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Water Flow in Vadose Zone with Root Water Uptake: From Measurements and Models to Optimal Irrigation

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Abstract

Water has been labeled 'blue gold', and 'blue gold' is destined to be the critical issue of the 21st Century. Globally, irrigation is responsible for 80 % of the world-wide spending of 'blue gold'. Development of sustainable irrigation practices will require that we understand better the biophysical processes of root-water uptake in soil, and transpiration from plant canopies. Soil water movement with root water uptake is a key process of water and chemicals transport in the soil-plant system. In this study, a two-dimensional model of root water uptake for apple trees was developed, and linked into a soil water dynamic model to enable simulation of water movement in soil via numerical solution of Richards's equation. The root water uptake model included root density distribution function, soil texture factor, potential transpiration and soil water stress-modified factor. The model's parameters were optimised by minimising the residuals between simulated and measured soil water contents. A tube-time domain reflectometry (TDR) was used to measure soil volumetric water content around a surface-irrigated apple tree up to 2 m depth at 12 locations. Simulated and measured water contents were in excellent agreement, with R^2 values generally ranging between 0.94 and 0.97 and root mean squared error (RMSE) of 0.012 m^3m^{-3}. Studies show that the maximum root water uptake was at depth 10–30 cm. The water uptake from the top 40 cm of the root zone, was on average 40–50 liters per day. Potentially the numerical model is a useful tool for various problems related to water flow transport with plant water uptake in variably saturated soils. Finally, we demonstrate how our scientific knowledge can be used to develop sustainable irrigation practices.

Keywords: Numerical model, Richards' equation, root distribution, soil properties, unsaturated soil

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