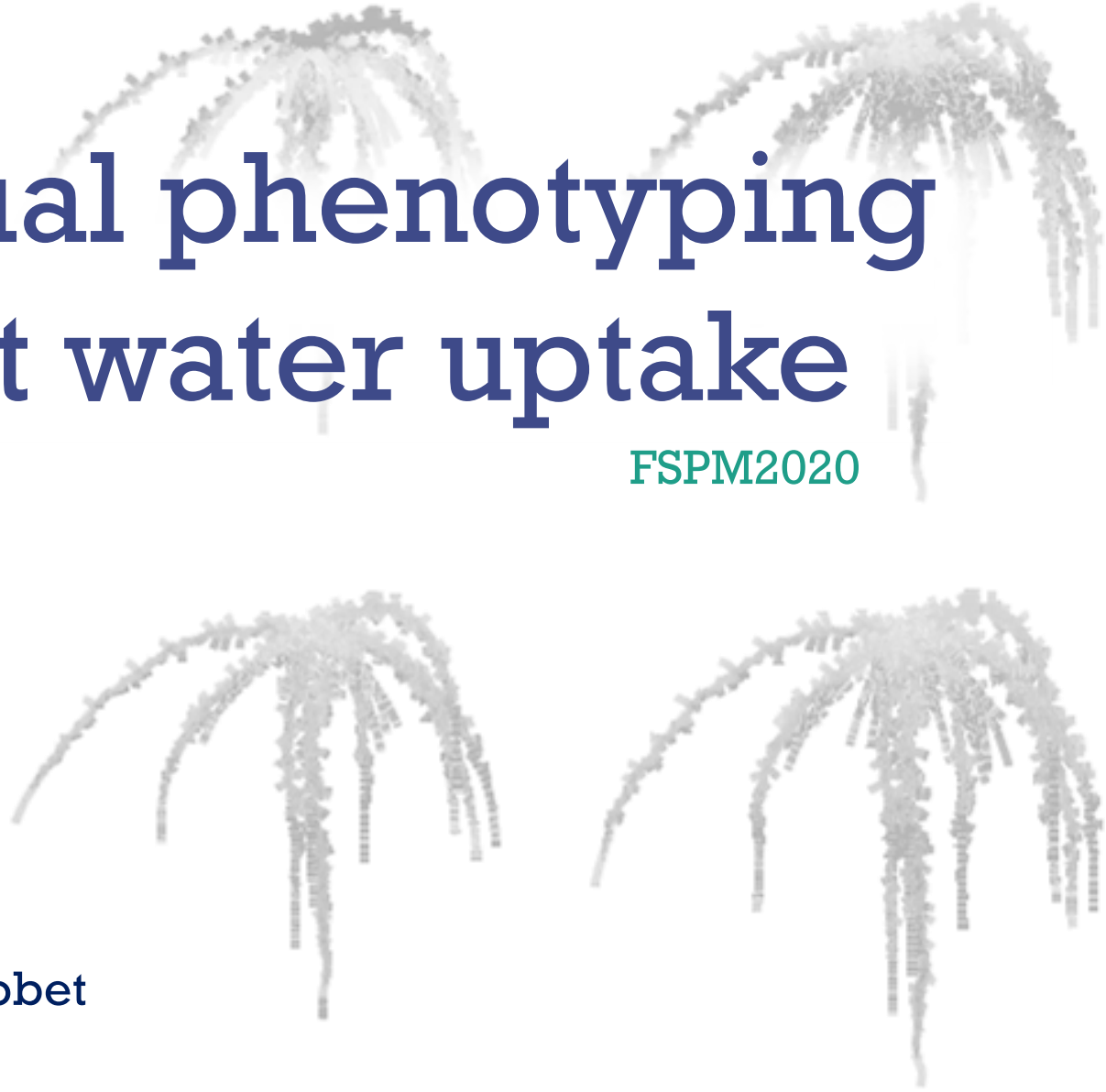
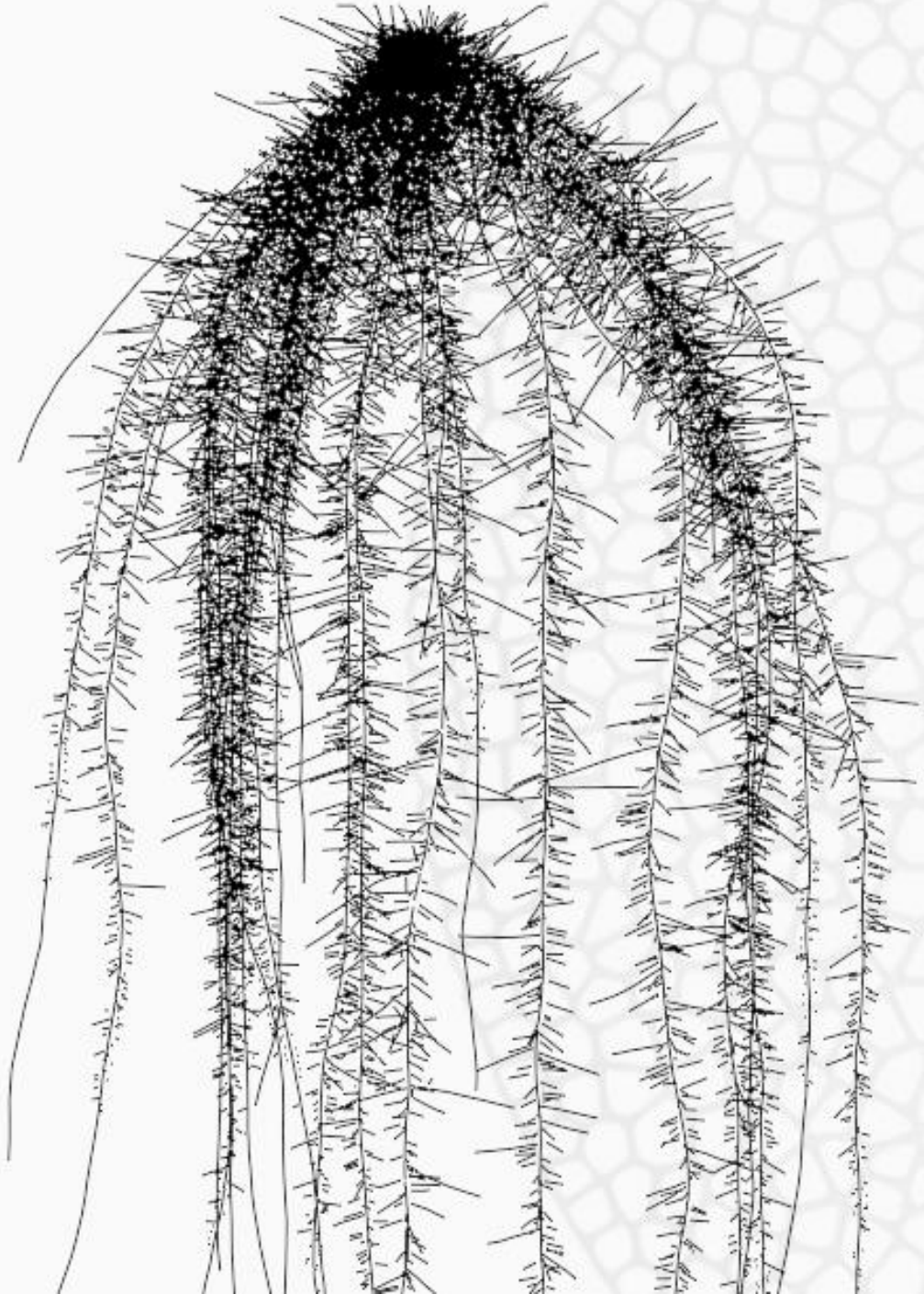
A multiscale virtual phenotyping pipeline for root water uptake

