Models assisted phenotyping for functional root phenes

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Context: Current plant breeding strategies for water stress management are fragmented. They do not cover the whole complexity of the soil-plant continuum. Current breeding strategies focus on a limited number of structural root phenes such as the insertion angle or the rooting depth. The quantification of functional phenes (e.g. root radial conductivity) is more complex to include into the phenotyping process than other phenes because there is no direct access to it. To increase plant performance in specific environments, we need a new methodology to quantify functional phenes.

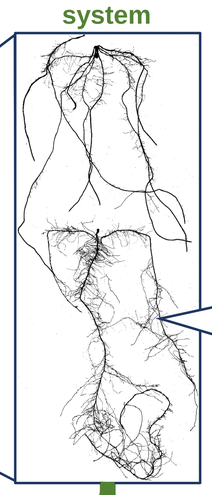
Goal: To develop a new phenotypic pipeline, with the assistance of models, to characterize how water is transported at the root system scale.

Overview of our methodology:

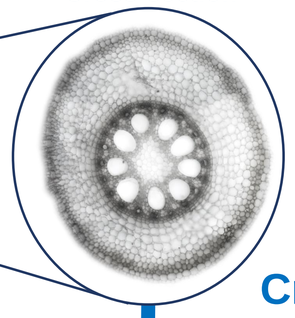
1. The experiment is conducted in greenhouse. It allows the adjustment of all the parameters of the different models based on the observed plants. A couple of measurements are taken to validate the methodology (e.g. Root system conductance (Krs) and Transpiration).

2. The image analysis software used to gather **root type features** is **SmartRoot**. **RootScan2** was used to get the **cross-section anatomy**. The pipeline is coded in R.

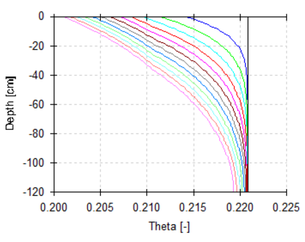
Scan of the root system



Cross-section



Soil properties



Hydrus1D

Šimůnek et al. 2008. "HYDRUS and Stanmod models". *Vadose Zone Journal* 7 (2).

Rooting depth

Root type features

CRootBox

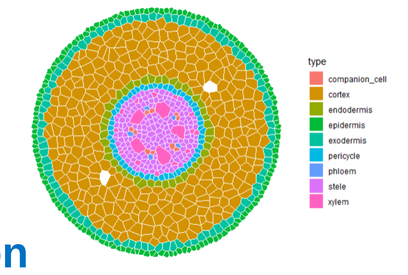
Schnepf et al. 2018. "CRootBox: A Structural–functional Modelling Framework for Root Systems." *Annals of Botany*.

Root system architecture

Soil water potential

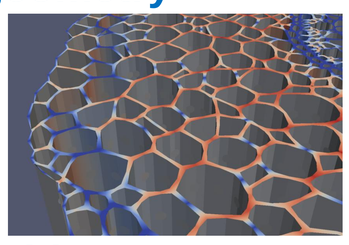
Cross-section anatomy

GRANAR



Cross-section geometry

MECHA



Couvreur et al. 2018. "Going with the Flow: Multiscale Insights into the Composite Nature of Water Transport in Roots." *Plant Physiology* 178 (4).

