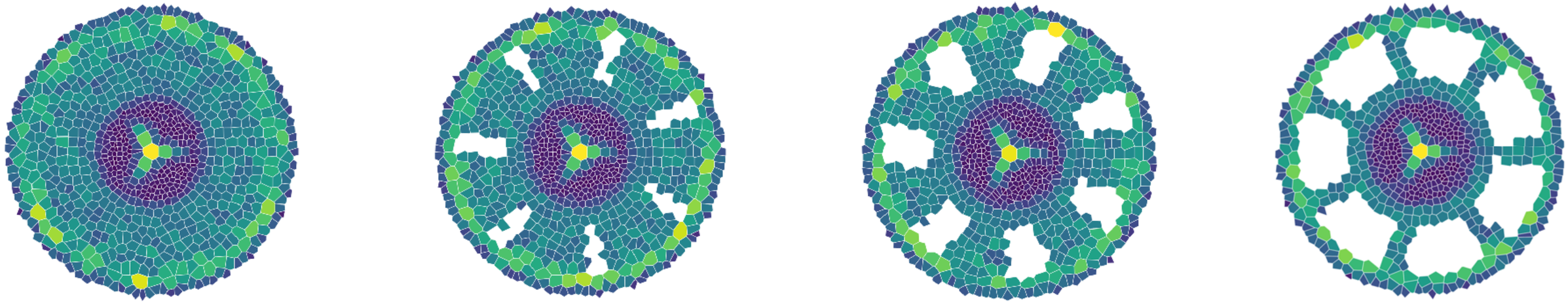


CONNECTING THE DOTS...

BETWEEN **COMPUTATIONAL** TOOLS TO ANALYSE SOIL–ROOT **WATER** RELATIONS

Guillaume Lobet, Valentin Couvreur, Xavier Draye, Mathieu Javaux, Daniel Leitner, Félicien Meunier, Sixtine Passot, Andrea Schnepf, Jan Vanderborght

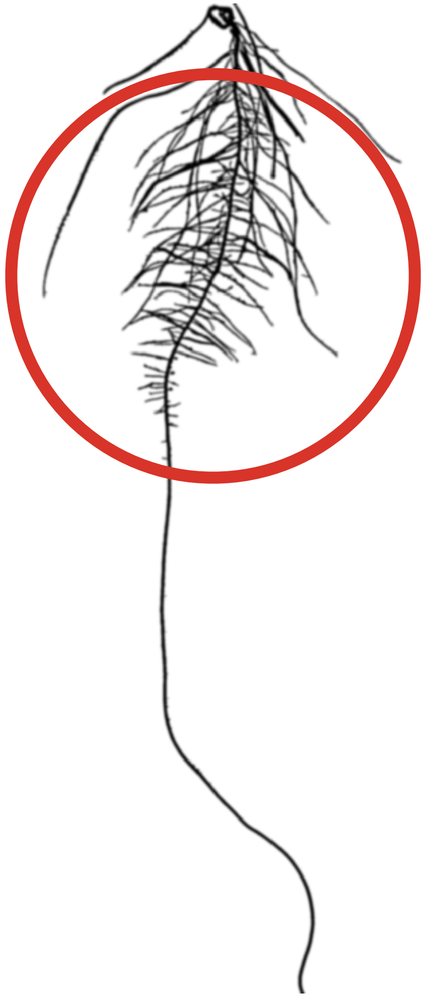
guillaumelobet

bit.ly/lobet-cis

Crops *in silico*

UCL Université catholique de Louvain

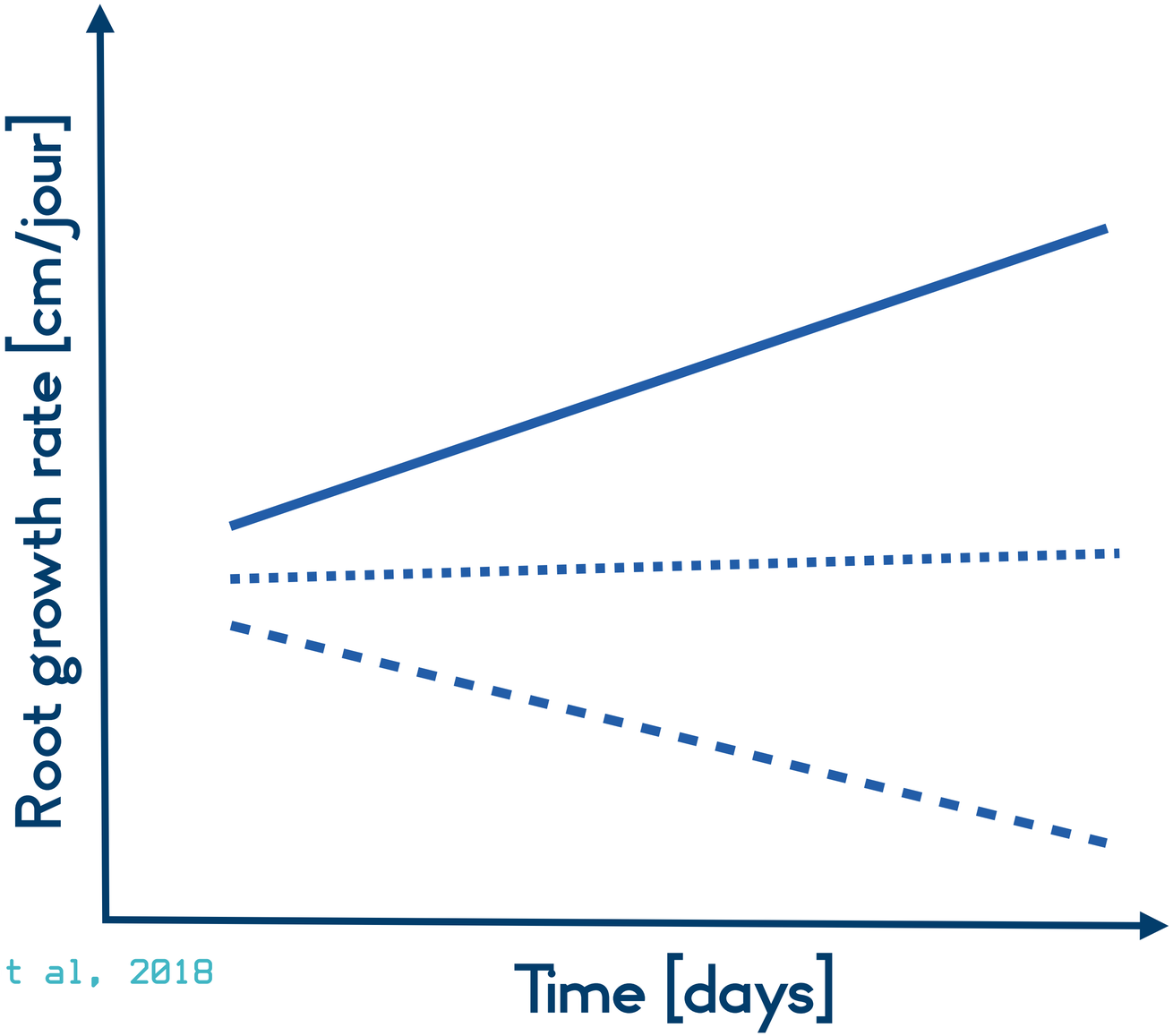
JÜLICH Forschungszentrum

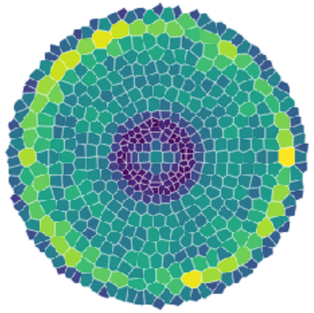


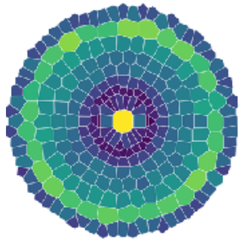
ROOT SYSTEMS
ARE **COMPLEX**
& GET **MESSY**
REALLY **QUICKLY**!

