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MARSHAL: a unique tool for deciphering the water flow in maize root system hydraulic architectures

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Existing literature about maize root system hydraulic and architectural properties is abundant and can serve as input for contrasted root system hydraulic architecture generation tools. Therefore observations of root hydraulic and architectural phenes in field and/or laboratory experiments must be first converted into parameters for feeding root growth model and water flow algorithms. MARSHAL aims at gathering the existing information about the maize plant and at making it available for the community. Existing maize root system architecture parameterizations as well as measured hydraulic functions were gathered in a common database and linked with the state-of-art model of the water transfer in the soil-plant-atmosphere continuum.

MARSHAL is as an online and flexible tool that generates contrasted root system hydraulic architectures using this database, calculates the water flow within the root system under user-provided boundary conditions (transpiration and soil water potential distribution) and calculates plant-scale macroscopic parameters. The generated root systems hydraulic architectures can be saved in common formats such as RSML to be easily imported in other models. Finally, MARSHAL is coupled with sensitivity and optimization algorithms in order to investigate the sensitive input parameters for a used-defined objective function or to provide an optimal set of parameters that minimizes an error function, alongside with parameter uncertainty.

As illustration of the model potentiality, we used MARSHAL to generate maize contrasted hydraulic architectures and we compared them with plant-scale observations of both architecture (root length density profile field measurements) and hydraulics (root system conductance measurements). The macroscopic parameters could be easily fitted with the model and the observed local variability of root phenes determined. The hydraulic architectures were then used as contrasted genotypes in a water flow model of the soil-plant-atmosphere continuum to highlight G x E interactions and they indeed performed differently in contrasted pedo-climatic conditions. Finally, MARSHAL served to validate a fully analytical model of the root system hydraulic architecture and to calculate the sensitivity of mature root system conductance, depth of standard uptake, volume and convex hull volume to the input parameters.