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Comparing 1D, 2D and 3D models for predicting root water uptake at the plant scale

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Numerous modeling approaches exist to simulate soil water extraction by plant roots. They mainly differ in terms of dimensionality (from 1-D to 3-D) and in the degree of detail involved in the root geometry. One dimensional models consider 1-D root length density profiles and assume uniform horizontal soil water distribution and are very efficient regarding computation time. On the opposite, very detailed 3-D approaches, which consider explicitly the root architecture and the root water flow, may need more computation power and time. In between these two extreme cases, other approaches exist, which may be more accurate and less computationally demanding. Our objective is to compare different modeling approaches and check how their implicit or explicit simplifications or assumptions affect the root water uptake (RWU) predictions.
Four models were subject to our comparison, all based on Richards equation. The first is a 1-D model solving Richards equation (SWAP) with the Feddes (1978) approach for RWU. The second one is also based on SWAP but with the root water uptake defined by a microscopic approach developed by de Jong van Lier (2008). The third one, FUSSIM, solves the Richards equation in 2-D based on a 2-D distribution of root length density (RLD). The fourth one is R-SWMS, a 3-D model simulating the water flow in the soil and in the roots, based on the complete root architecture description. A 45-day maize root was generated in 3-D and simplified in 2-D or 1-D RLD distributions. We simulated a constant uptake rate for 30 days with a 1-day rainfall at day 15 in three different soil types. We compared relative water uptake versus relative root length density profiles, and actual transpiration time series. On the one hand, the general trends of cumulative transpiration with time for the three soils were relatively similar for all models. On the other hand, some features like hydraulic lift are simulated by both FUSSIM and RSWMS models while other models do not explicitly estimate the water potential in the plant and roots.