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Implementation and Application of a new HYDRUS Add-On Module to Model the Interactions Between Plant Roots, Soil Properties, and Water Flow Conditions in Soils

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As roots react dynamically to environmental conditions modeling of these dynamic reactions is essential to understand the use of nutrient resources and soil water by plants.
The standard versions of the HYDRUS software neither consider the influence of soil conditions on root growth nor the feedback between root growth and water availability. Instead root growth is defined only using static parameters independent of soil characteristics. To account for the influence of soil conditions on root growth and the feedback between root growth and water availability, we developed a new root growth module as an add-on for the HYDRUS software.
The new module was developed based on the adaption of an already existing root growth model (Jones et al., 1991) which takes into account different environmental stresses. The model assumes that root growth and the root spatial distribution is influenced under suboptimal conditions by various environmental factors such as soil water content, soil temperature, soil strength, poor aeration, coarse fragments, aluminum toxicity, and calcium deficiency.
As in the original HYDRUS module the rooting depth is derived with a time-dependent growth function independent of environmental factors. This rooting depth is now considered as the potential rooting depth which would be reached when the development of the root system would be independent of environmental conditions. In a second step an actual rooting depth is evaluated by taking into account sub-optimal environmental conditions via the stress factor approach (Jones et al., 1991). The actual root length density distribution is then calculated based on shape functions. These shape functions initially represent the potential root length density distribution under optimal conditions. The actual root length density distribution is again obtained with the stress factor approach.

The modified modeling approach is only a first approximation of the effects of environmental factors on root growth and thus still needs to be verified against experimental data. In a first step we tested the newly implemented effect of soil temperature on root growth.
This was done by comparing modeling results with measured rooting depths in an aeroponic experimental system with bell pepper. Inverse optimization was used to estimate a single set of parameters that was found to well reproduce measured time series of rooting depths for all three temperature treatments. A sensitivity analysis showed that the root growth module that only considers temperature stress, had the advantage of only slightly increasing the complexity of the standard HYDRUS models.
The implementation of growth and stress functions in the HYDRUS software provides the opportunity to derive parameters of these functions from laboratory or field experimental data using inverse modeling.
While the results showed that the temperature dependent root growth modeling approach well reproduced real root growth data, the implementation of the other stress factors on root growth still needs to be validated against experimental data.

Jones, C., W.L. Bland, J.T., Ritchie, and J.R. Williams, 1991. Simulation of root growth. In: Modeling plant and soil systems. Agron. Monogr. 31. ASA-CSSA-SSSA, Madison, WI.p. 91-123.