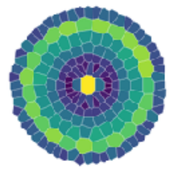
LATERAL ROOT CAN HAVE **DIFFERENT BEHAVIOURS**

Sixtine
Passot

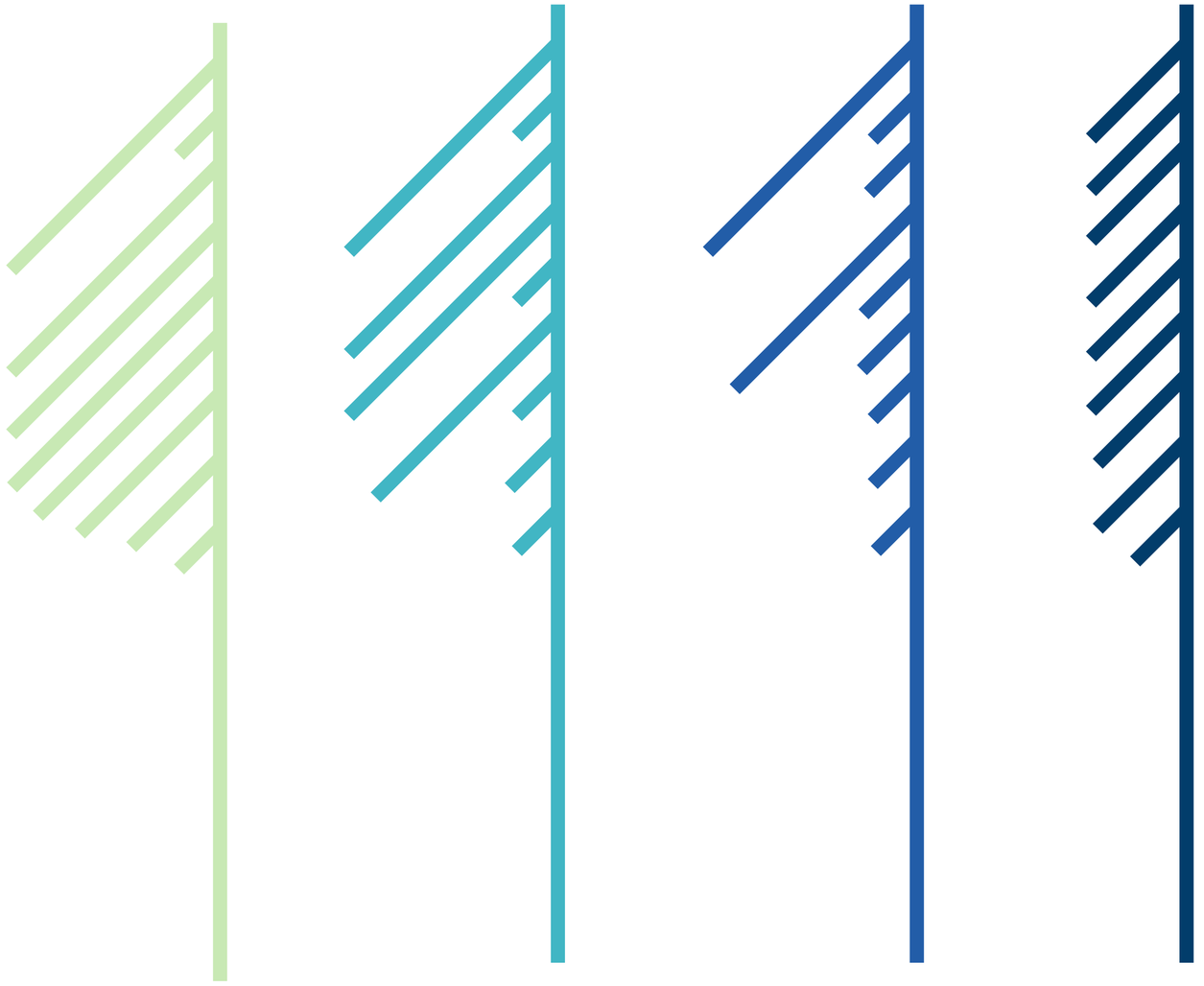




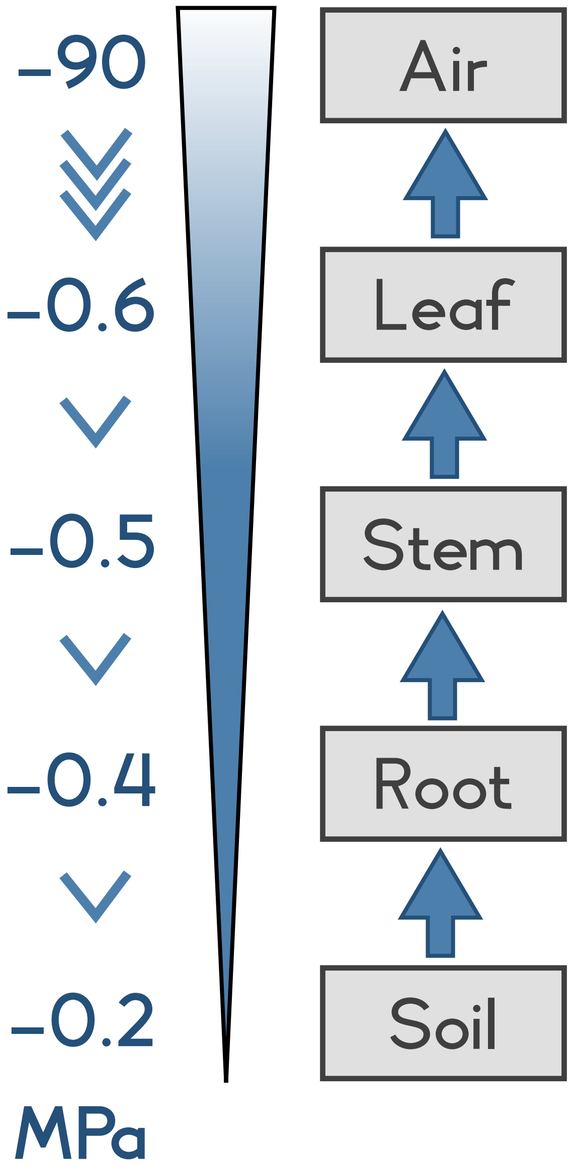


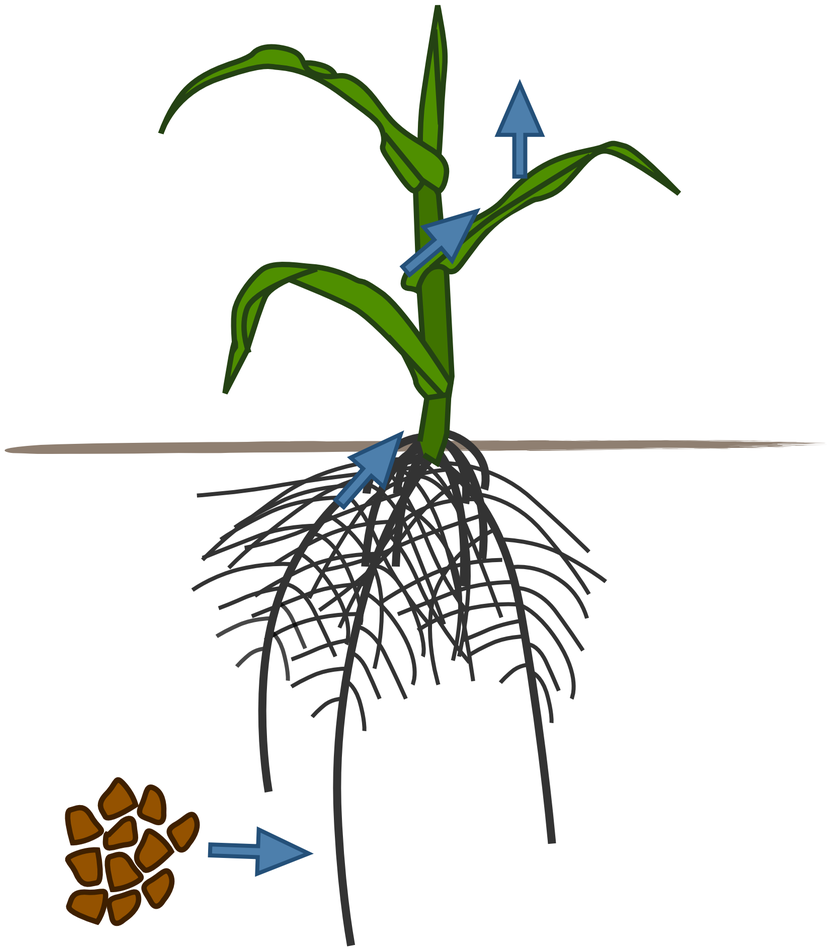


Passot, Moreno et al, 2018
PMID: 29752308



WHAT IS THE **FUNCTIONAL ADVANTAGE** OF HAVING DIFFERENT LATERAL ROOT TYPES?





WATER FLOW IN THE SOIL–**PLANT**–ATMOSPHERE IS A **PASSIVE** PROCESS

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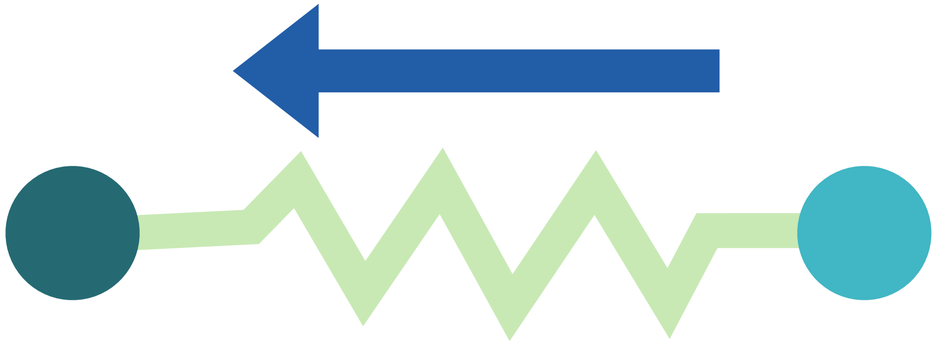
$$FLUX = \Delta P \cdot K$$



−0.6 MPA

−0.5 MPA

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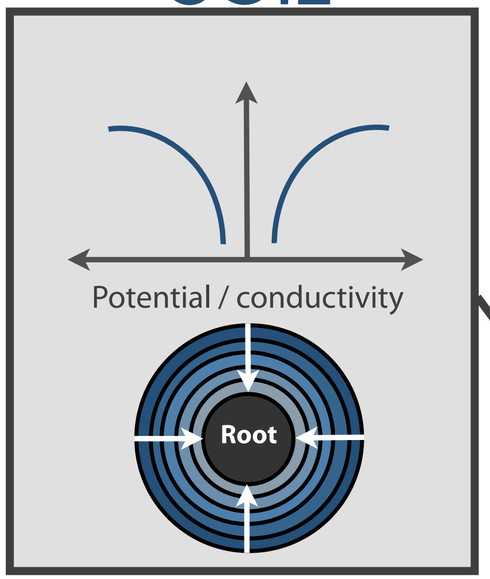
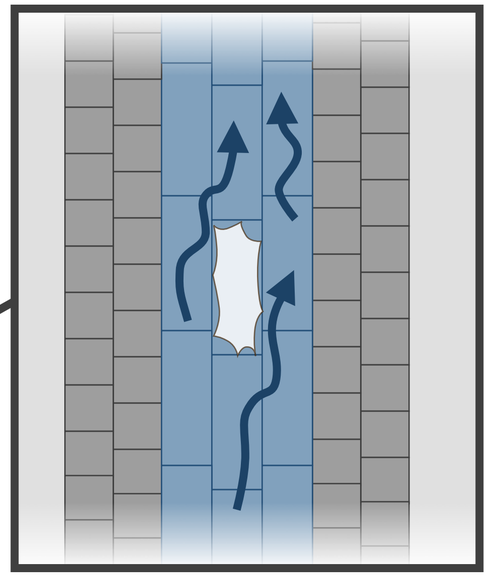
CONDUCTIVITIES CAN BE **REGULATED**

