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Root water uptake model based on water potential gradient with water redistribution via roots: application to coniferous forest site

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A simple macroscopic vertically distributed plant root water uptake (RWU) model based on traditional water-potential-gradient formulation (Vogel et al., 2013), in which the uptake rates are directly proportional to the potential gradient and indirectly proportional to the local soil and root resistances to water flow, was tested. This RWU modeling approach was implemented in a one-dimensional dual-continuum model of soil water flow based on Richards' equation and used to simulate soil water distribution changes during a vegetation season at a forest site located in a temperate humid climate of central Europe. The main objectives were to test the ability of the presented RWU model to simulate the observed soil-plant-atmosphere interactions, and to examine the differences between empirical and more physically-based RWU modeling approaches (accommodated in the same soil water flow model).

The tested RWU model was capable of simulating both the compensatory root water uptake, in situations when reduced uptake from dry layers was compensated for by increased uptake from wetter layers, and the root-mediated hydraulic redistribution of soil water, contributing to more natural soil moisture distribution throughout the root zone.

Comparison of the model results with the sap flow observed reveals some limitations related to the quasi-steady-state assumption for the plant xylem and zero transpiration rates prescribed during nights and precipitation. This stated, the model seems to simulate adequately both the regular nightly hydraulic redistribution, due to reduced night transpiration, and the episodic daytime hydraulic redistribution during wet canopy events.

The model results were compared to simulations produced using the semi-empirical RWU model of Feddes. Based on both an improved agreement between the observed and simulated soil water pressure responses to daily variations of transpiration, and a more realistic seasonal distribution of the transpiration rate reduction, we concluded that the physically based root water uptake model with negative RWU rates enabled substantially better approximation of the soil water extraction by spruce trees under moderate water scarcity.

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