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Impact of 3-D root uptake on solute transport: a numerical study

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Water uptake by plant roots may have an important impact on the 3-D soil water flow velocity distribution, which, in turn, affects solute transport. This numerical study aims at investigating how solute fate is impacted by root uptake simulated with a 3D biophysical model. This model solves the Richards equation in 3-D in the soil and the flow equation within the plant root xylem vessels. Solute is modeled by a 3-D particle tracker (PARTRACE).

Two types of root architecture were compared in these virtual 3D experiments: fibrous and tap-rooted systems. First, a constant transpiration strictly smaller than the downward boundary flux was imposed and run until steady-state flow was reached. Second, a particle tracker was used to simulate a solute step application under the steady state flow water potential distribution. Three solute uptake processes were analyzed: passive uptake, active uptake and full exclusion (no uptake). Third, breakthrough curves at three different depths were compared between these scenarios and fitted with a 1D numerical flow model under steady-state conditions to obtain apparent CDE parameters.

Both apparent velocity and dispersivity are affected by root uptake. In addition, under high exclusion processes (slight or no active uptake), solutes accumulate around roots and generate a long tailing to the breakthrough curves, which cannot be reproduced by 1-D models that simulates root water uptake with solute exclusion. This may have an important impact on pollutant mass transfer to groundwater.