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Optimising root system hydraulic architectures for water uptake

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In this study we started from local hydraulic analysis of idealized root systems to develop a mathematical framework necessary for the understanding of global root systems behaviors. The underlying assumption of this study was that the plant is naturally optimised for the water uptake. The root system is thus a pipe network dedicated to the capture and transport of water. The main objective of the present research is to explain the fitness of major types of root architectures to their environment.

In a first step, we developed links between local hydraulic properties and macroscopic parameters of (un)branched roots. The outcome of such an approach were functions of apparent conductance of entire root system and uptake distribution along the roots. We compared our development with some allometric scaling laws for the root water uptake: under the same simplifying assumptions we were able to obtain the same results and even to expand them to more physiological cases. Using empirical data of measured root conductance, we were also able to fit extremely well the data-set with this model.

In a second stage we used generic architecture parameters and an existent root growth model to generate various types of root systems (from fibrous to tap). We combined both sides (hydraulic and architecture) then to maximize under a volume constraint either apparent conductance of root systems or the soil volume explored by active roots during the plant growth period. This approach has led to the sensitive parameters of the macroscopic parameters (conductance and location of the water uptake) of each single plant selected for this study.

Scientific questions such as: "What is the optimal sowing density of a given hydraulic architecture ?" or "Which plant traits can we change to better explore the soil domain ?" can be also addressed with this approach: some potential applications are illustrated. The next (and ultimate phase) will be to validate our conclusions with real architectures data and with a physical model of the water fluxes in the soil-plant continuum.