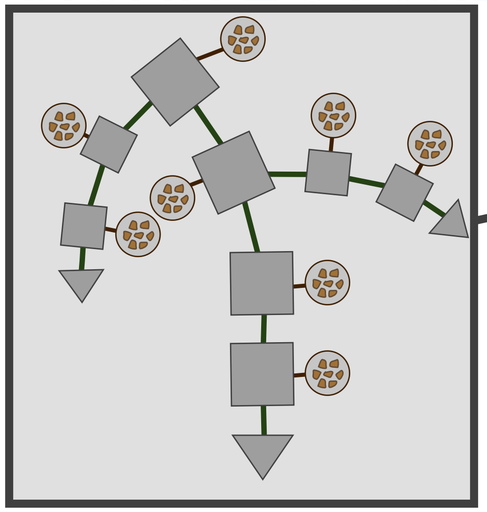
SOIL

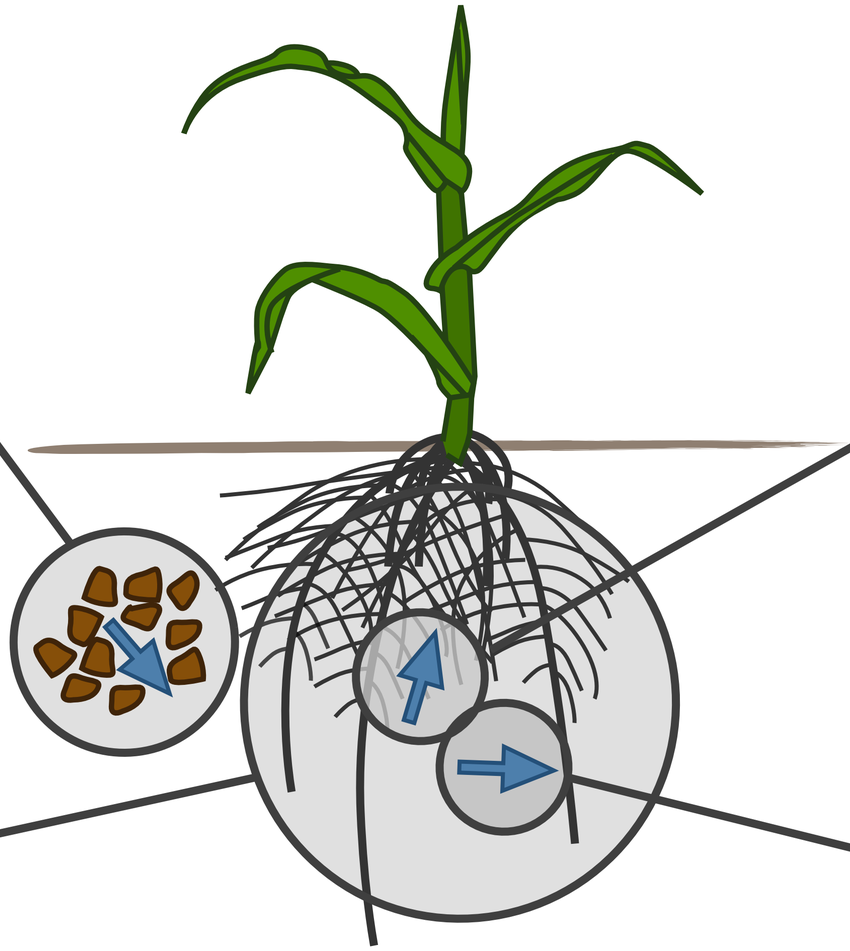


AXIAL CONDUCTIVITY

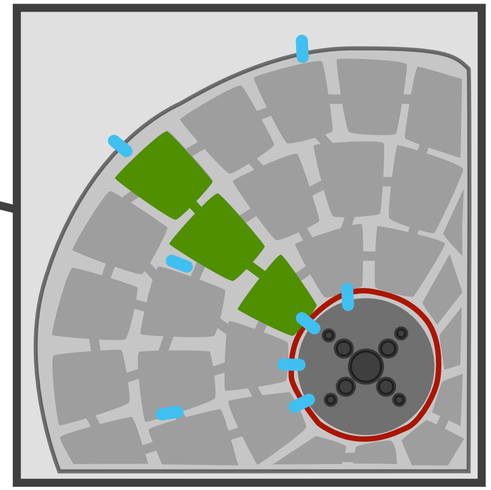


ARCHITECTURE





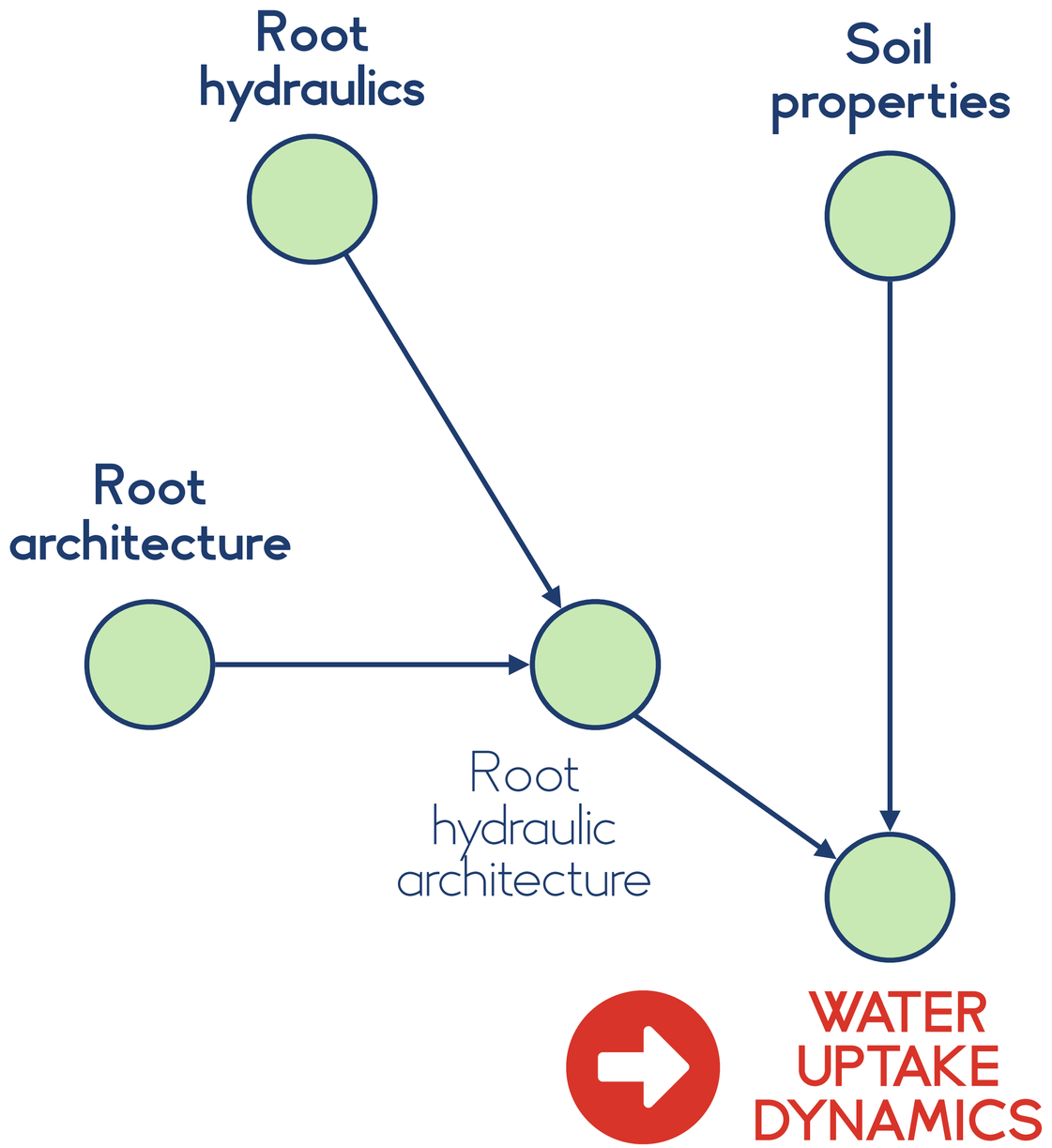
RADIAL CONDUCTIVITY



Lobet et al 2014
PMID: 24515834

JÜLICH
Forschungszentrum

VARIABLES NEEDED TO UNDERSTAND WATER FLOW IN THE SOIL–PLANT SYSTEM



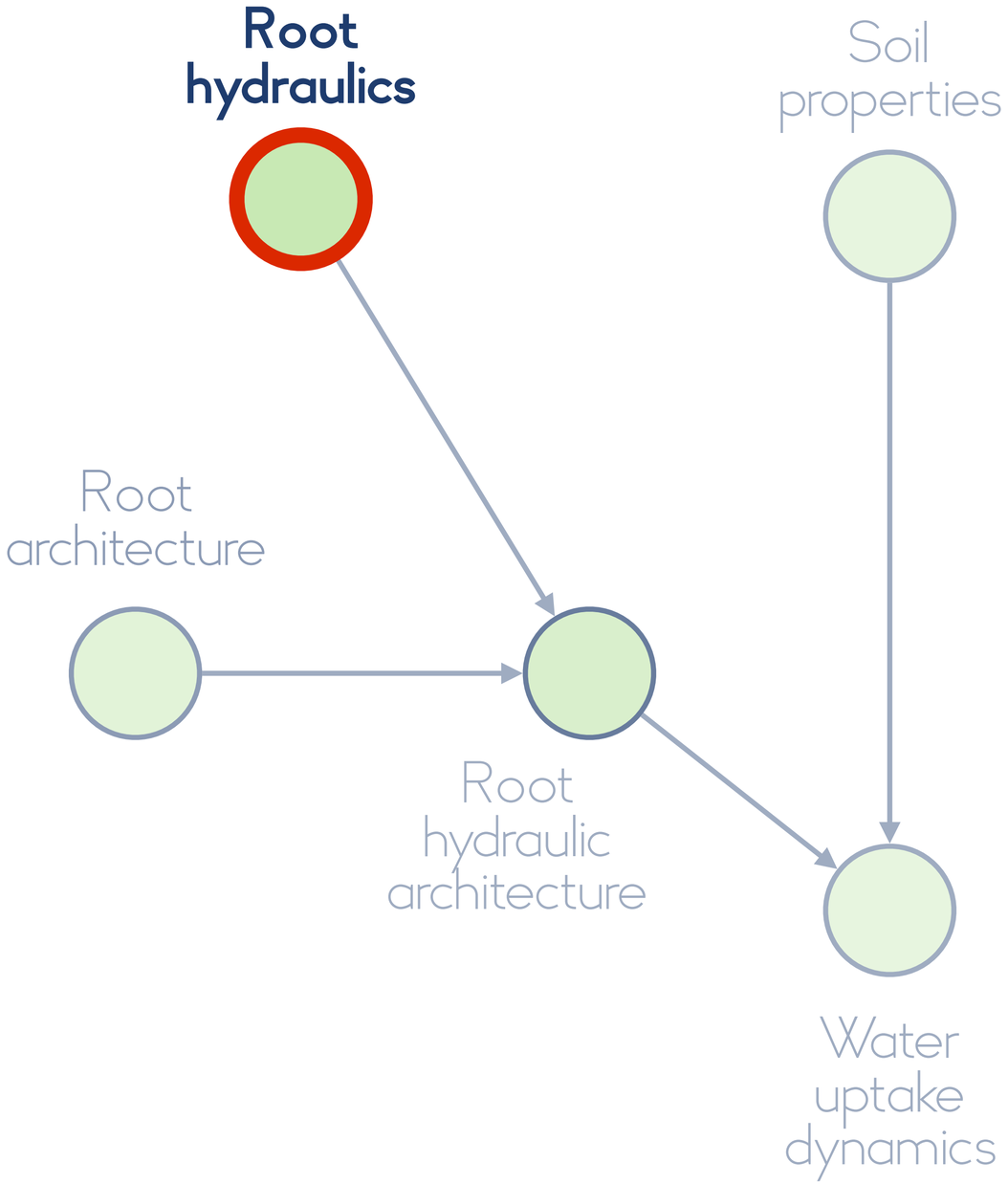
1

ROOT HYDRAULICS

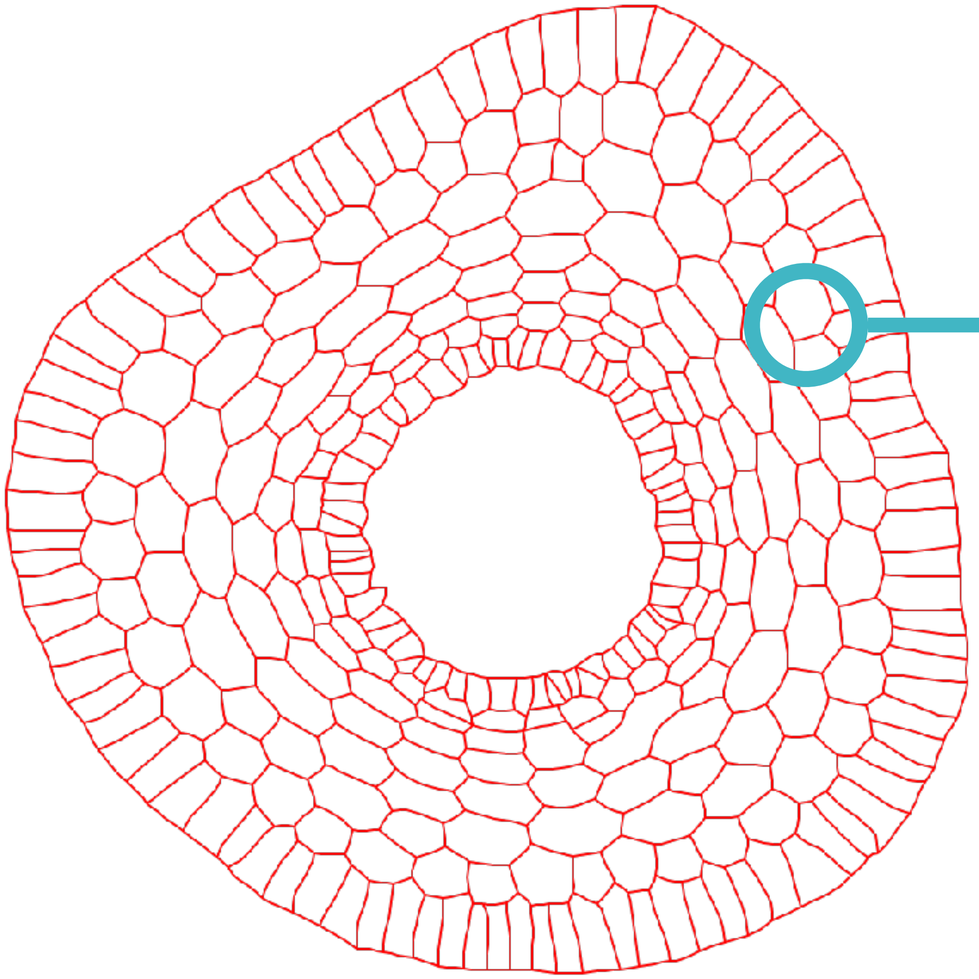
Xavier
Draye

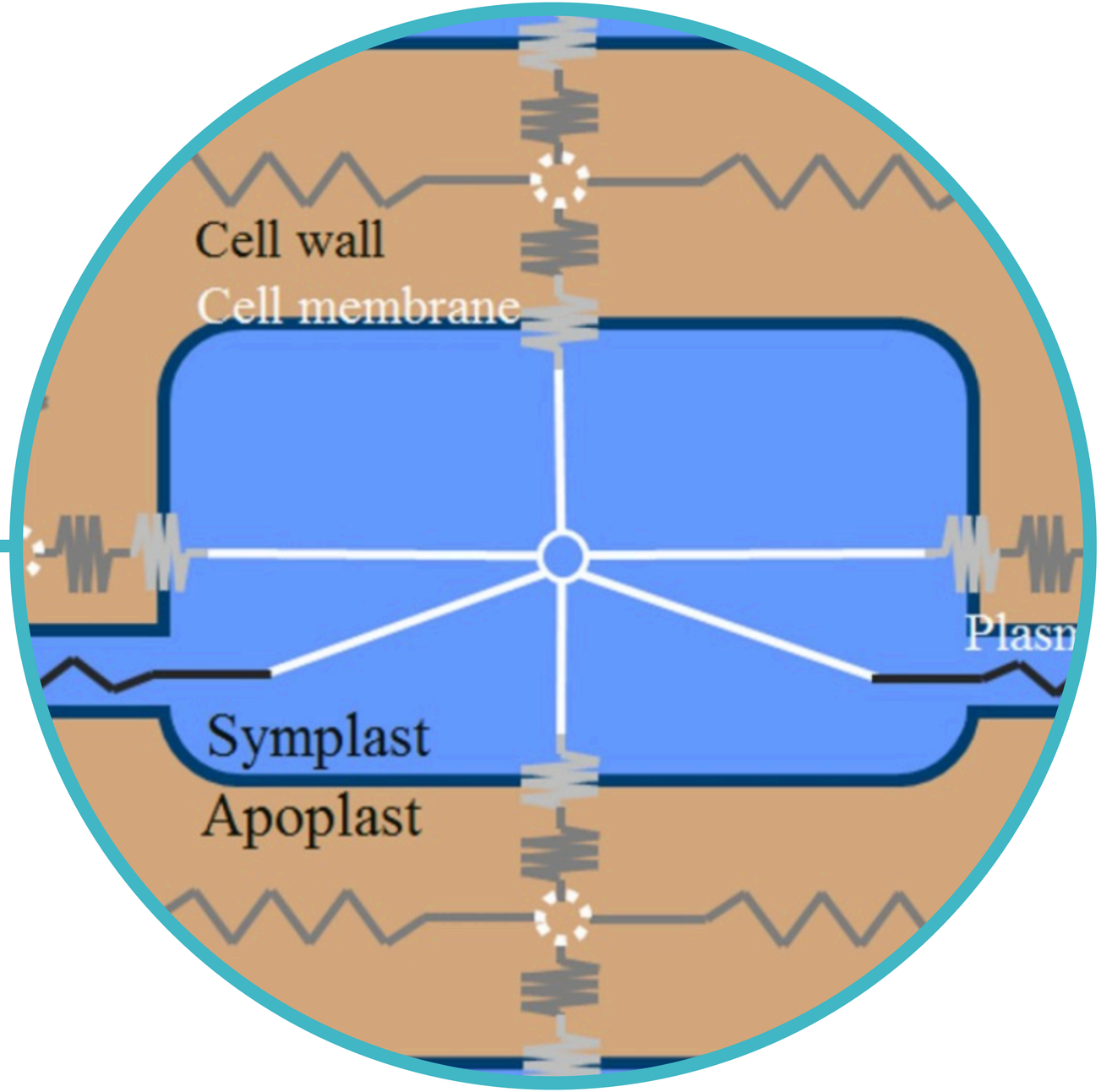
Valentin
Couvreur

Guillaume
Lobet



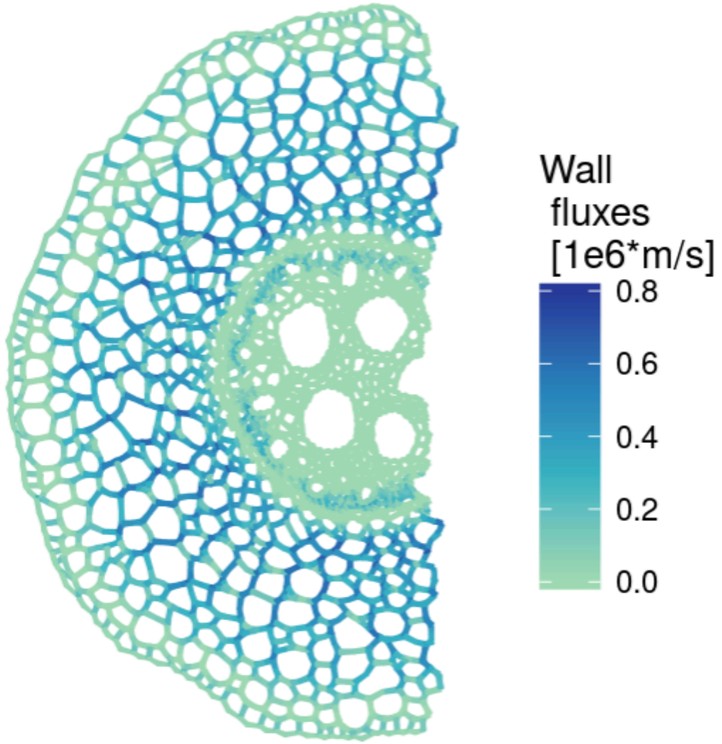
ROOT **ANATOMY** + **CONDUCTIVITIES**



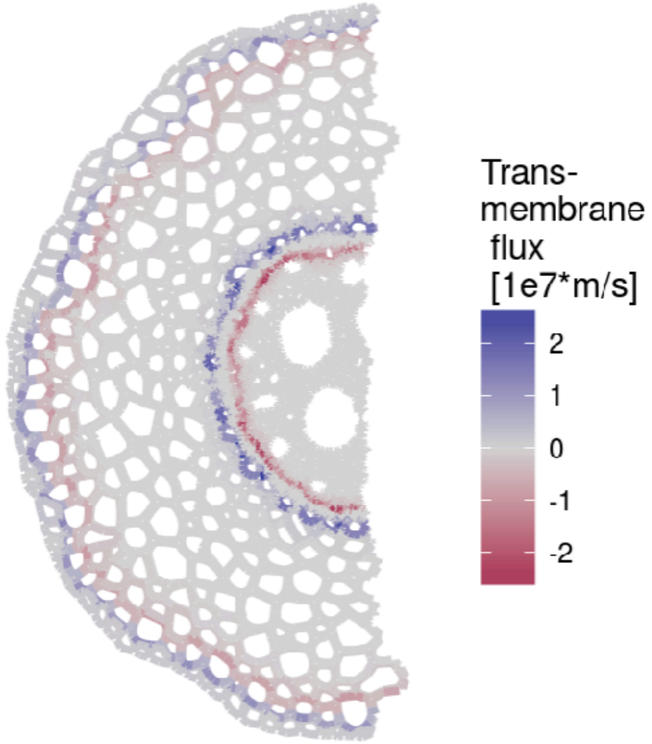


MODELLING **WATER** FLOW AT THE **ORGAN** SCALE

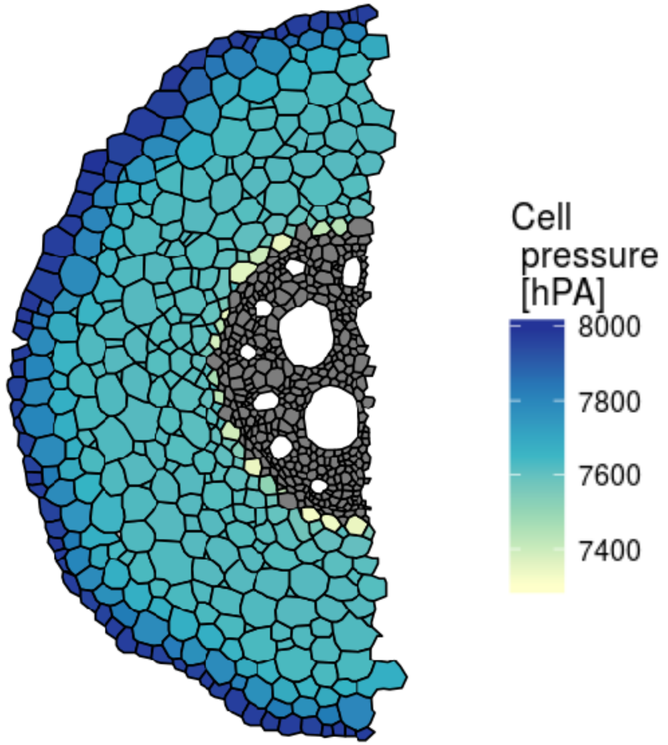
– MECHA –



FLUXES IN
CELL WALLS



FLUXES IN
CELL MEMBRANES



PRESSURES IN
CELLS

RADIAL CONDUCTIVITY+ **AXIAL** CONDUCTIVITY

MECHA - Model of Explicit Cross-section Hydraulic Anatomy

Valentin Couvreur, Marc Saget, Guillaume Lobet, Mathieu Javaux, François Chaumont and Xavier Draye

Université catholique de Louvain, Forschungszentrum Juelich GmbH

Choose plant | Change parameters | About

Choose a simulation to visualize

1. Select a plant type

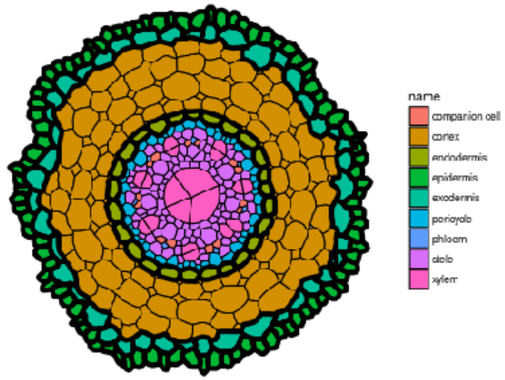
MilletPR1

MECHA was run for different cross section geometries and plant type. Te results were pre-processed to be easily visualised here.