FSPM2020



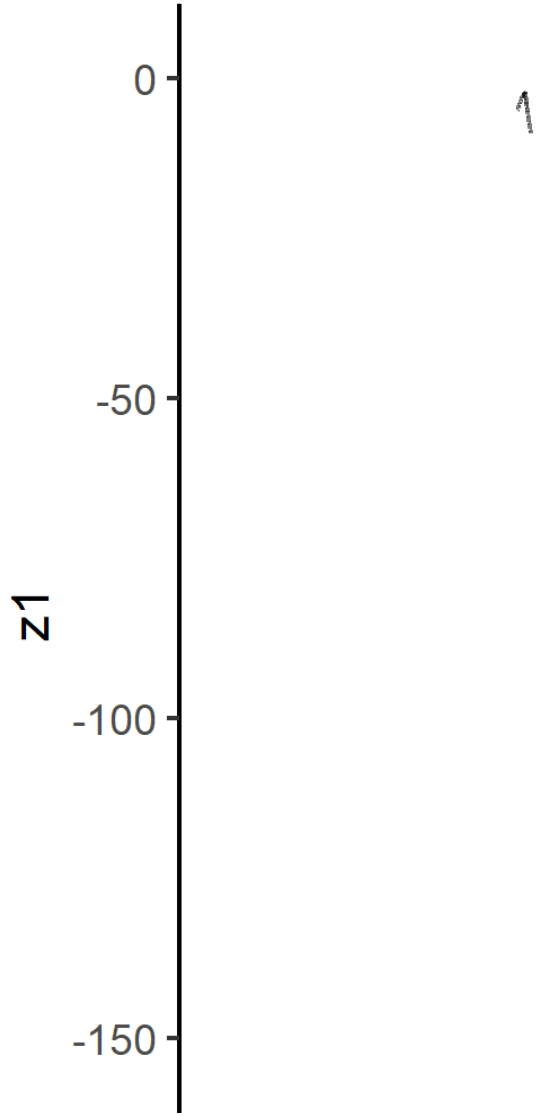
Adrien Heymans, Valentin Couvreur, Guillaume Lobet

UCLouvain



What are the root traits that together creates a favorable combination in a specific environment?

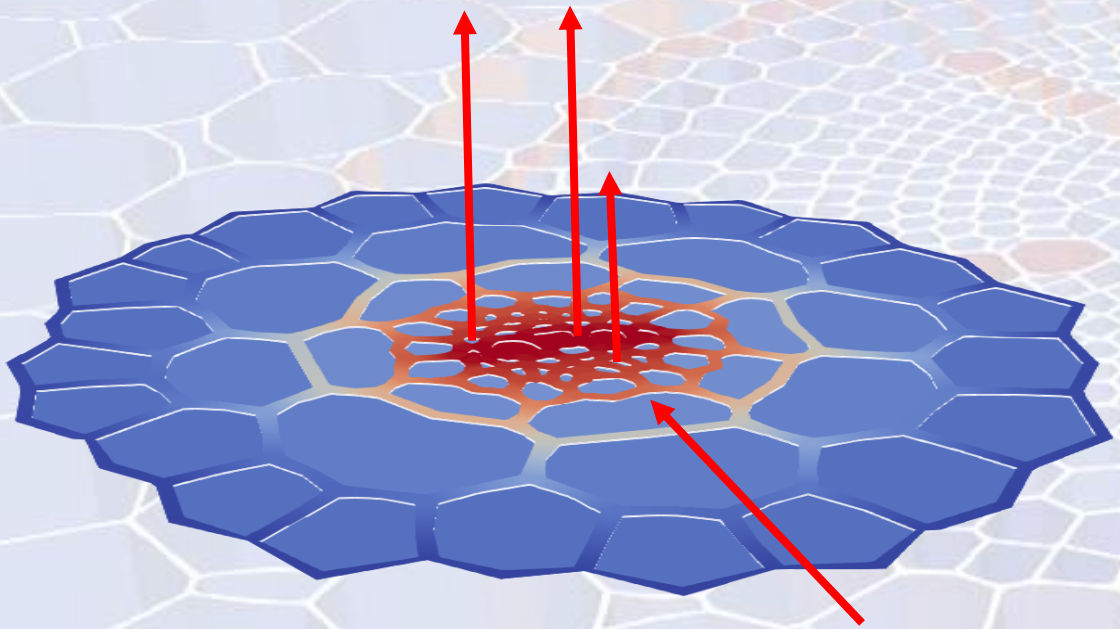
Root system architecture:



