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Root activity for water uptake: a hydraulic approach

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Despite most macroscopic models for root water uptake considering root length density (RLD) to describe root water uptake (RWU) distribution, there are numerous studies demonstrating inconsistencies between soil water content profile and RLD that can be attributed to the inability of some roots to extract water. In fact, the physical relationship between RWU and the root system ignores the hydraulic characteristics of the root. To cope with this rigid assumption, the activity of a root system can be defined as the portion of the root system extracting majority of soil water. Root water uptake activity depends on the hydraulic head gradient between root-soil interface and xylem and on root segment conductance, which are terms not considered in macroscopic models. Therefore, both soil and root hydraulic properties are critical in determining RWU activity. Yet, in real root systems, active root fraction is continuously changing due to root development, root adaptation and soil moisture heterogeneity, which are not possible to be assessed considering the currently available experimental facilities. Therefore, our aim in this study is threefold: (1) establish a theoretical framework to investigate root water uptake activity; (2) Investigate with 0D hydraulic architecture model and 3D architectural soil-root water flow model to estimate the active root fraction and to find the effective parameters on active root fraction and finally (3) demonstrate and provide orders of magnitude of active root fraction for real situations. The initial results showed that RWU activity for a single segment depends on radial hydraulic conductivity distribution if xylem conductance is not limiting. The active fraction of the root for fibrous and taproot systems at different ages with their realistic root hydraulic properties was investigated under equilibrium and realistic soil water potential and compared with some existing values in literature. The simulated active root fraction and obtained ones from the previous studies rarely exceed 30% of the whole root system. The active root fraction is therefore an important factor to know and characterize to properly estimate soil resistance and stress onset.