UCL Université catholique de Louvain — JÜLICH FORSCHUNGSZENTRUM

Tissue layers

Visualisation of the different cell layers used in the simulation



Select the information to visualize

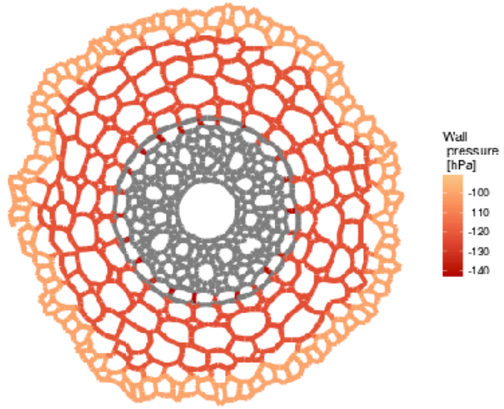
potentials

Synthetic information about the simulation

param	value	unit
Cross-section height	0.008	cm
Cross-section perimeter	0.0863	cm
Cross-section radial conductivity	2.93e-04	cm/hPa/d
Xylem pressure potential	1100	hPa
Soil pressure potential	-100	hPa
Xylem osmotic potential	-1500	hPa
Soil osmotic potential	-200	to
Soil contact	0e+00	microns
Wall conductivity	0.0066	cm^2/hPa/d
Plasmodesmata conductivity	3.1e-11	cm^3/hPa/d
Aquaporin conductivity	4.3e-04	cm/hPa/d
Cortex osmotic potential	-8000	hPa

Cell walls pressure

Pressure within the cell walls of the cross section



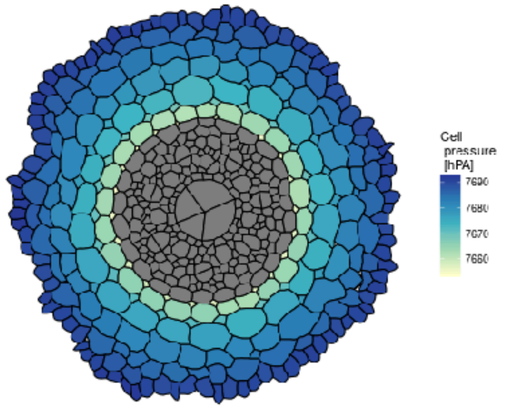
Display range:

-142.25 — -90.01 | 1,139

-151 -22.1 106.8 235.7 364.6 493.5 622.4 751.3 880.2 1,136

Cells potentials

Pressure within the cell of the cross section



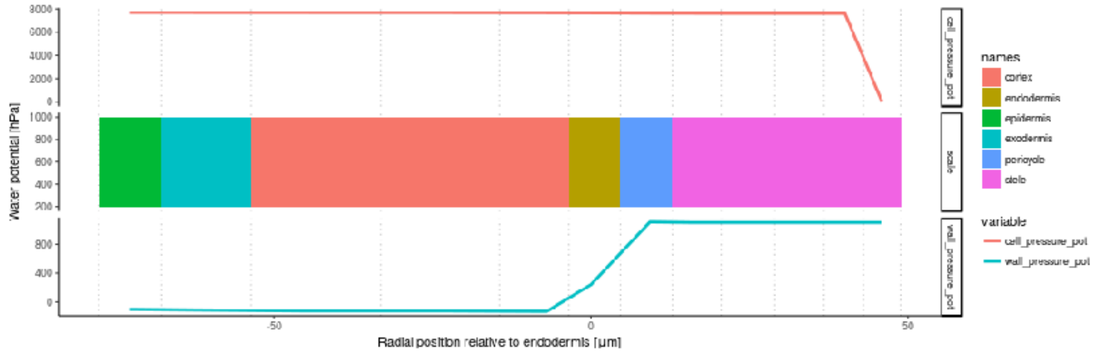
Display range:

1,101 | 7,654 — 7,693

1,101 2,419.4 3,737.8 5,056.2 6,374.6 7,693

Average cell and wall pressure

Visualisation of the average cell and wall pressure across the cross-section

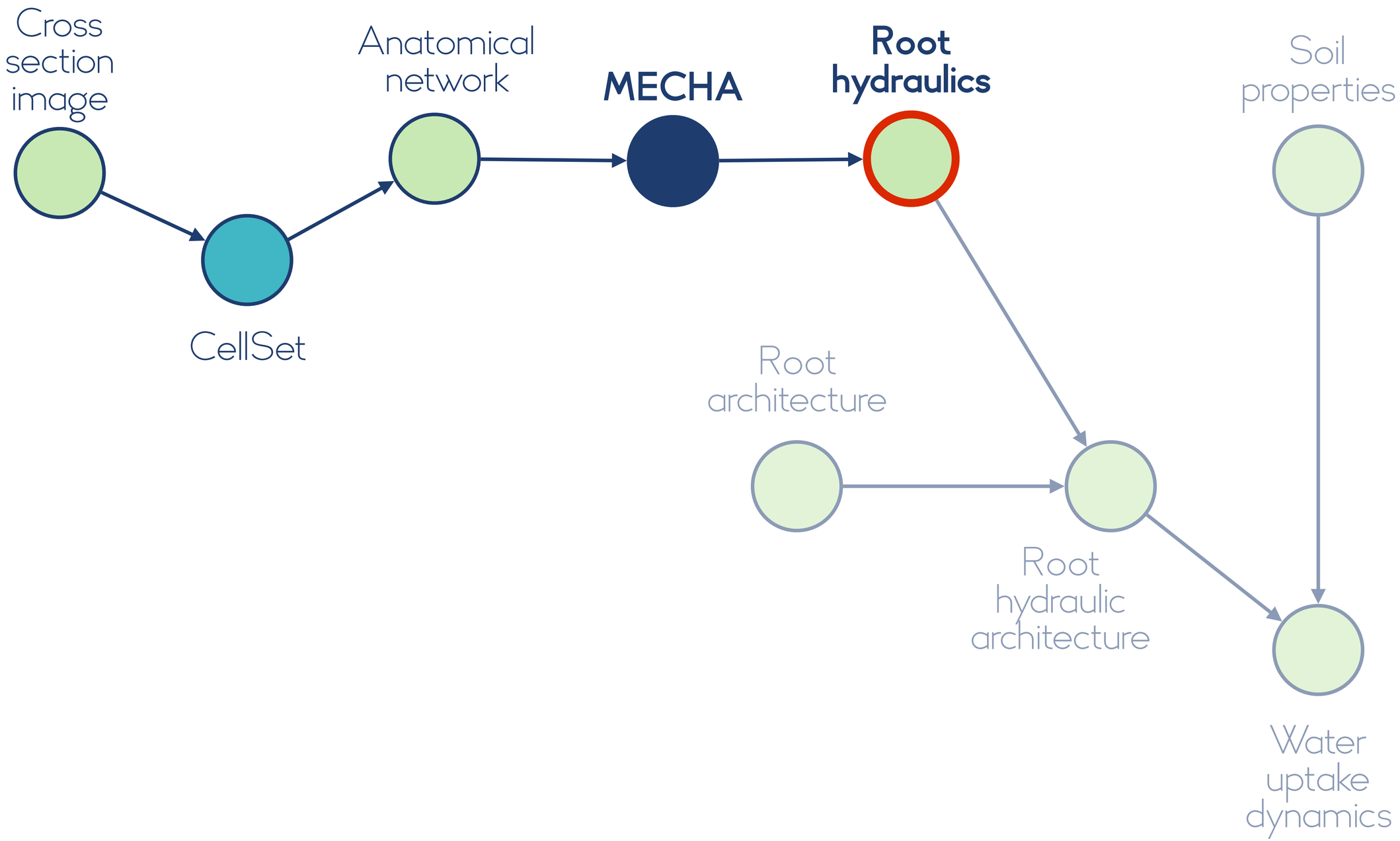


Open Source

mecharoot.github.io

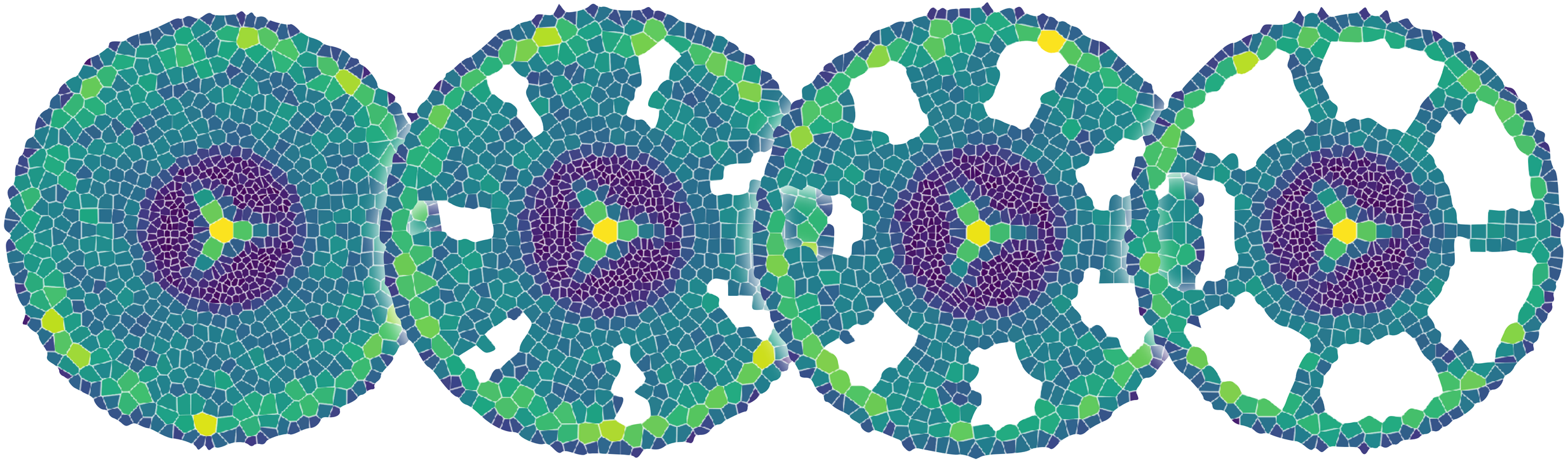
Couvreur et al, 2017
DOI: 10.1101/147314