A structure in space and in time

Root hydraulics:

Axial hydraulic conductance (k_x)



Radial hydraulic conductivity(k_r)

Root system hydraulic architecture:

$$J_{r,i} = 2 \cdot \kappa_i \cdot tanh\left(\frac{\tau_i l_i}{2}\right) \cdot \left(\Psi_{sr} - \left(\frac{\Psi_{x-1,i} + \Psi_{x,i}}{2}\right)\right)$$

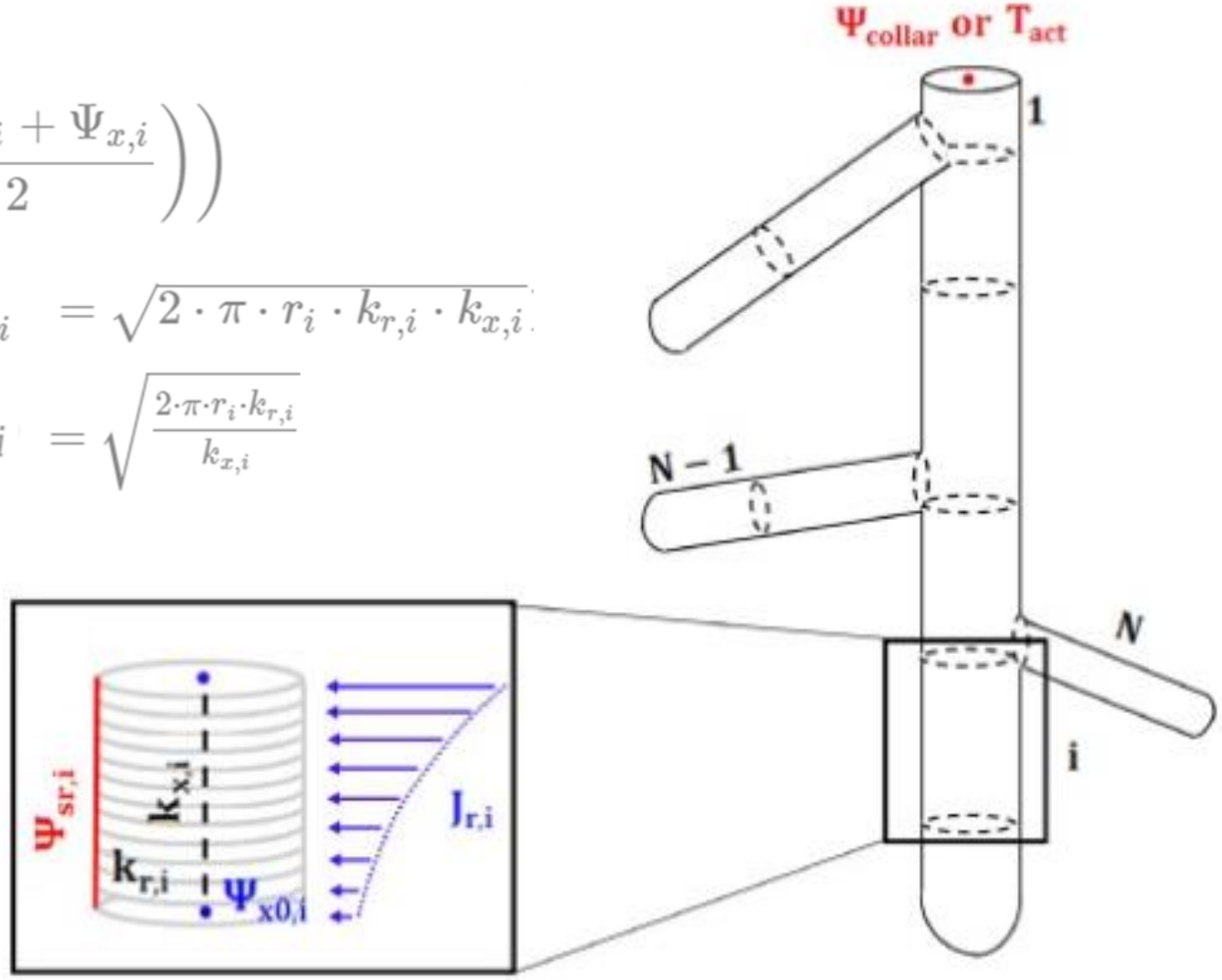
$$T_{act} = \sum_{i=1}^{N_{seg}} J_{r,i}$$

$$K_{rs} = \frac{T_{act}}{\Psi_{sr} - \Psi_{collar}}$$

$$SUF_i = \frac{J_{r,i}}{T_{act}}$$

$$\kappa_i = \sqrt{2 \cdot \pi \cdot r_i \cdot k_{r,i} \cdot k_{x,i}}$$

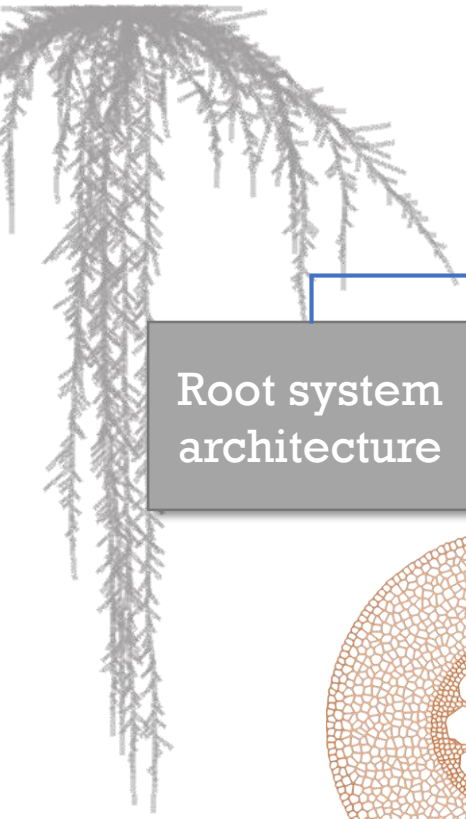
$$\tau_i = \sqrt{\frac{2 \cdot \pi \cdot r_i \cdot k_{r,i}}{k_{x,i}}}$$

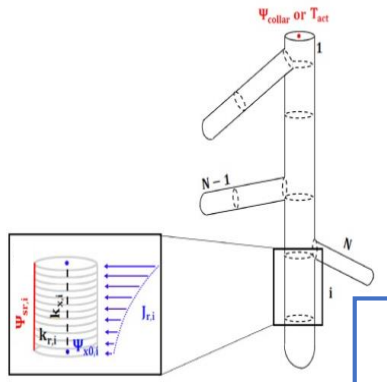


MARSHAL

Meunier et al., 2020.

