the soil layer. Having only a two dimensional space available causes the necessity to average the hydraulic states and root information over the third dimension.
In this particular work, an interface between both above mentioned models was implemented to enhance the soil-root-tree connection in HYDRA. The aim was to improve the model in two ways: On one hand this opens the way to work with realistic initial potentials instead of an artificial single parameter, and on the other hand HYDRA gets a dynamic input at the tree-root-soil boundary. The similar concepts of both models allowed such an interface which, furthermore, allowed to study HYDRA regarding changing hydraulic soil conditions caused, e.g., by varying precipitation rates. The preliminary results show that a higher degree of realism of the simulation can be obtained. Furthermore, the pattern of the potentials within a tree has become sensitive to the hydraulic conditions in the soil and beyond that to precipitation. Thus, by introducing the interface the model HYDRA has also obtained a further interface to the environment of the tree, additional to that provided by evapotranspiration.

References

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