JÜLICH Forschungszentrum


Cross section image
CellSet
Anatomical network
MECHA
Root hydraulics
Soil properties
Root architecture
Root hydraulic architecture
Water uptake dynamics

GENERATOR OF ANY TYPE OF ROOT ANATOMY

– GRANAR –

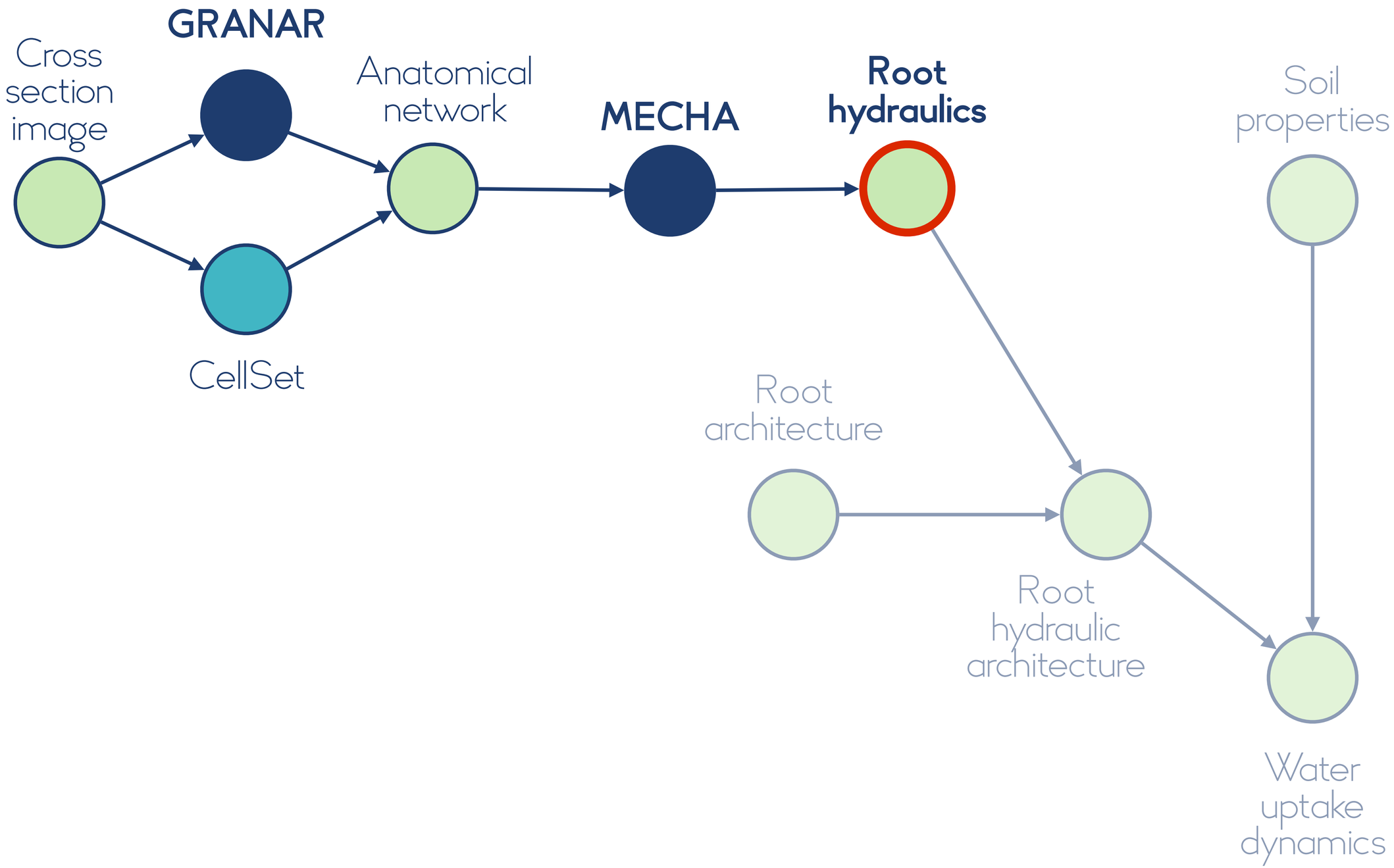


XYLEM POLES / CORTEX / AERENCHYMA / ...

Open Source

bit.ly/granar-root

JÜLICH
Forschungszentrum

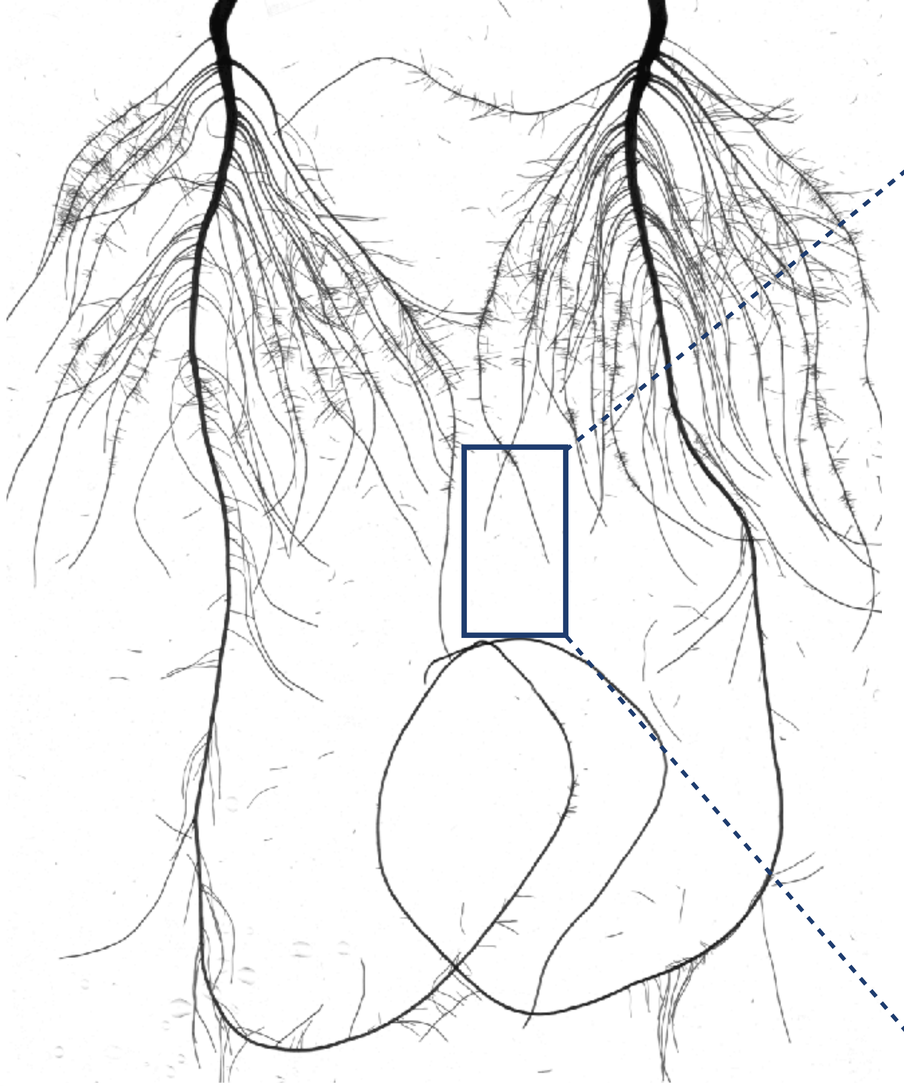

GRANAR
Cross section image
CellSet
Anatomical network
MECHA
Root hydraulics
Soil properties
Root architecture
Root hydraulic architecture
Water uptake dynamics

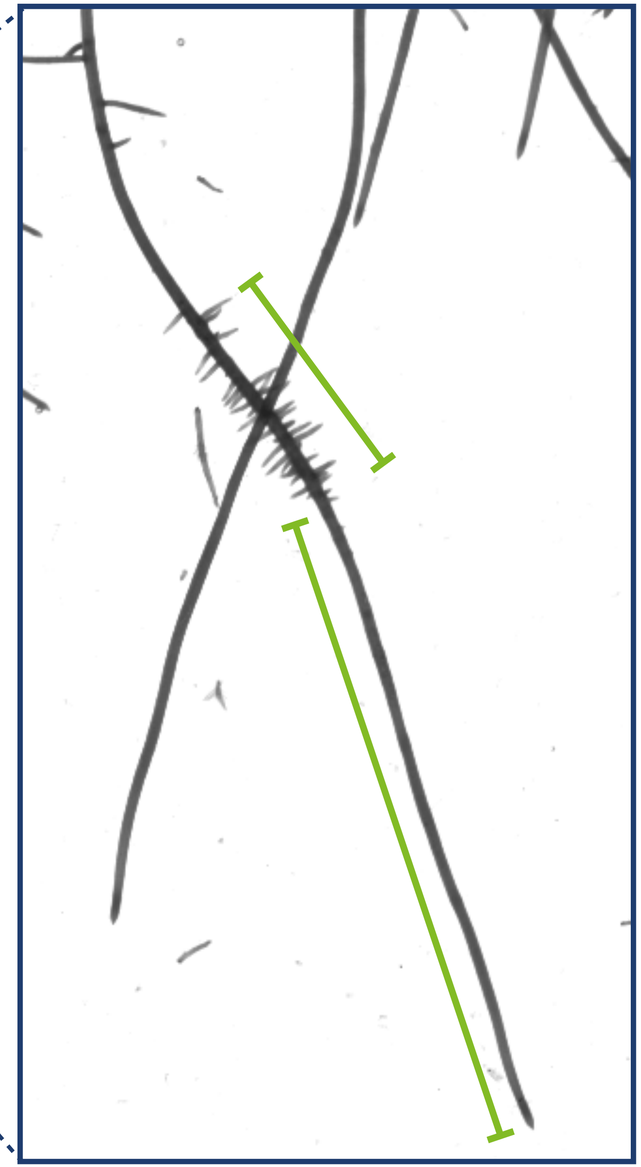
2 ROOT SYSTEM ARCHITECTURE

Andrea **Schnepf**

Daniel **Leitner**

Guillaume **Lobet**





SAMPLE
THE IMAGE

PARAMETERS
FOR ROOT
MODEL

Open Source

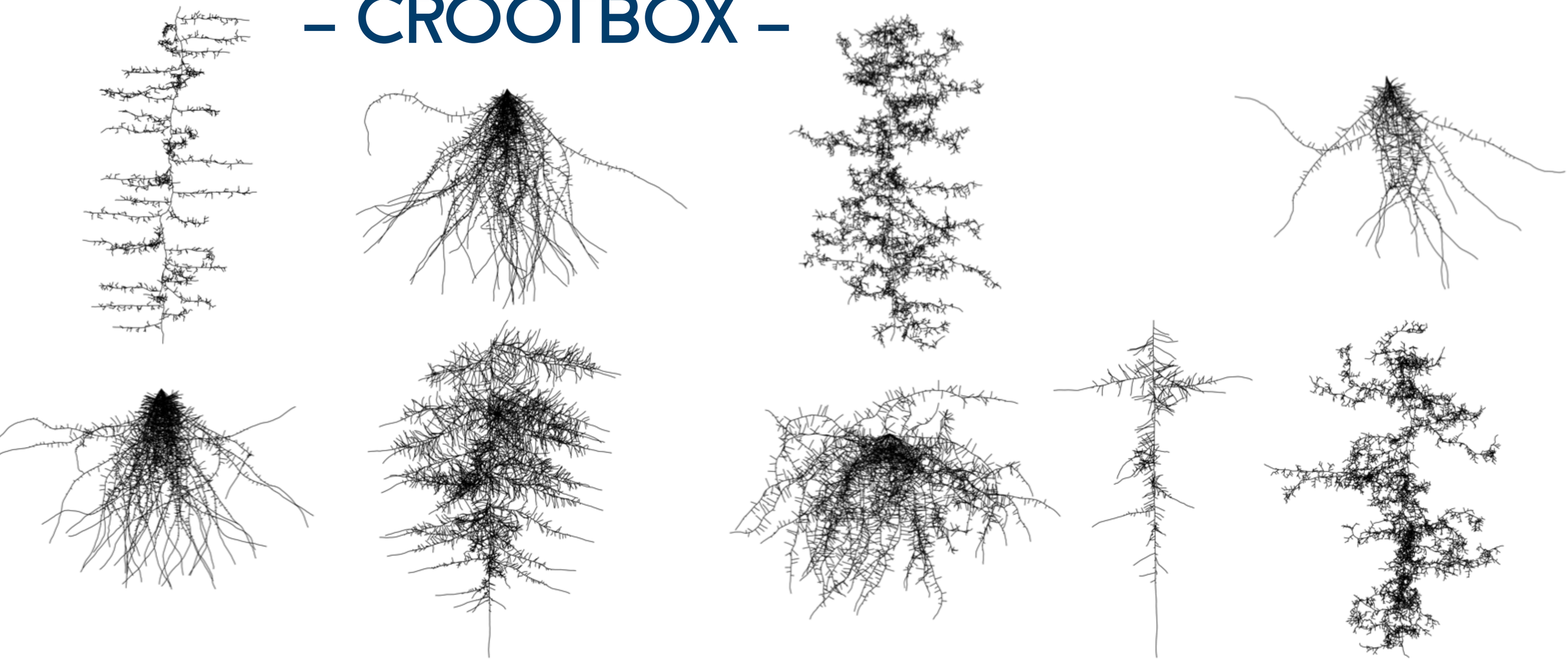
smartroot.github.io

Lobet et al, 2011
PMID: 21771915

– SMARTROOT –

JÜLICH
Forschungszentrum

– CROOTBOX –



"SMALL" SET OF PARAMETERS

SIMULATE ANY TYPE OF **ROOT ARCHITECTURE**

JÜLICH
Forschungszentrum

CRootBox

This app displays the capabilities of the CRootBox model. Choose a dataset, unleash CRootBox, then try changing the parameters.