Summary:





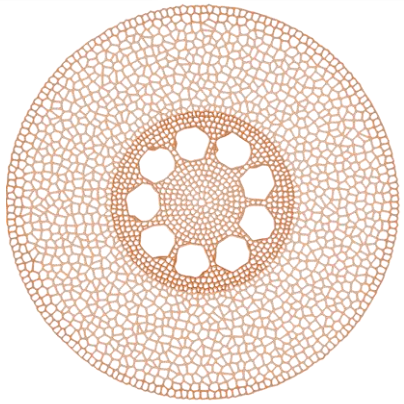
Root system architecture

Root anatomy

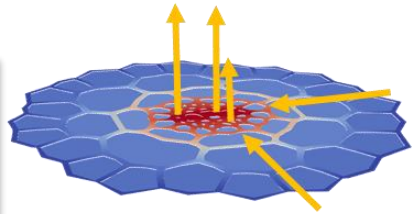
Root hydraulic conductivity

Root system hydraulic architecture

Soil water profile



Cell hydraulic properties



Precipitation

Ψ_{collar}

Weather data & shoot water demands

Hydrus1D

MARSHAL

Let's model that!

CPlantBox

GRANAR

MECHA

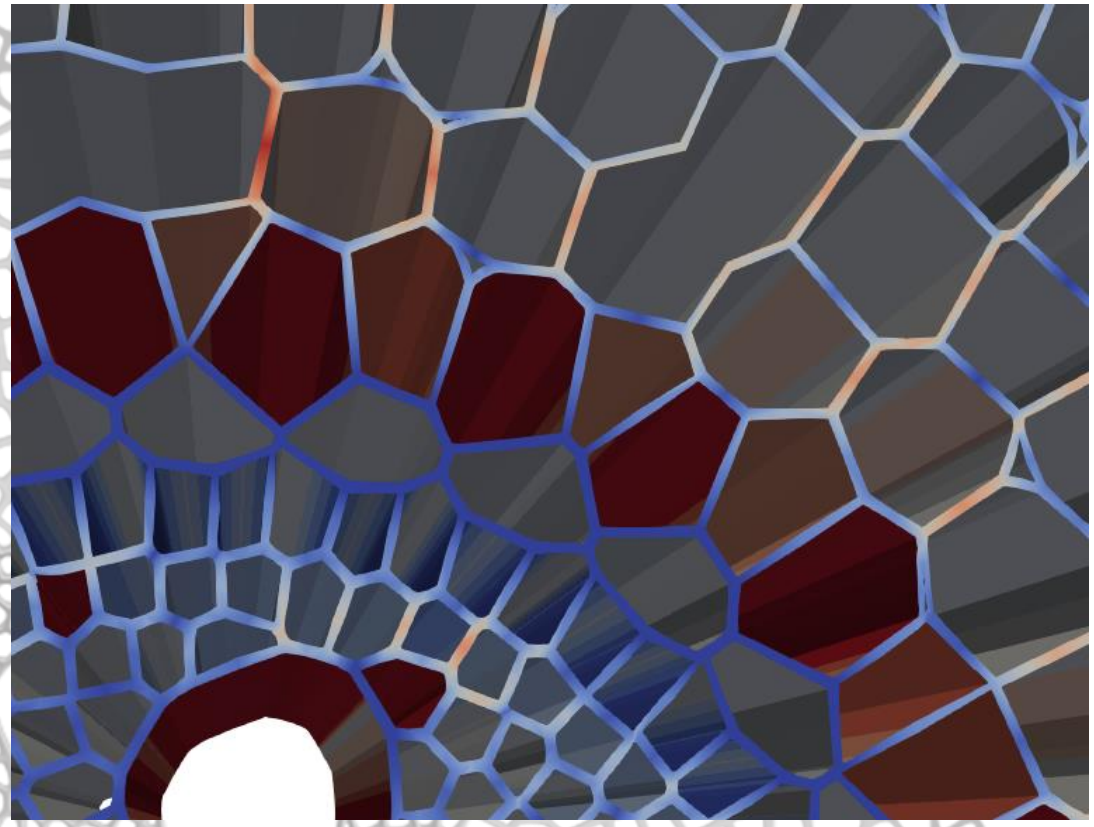
The narrow, the average and the wide.

CPlantBox to create root system architecture (*Zea mais* var. B73)