Root type conductivities

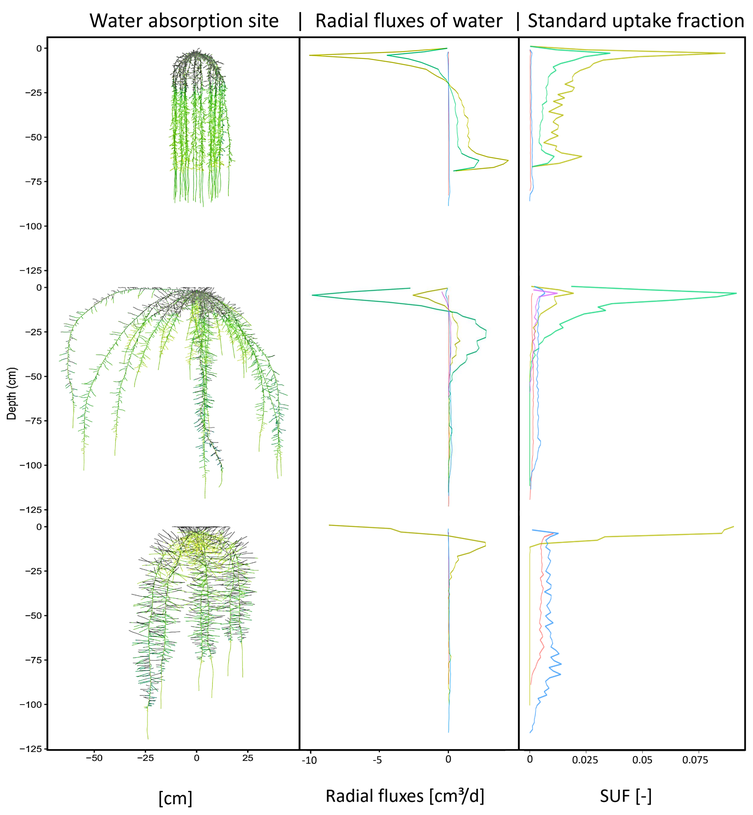
MARSHAL

Root system hydraulic architecture

Future work:

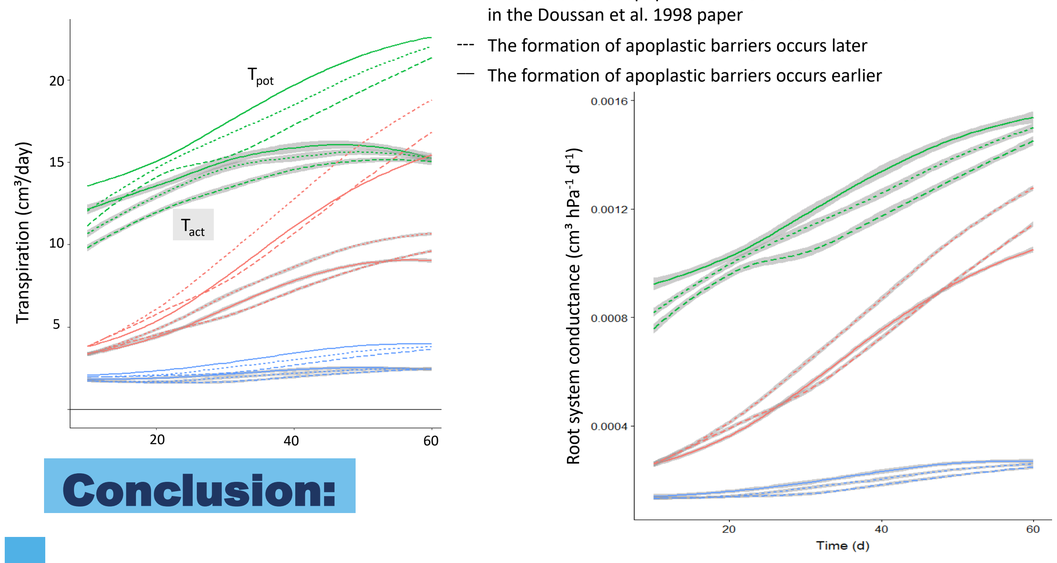
A feedback loop will be implemented between the root system hydraulic architecture and the soil water potential.

Ouput from MARSHAL: In this case study, we have three kind of root system architectures, three scenarios of conductivities and a vertical profile for the soil water potential which is drying up.



The radial fluxes of water informs on water redistribution in the soil and how much water is taken up. While the standard uptake fraction shows the preferential area of uptake in a soil with homogenous water potential.

Transpiration:



Conclusion:

There is an interaction between the root system architecture and the root conductivities.

References: C. Doussan, L.C. Page, and G. Vercambrea. 1998. "Modelling of the Hydraulic Architecture of Root Systems: An Integrated Approach to Water Absorption–Model Description." *Annals of Botany* 81: 213–23.

https://github.com/MARSHAL-ROOT/marshal-pipeline

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