Daniel Leitner, Guillaume Lobet, Magdalena Landl, Mirjam Zorner, Shehan Morandage, Trung Hieu Mai, Cheng Sheng, Jan Vanderborgth, Andrea Schnepf

Forschungszentrum Juelich GmbH

1. Load parameter set

1. Select root system dataset

Brassica napus a

The algorithmic beauty of plant roots – an L-System model for dynamic root growth simulation
Leitner D, Klepsch S, Knieß A, Schnepf A
Mathematical and Computer Modelling of Dynamical Systems, 16, 575-587, 2010
View paper

Black and white root system

Unleash CRootBox

2. Update parameters

2. Select root type

taproot

Select parameter to change

Length of basal zone [cm]

Parameter mean:

0 4 8
0 0.8 1.6 2.4 3.2 4 4.8 5.6 6.4 7.2 8

Parameter deviation [%]:

0 5 50
0 5 10 15 20 25 30 35 40 45 50

Length of basal zone [cm]
Length of the unbracnhed basal zone of the root

3. Select plant parameter to change

Planting depth [cm]

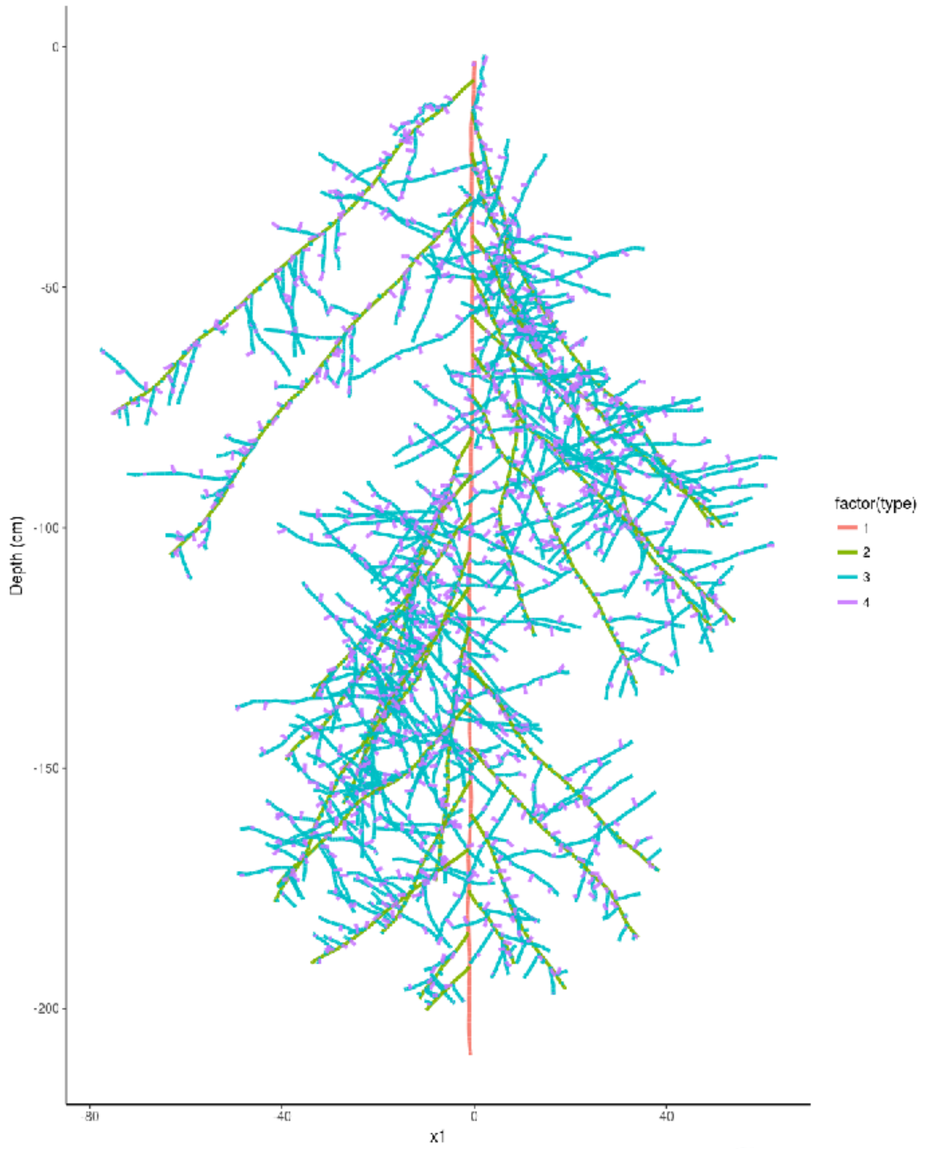
Parameter value:

0 3 6
0 0.6 1.2 1.8 2.4 3 3.6 4.2 4.8 5.4 6

Planting depth [cm]
The depth, in cm, at which the seed is placed in the soil

Update root system

Root system representation | Root length profile



Open Source

bit.ly/crootbox

Schnepf et al, 2018
PMID: 29432520

JÜLICH
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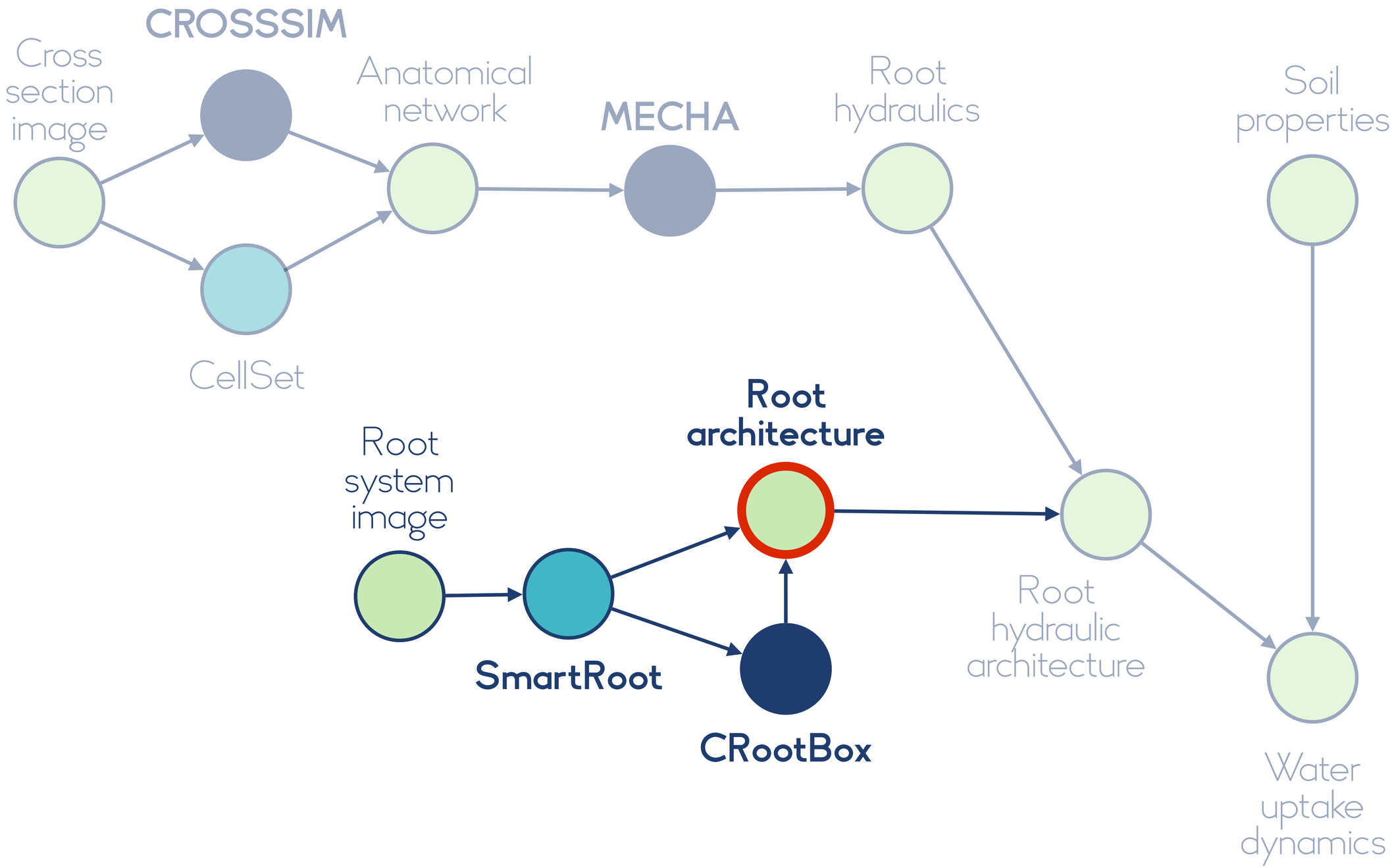
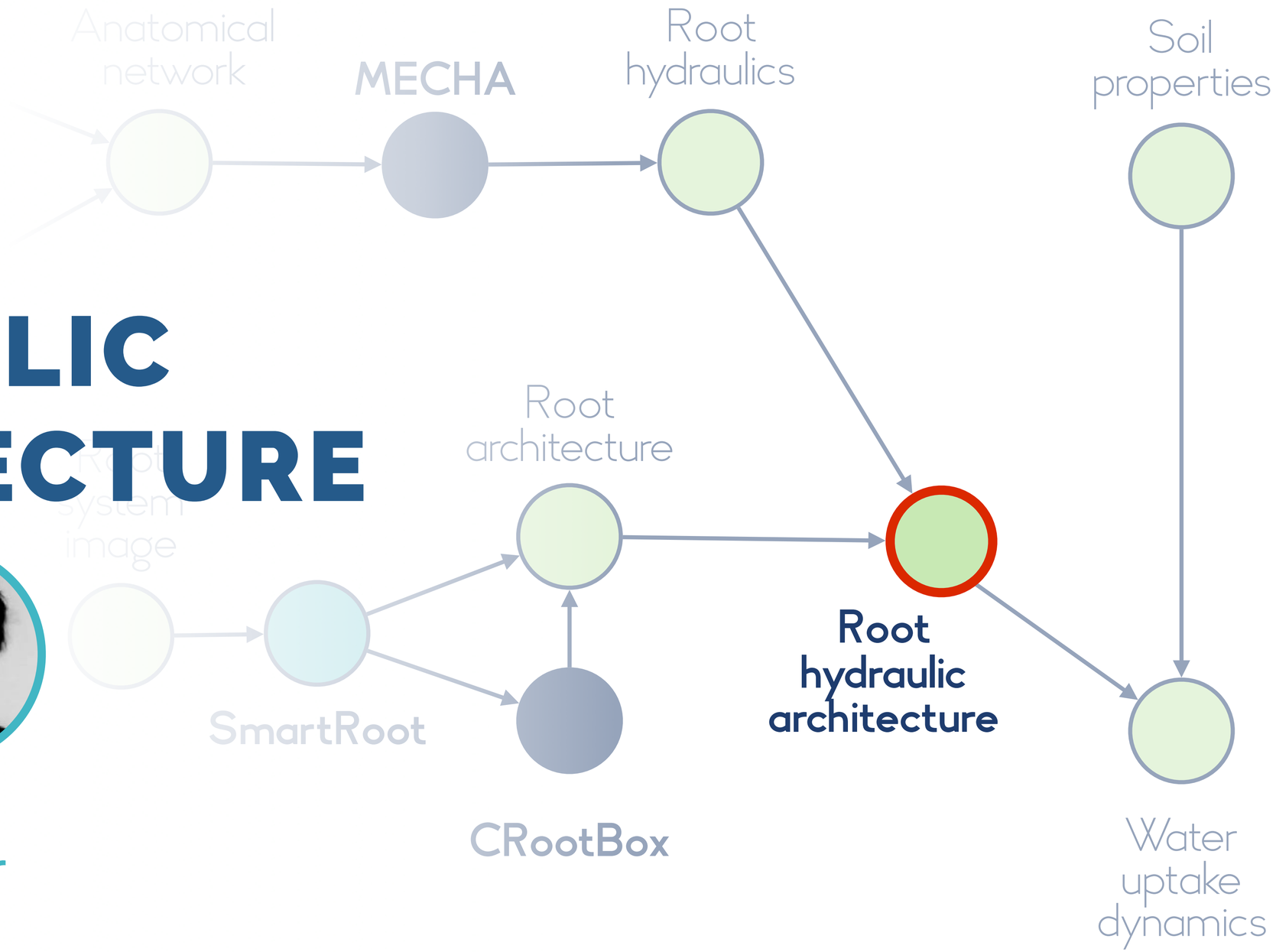

CROSSSIM
Cross section image
CellSet
Anatomical network
MECHA
Root hydraulics
Soil properties
Root system image
Root architecture
SmartRoot
CRootBox
Root hydraulic architecture
Water uptake dynamics

3

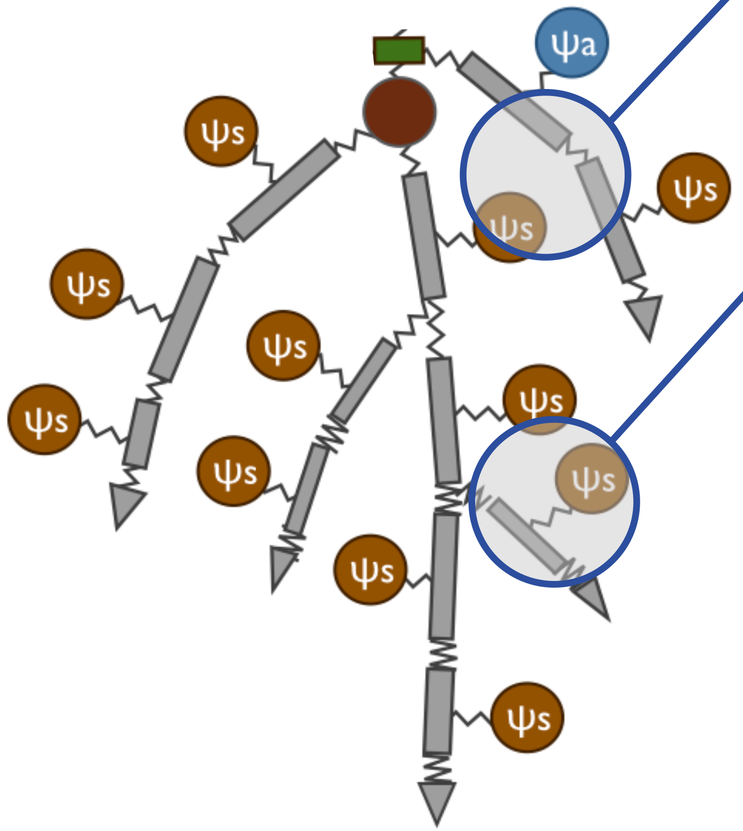
ROOT HYDRAULIC ARCHITECTURE

Mathieu
Javaux

Félicien
Meunier



ROOT SYSTEM + CONDUCTIVITIES = **HYDRAULIC ARCHITECTURE**



Axial flux

$J = Kx \cdot (Pr_1 - Pr_2)$

Radial flux

$J = Kr \cdot (Pr_1 - Psoil)$

FLUXES

ROOT SYSTEM CONDUCTIVITY [Krs]