Schnepf et al., 2018. **CRootBox**

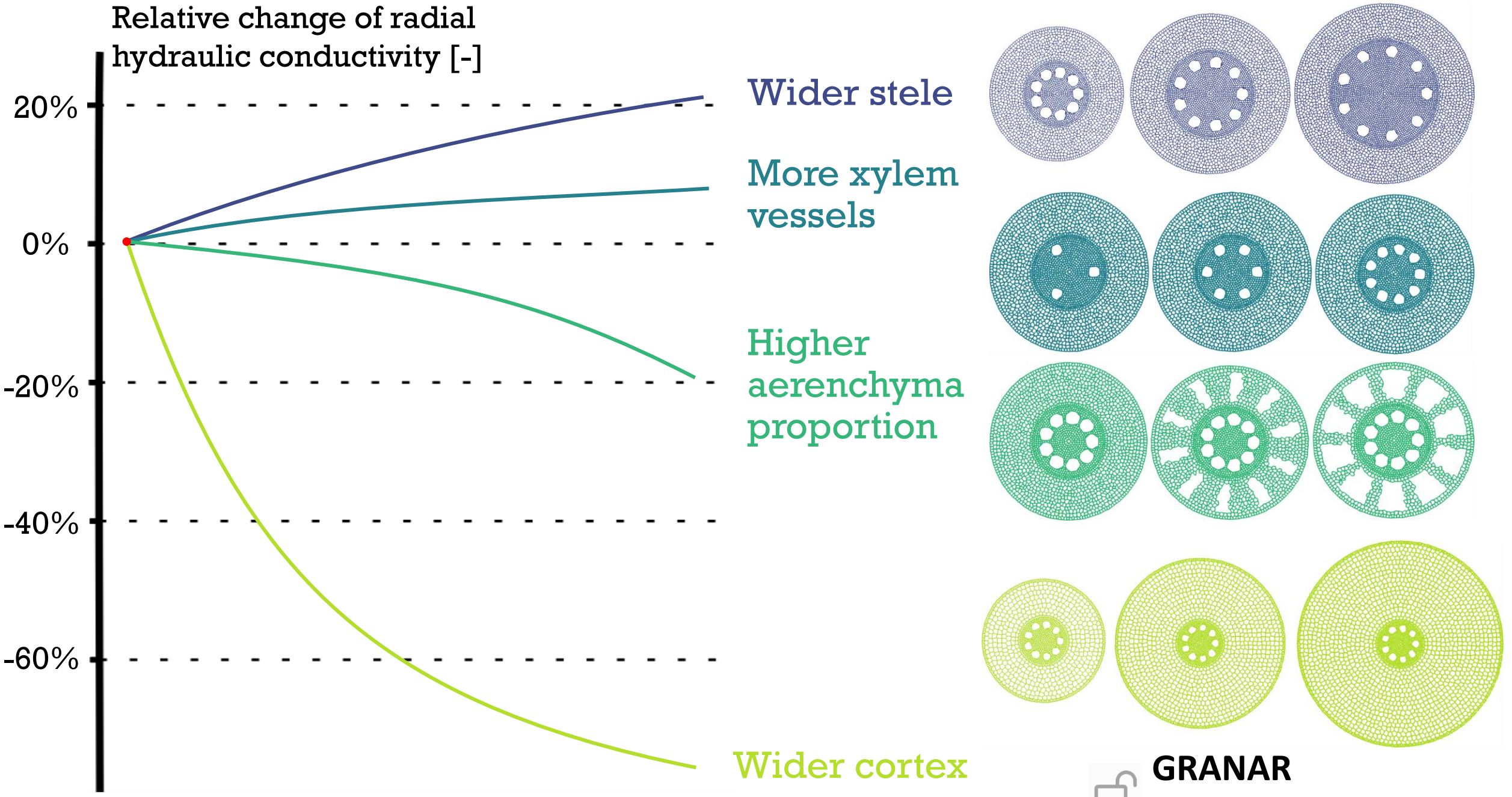
Zhou et al., 2020. **CPlantBox**

Root cross-section and hydraulic conductivities.



GRANAR
Heymans et al., 2020.

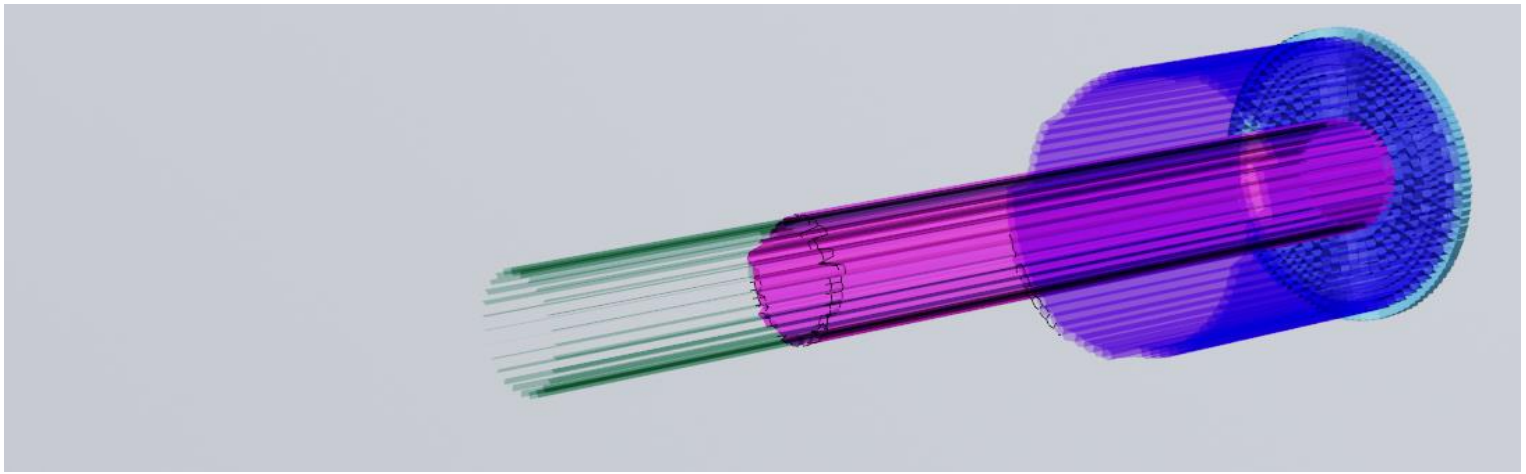
MECHA
Couvreur et al., 2018.

