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Modelling water uptake efficiency of root systems

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Water uptake is crucial for plant productivity. Trait based breeding for more water efficient crops will enable a sustainable agricultural management under specific pedoclimatic conditions, and can increase drought resistance of plants. Mathematical modelling can be used to find suitable root system traits for better water uptake efficiency defined as amount of water taken up per unit of root biomass. This approach requires large simulation times and large number of simulation runs, since we test different root systems under different pedoclimatic conditions.

In this work, we model water movement by the 1-dimensional Richards equation with the soil hydraulic properties described according to the van Genuchten model. Climatic conditions serve as the upper boundary condition. The root system grows during the simulation period and water uptake is calculated via a sink term (after Tron et al. 2015).

The goal of this work is to compare different free software tools based on different numerical schemes to solve the model. We compare implementations using DUMUX (based on finite volumes), Hydrus 1D (based on finite elements), and a Matlab implementation of Van Dam, J. C., & Feddes 2000 (based on finite differences). We analyse the methods for accuracy, speed and flexibility.

Using this model case study, we can clearly show the impact of various root system traits on water uptake efficiency. Furthermore, we can quantify frequent simplifications that are introduced in the modelling step like considering a static root system instead of a growing one, or considering a sink term based on root density instead of considering the full root hydraulic model (Javaux et al. 2008).

References

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