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A one-dimensional porous media approach to describe water flow in the soil-plant continuum

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The estimation of water flow in plants including root water uptake is crucial to quantify transpiration and hence the water exchange between land surface and atmosphere. In particular, the soil water extraction by plant roots which provides the water supply of plants is a highly dynamic and non-linear process interacting with soil transport processes that are mainly determined by the natural soil variability at different scales. But also the hydraulic interaction between leaves and atmosphere is highly complex. It strongly depends on the regulation of stomatal conductivity and thus is directly related to photosynthesis and plant growth. To better consider this root-soil and leaf-atmosphere interactions we extended and further developed a finite element tree crown hydro-dynamics model based on the one-dimensional porous media equation by including in addition to the explicit three-dimensional architectural representation of the tree crown a corresponding three-dimensional characterisation of the root system.

The one-dimensional xylem water flow model was then coupled to a soil water flow model derived also from the one-dimensional porous media equation. We apply the new model to conduct sensitivity analysis of root water uptake and transpiration dynamics and study drying soil and hydraulic lift scenarios. Using data from lysimeter experiments with young beech trees it is shown, that the model is able to correctly describe transpiration and soil water flow. In conclusion, the one-dimensional porous media approach based on three-dimensional plant architecture to describe water flows in the soil-plant continuum povides an computationally efficient method to reproduce the main mechanisms of plant hydro-dynamics including root water uptake from soil.