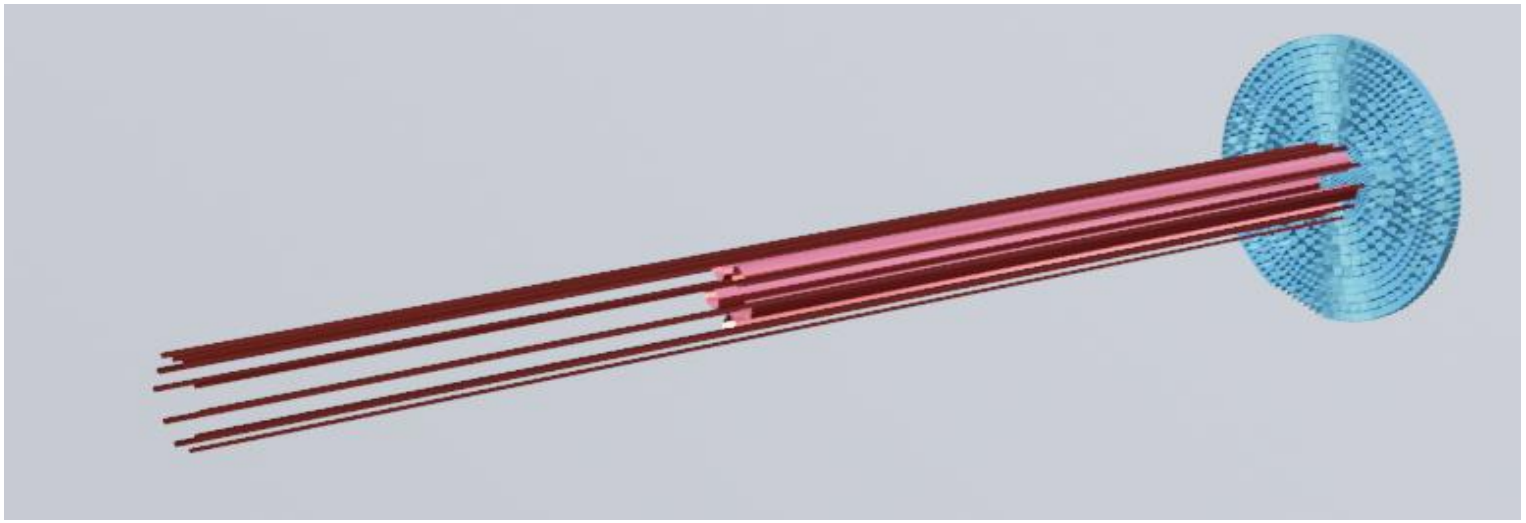


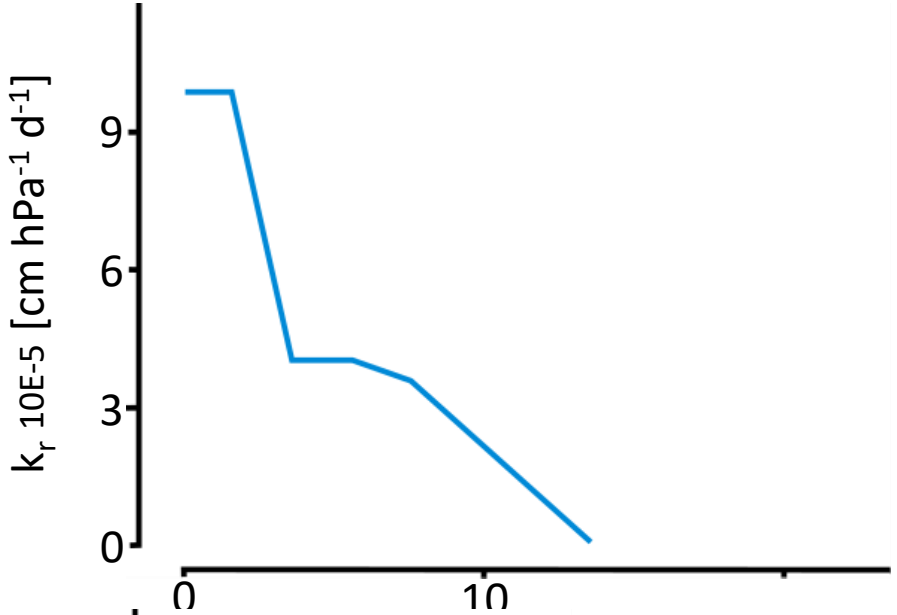
GRANAR

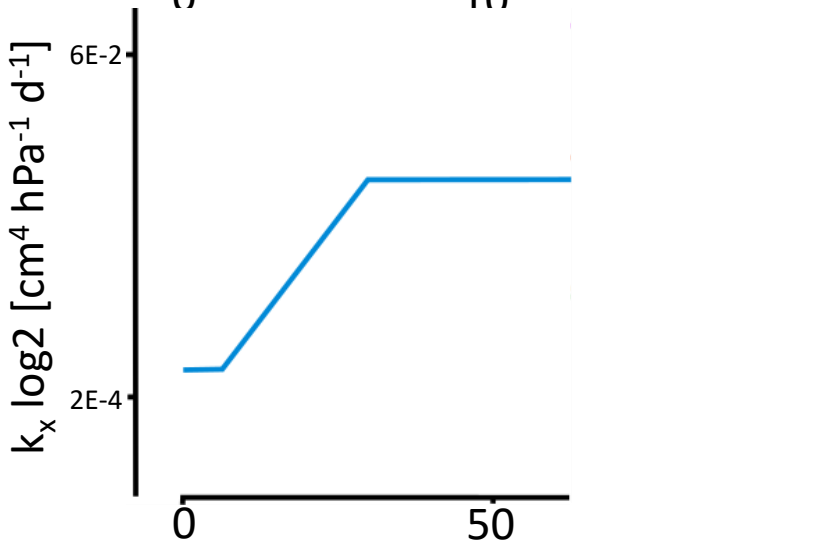
Heymans et al., 2020.

Along the root axis:









Coupling the RSHA with its environment.