JÜLICH Forschungszentrum

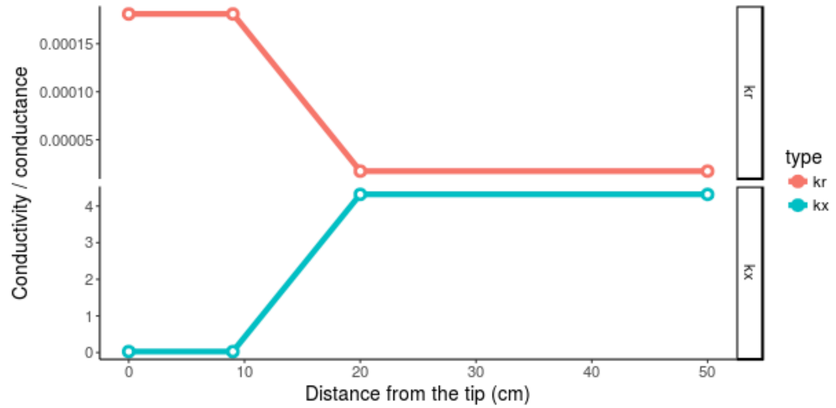
MARSHAL

Root architecture | Root conductivities | Environment

Root system representation | Root depth profile | Simulations evolution | Download data | About CRootBox

Select root type

Taproot



X value

Y value

What to display

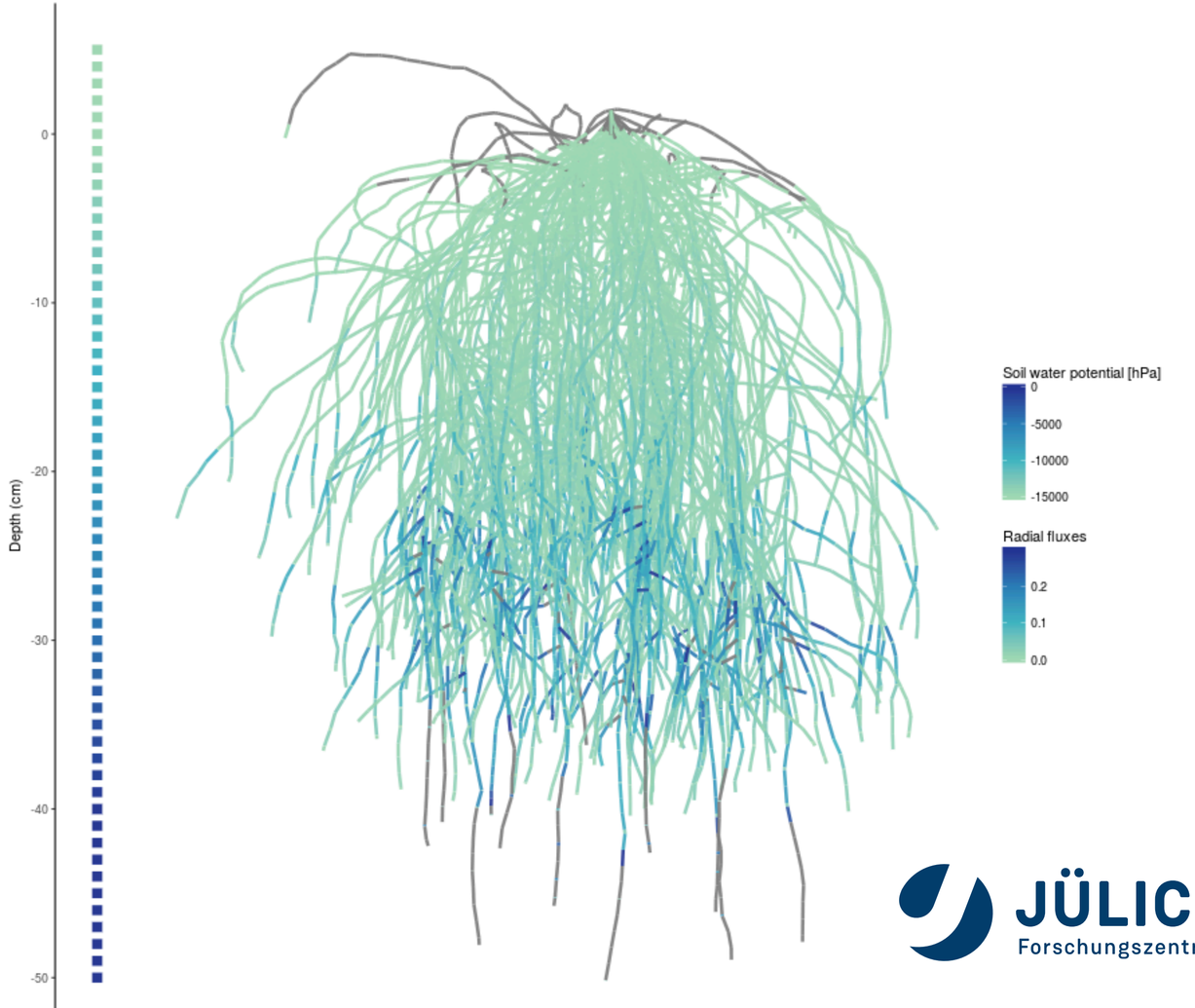
Radial fluxes

Taproot | LongLateral | Basalroot | Shootborneroot | Lateral

Display range:

0 | 0.3 | 1.9

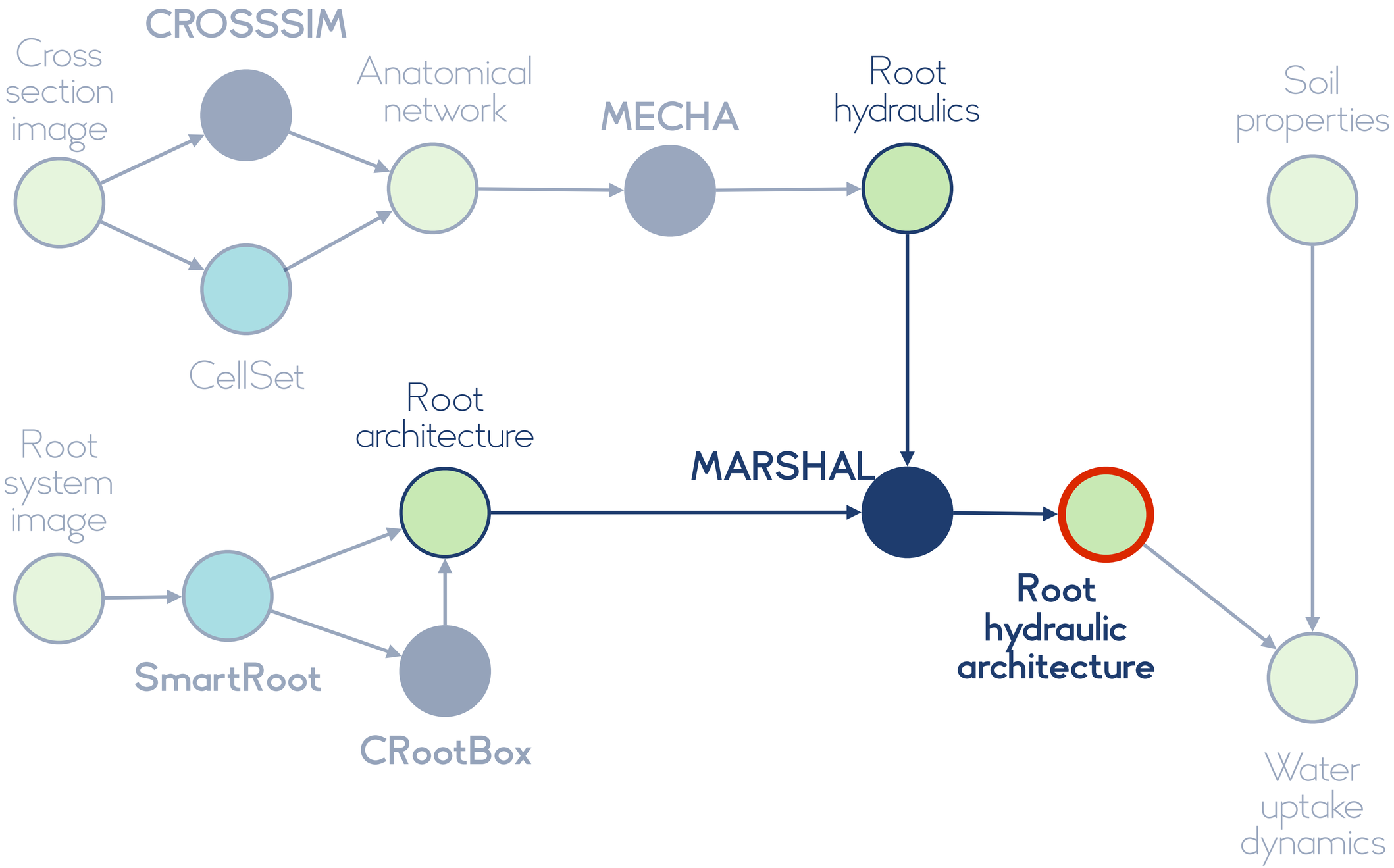
0 | 0.19 | 0.38 | 0.57 | 0.76 | 0.95 | 1.14 | 1.33 | 1.52 | 1.71 | 1.9



– MARSHAL –

bit.ly/marshal-root

JÜLICH Forschungszentrum


CROSSSIM
Cross section image
Anatomical network
MECHA
Root hydraulics
Soil properties
CellSet
Root system image
Root architecture
MARSHAL
Root hydraulic architecture
SmartRoot
CRootBox
Water uptake dynamics

