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Modified Feddes type stress reduction function for modeling root water uptake: Accounting for limited aeration and low water potential

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Modeling water flow in the soil-plant-atmosphere continuum with the Richards equation requires a model for the sink term describing water uptake by plant roots. Despite recent progress in developing process-based models of water uptake by plant roots and water flow in aboveground parts of vegetation, effective models of root water uptake are widely applied and necessary for large-scale applications. Modeling root water uptake consists of three steps, (i) specification of the spatial distribution of potential uptake, (ii) reduction of uptake due to various stress sources, and (iii) enhancement of uptake in part of the simulation domain to describe compensation. We discuss the conceptual shortcomings of the frequently used root water uptake model of Feddes and suggest a simple but effective improvement of the model. The improved model parametrizes water stress in wet soil by a reduction scheme which is formulated as function of air content where water stress due to low soil water potential is described by the original approach of Feddes. The improved model is physically more consistent than Feddes' model because water uptake in wet soil is limited by aeration which is a function of water content. The suggested modification is particularly relevant for simulations in heterogeneous soils, because stress parameters are uniquely defined for the entire simulation domain, irrespective of soil texture. Numerical simulations of water flow and root water uptake in homogeneous and stochastic heterogeneous soils illustrate the effect of the new model on root water uptake and actual transpiration. For homogeneous fine-textured soils, root water uptake never achieves its potential rate. In stochastic heterogeneous soil, water uptake is more pronounced at the interfaces between fine and coarse regions which has potential implications for plant growth, nutrient uptake and depletion.