Ψcollar

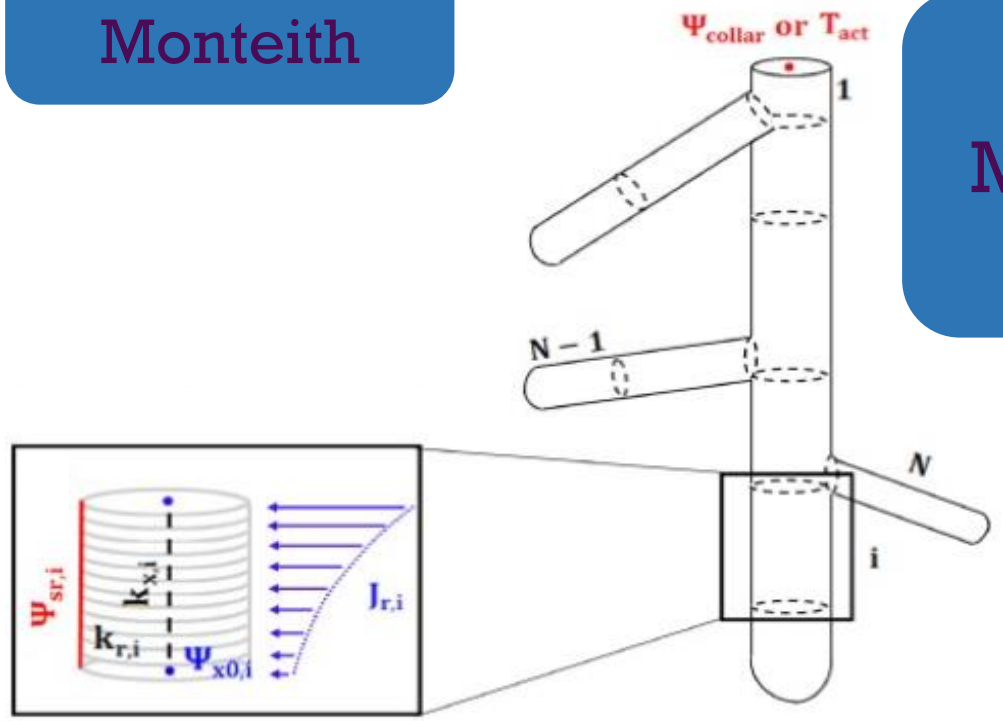
Penman-Monteith

Ψsoil

MARSHAL

Hydrus 1D + Couvreur Model

Standard Sink Fraction, K_{rs}, K_{comp}, T_{act}



Cortex width ?

Aerenchyma proportion ?

What are the local root traits which usually are found in the phenotypes with a high root system conductance?

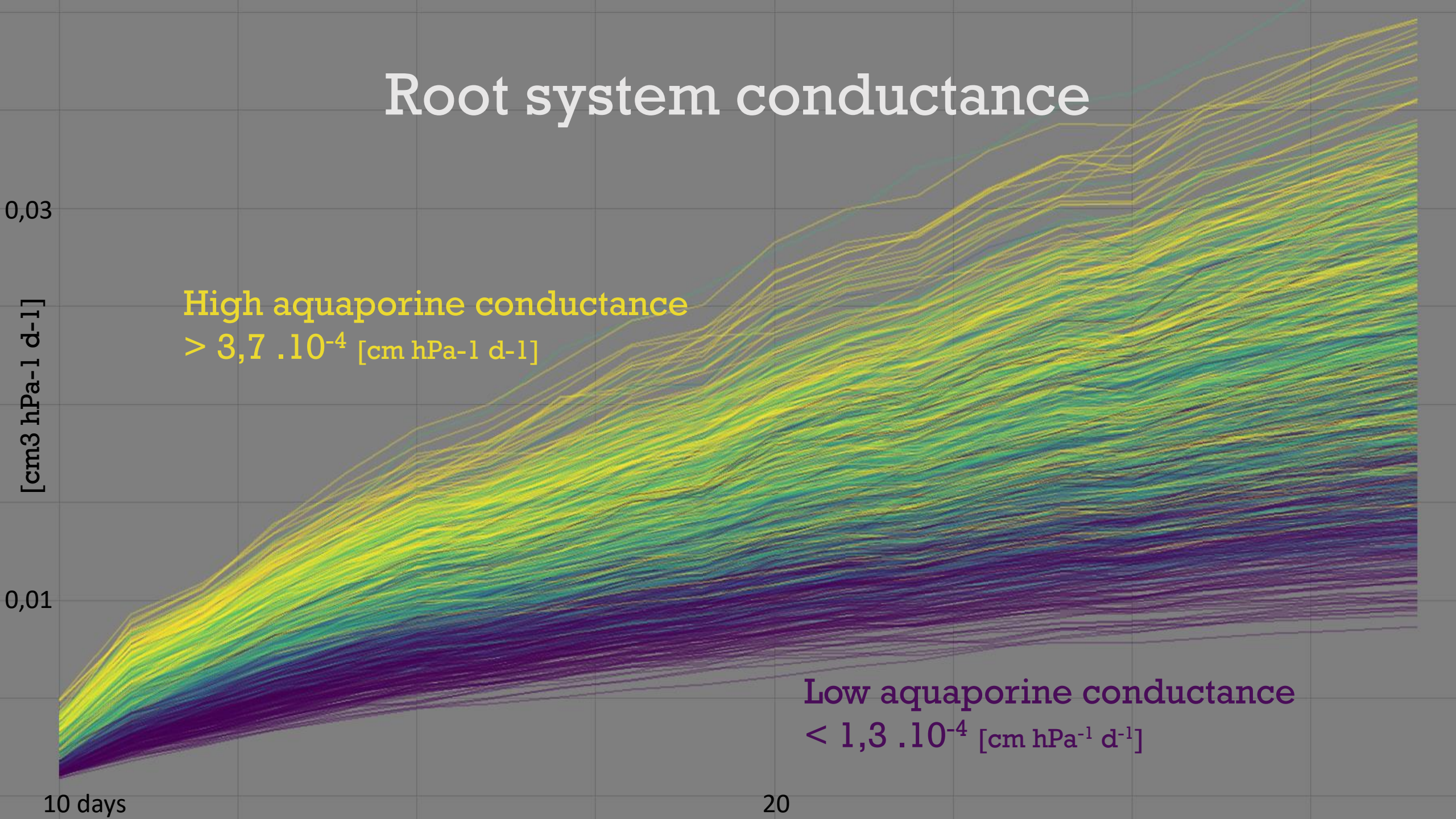
kAQP ?

Xylem diameter ?

Simulation time!

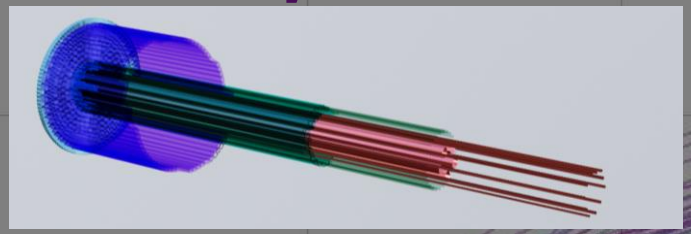
- 1500 Root Systems Architectures
  - *var. B73* RSA type
- 10 Root Cross Sections per RSA
  - 8 parameters (anatomy and cell hydraulic properties)
- 3 Root Hydraulic scenarios per RCS
  - 3 temporal parameters (apo bar and xylem)

Root system conductance



Root system conductance

Short period between apoplastic barrier formation and maturation of the meta-xylem vessels

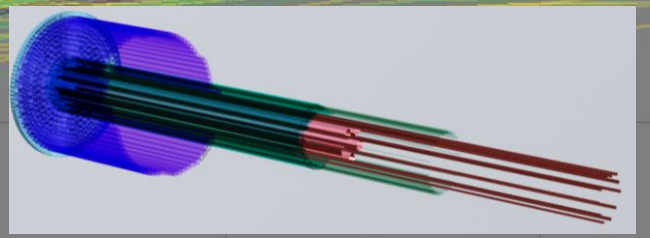


0,03

[cm3 hPa-1 d-1]

0,01

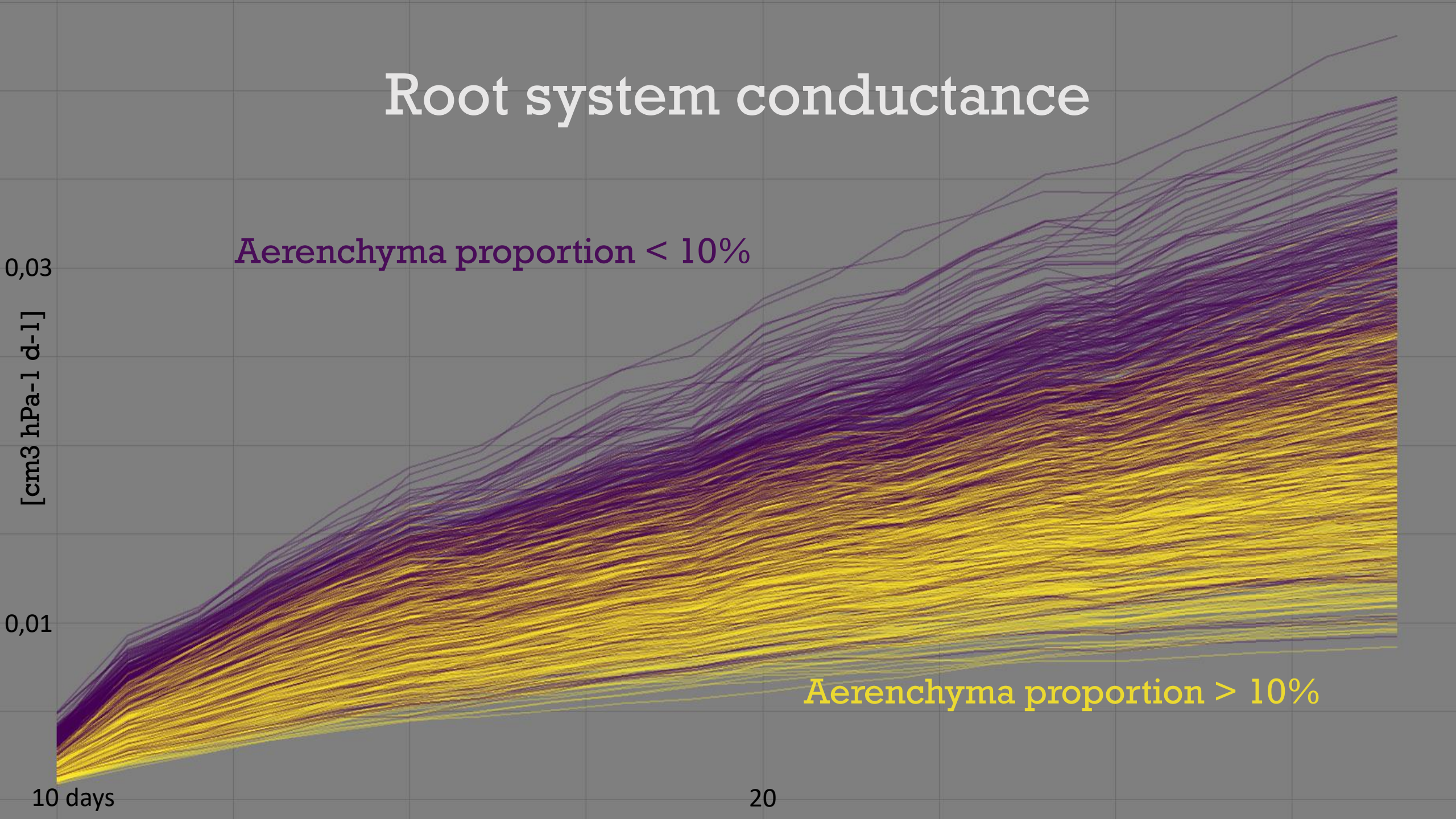
Long period



10 days

20

Root system conductance



Take home messages:

- Root Cross section can be used to estimate k_r and k_x
  - GRANAR – MECHA coupling
- MARSHAL can be used to quickly access macro hydraulic properties
- Locals root traits can be tested in a modeling pipeline to see their global influence on k_{rs}
  - Ex: kAQP or aerenchyma % have a global effect on k_{rs}

Thanks you for your attention

Guillaume Lobet

Adrien Heymans

Valentin Couvreur

Daniel Leitner

Félicien Meunier

Mathieu Javaux

Xavier Draye

UCLouvain

fnrs

LA LIBERTÉ DE CHERCHER