4

WATER UPTAKE DYNAMICS

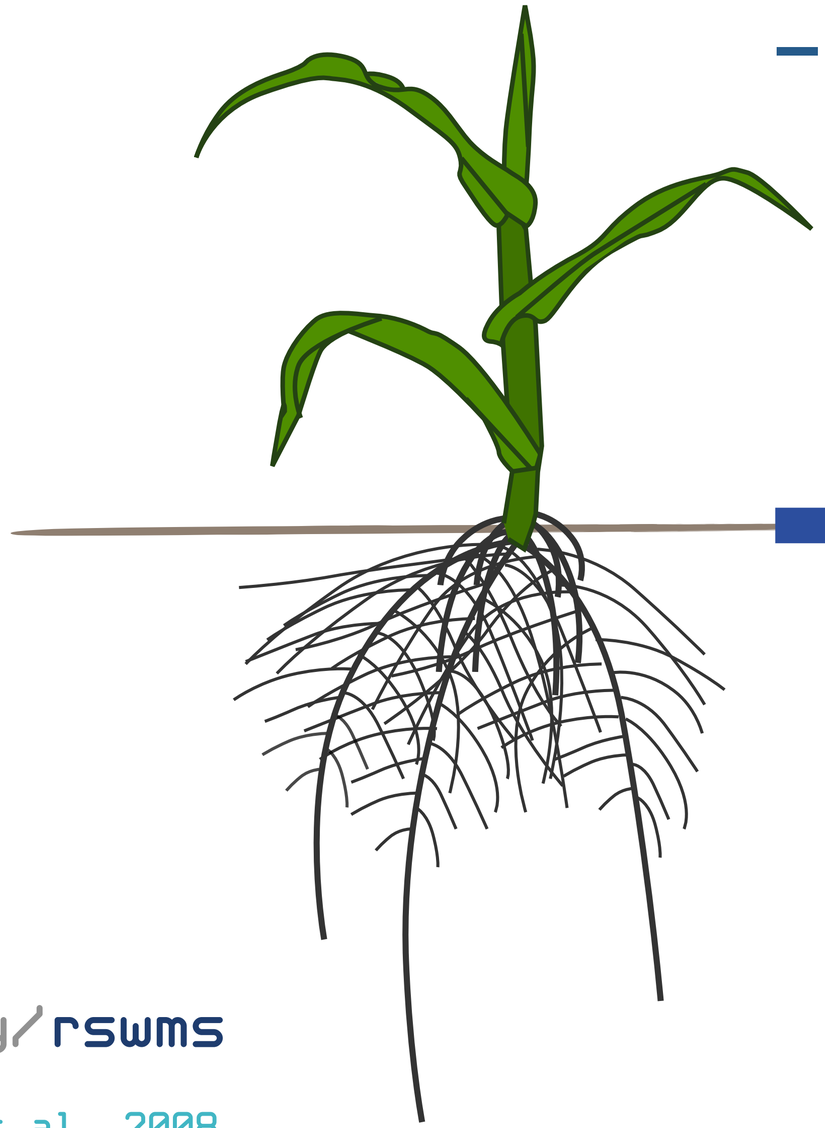
Mathieu
Javaux

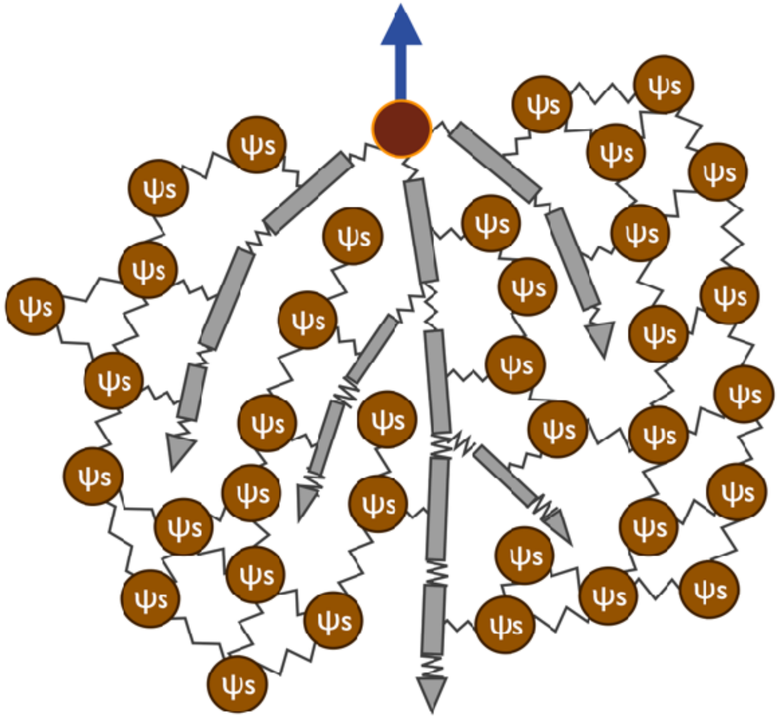
Félicien
Meunier

Valentin
Couvreur

MODELLING **SOIL-PLANT** WATER MOUVEMENT

– RSWMS –





bit.ly/rswms

Javaux et al, 2008
DOI: 10.2136/vzj2007.0115

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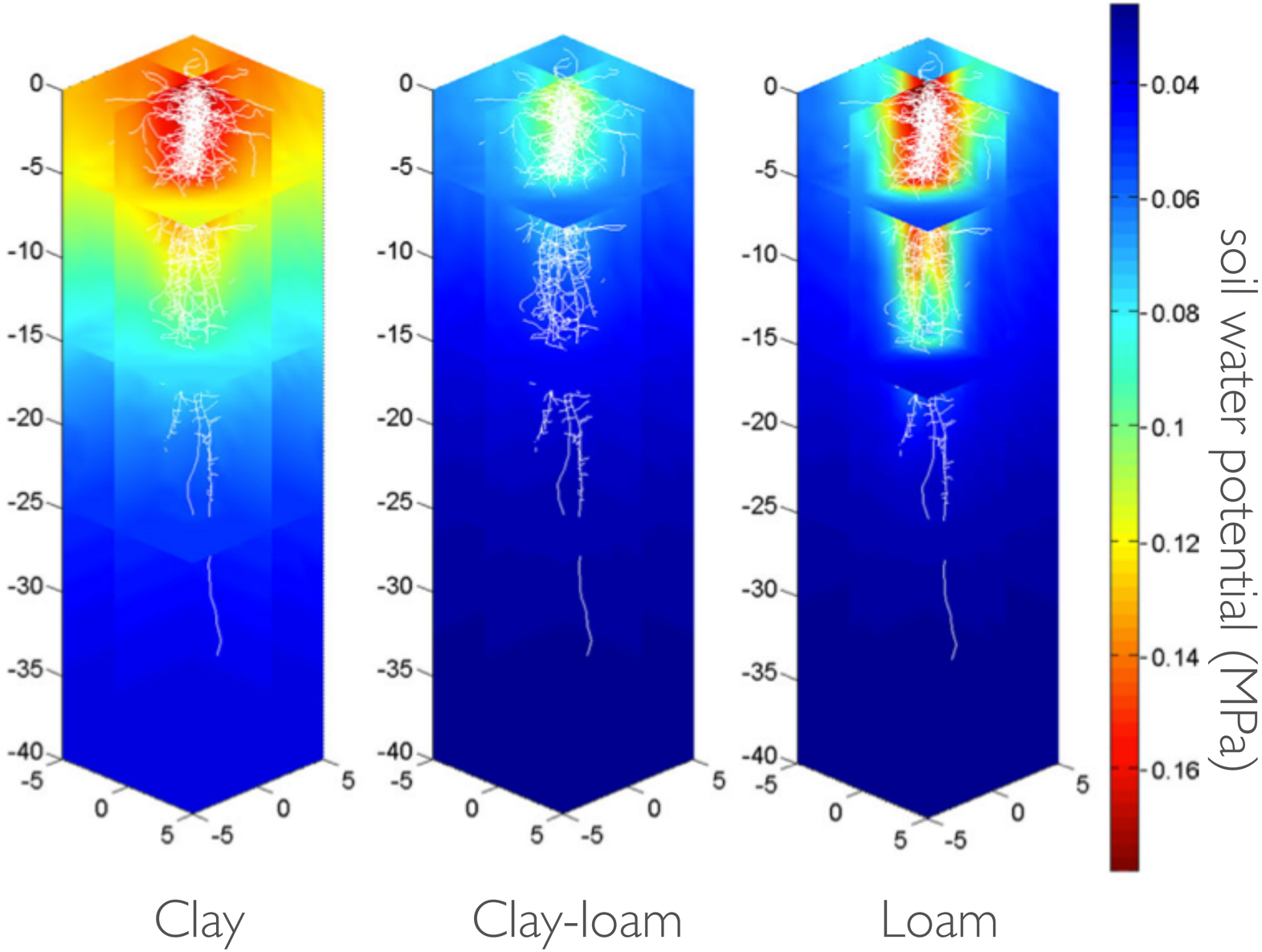
SOIL PROPERTIES SHAPE THE WATER UPTAKE

= ROOT ARCHITECTURE

= HYDRAULIC PROPERTIES

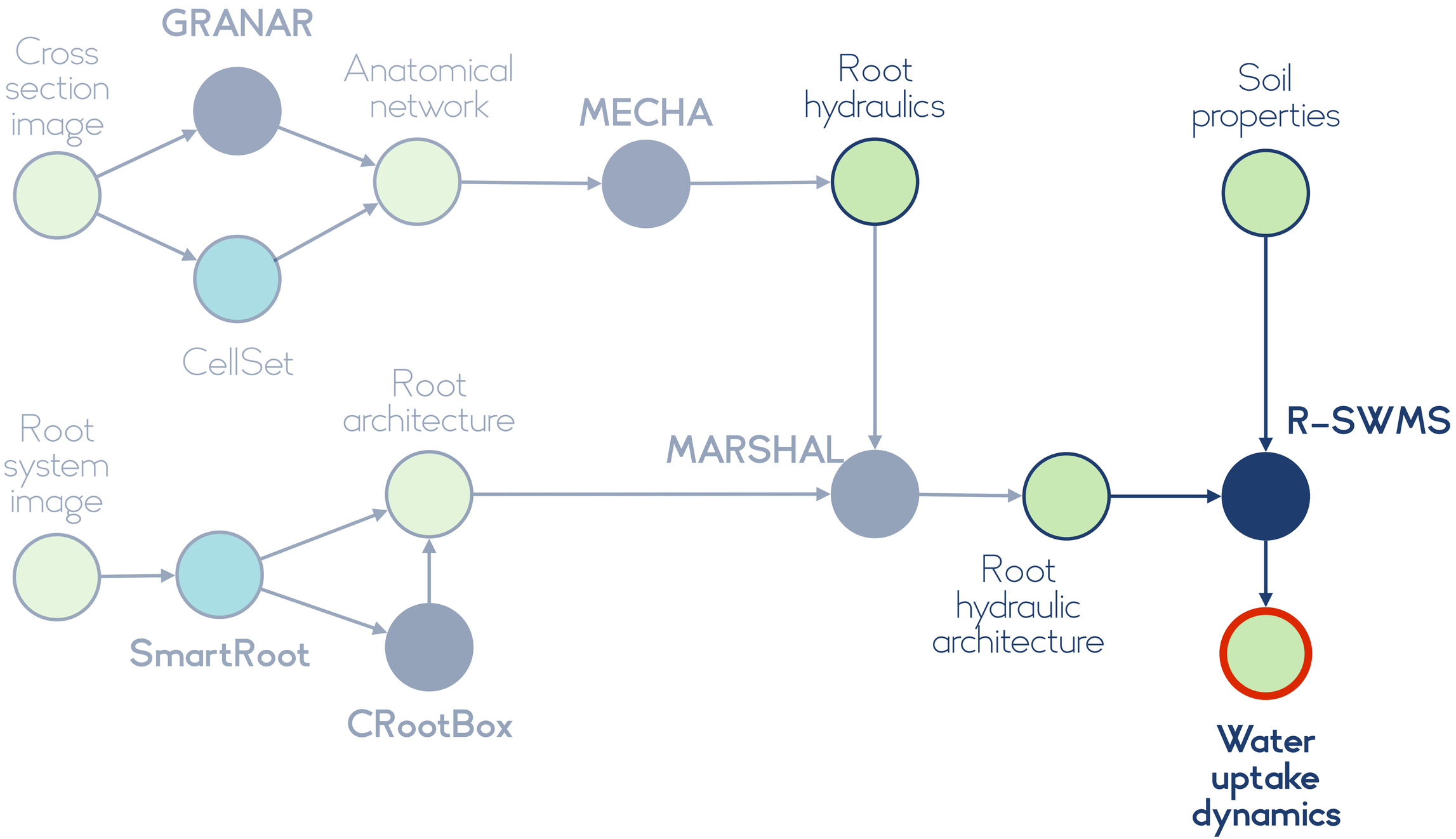
= INITIAL WATER CONTENT

DIFFERENT SOIL TYPES

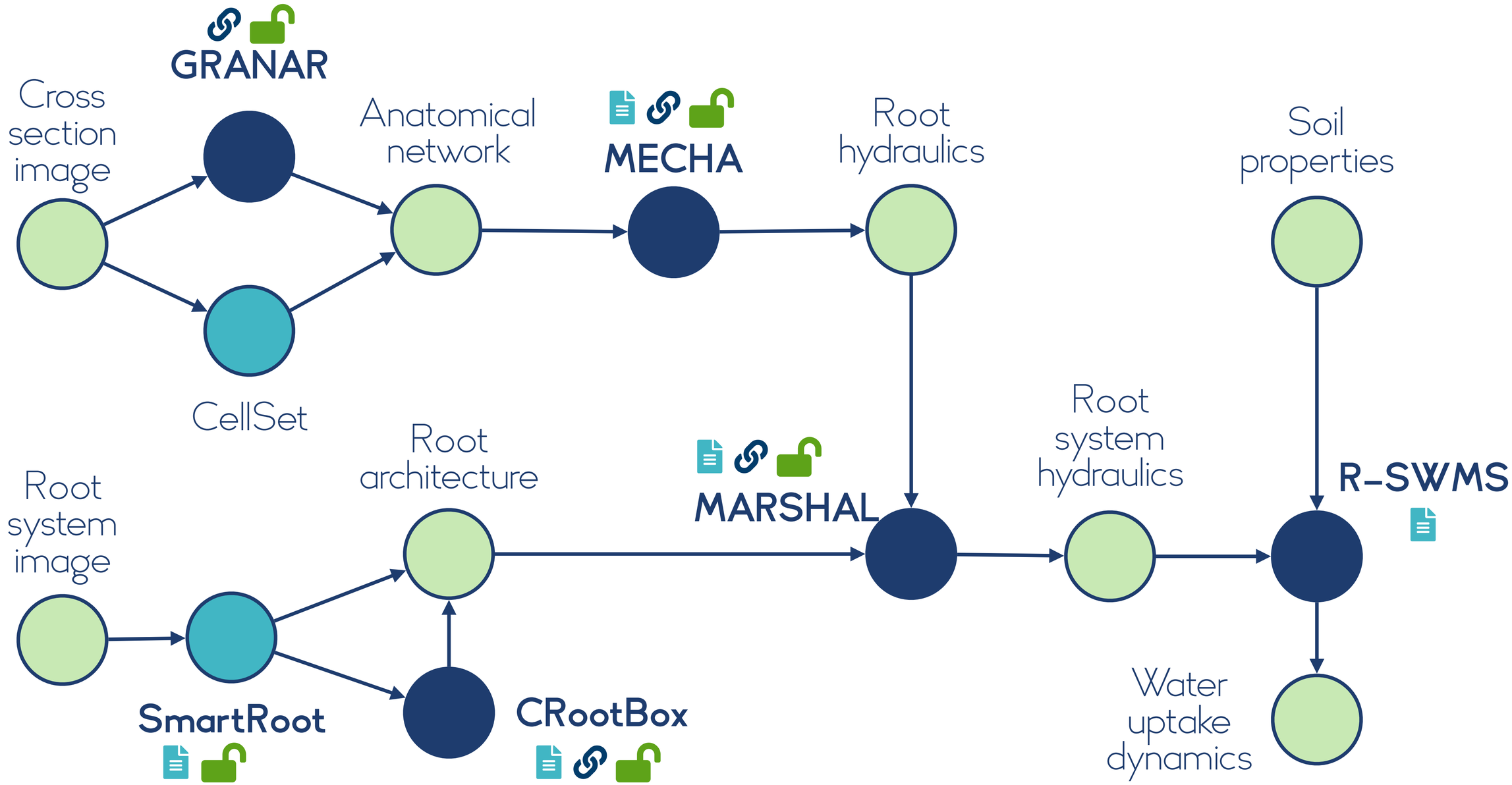


Clay Clay-loam Loam

Draye et al, 2010
PMID: 20453027


GRANAR
Cross section image
Anatomical network
MECHA
Root hydraulics
Soil properties
CellSet
Root system image
Root architecture
MARSHAL
R-SWMS
SmartRoot
CRootBox
Root hydraulic architecture
Water uptake dynamics

WRAPPING UP



bit.ly/water-network-app

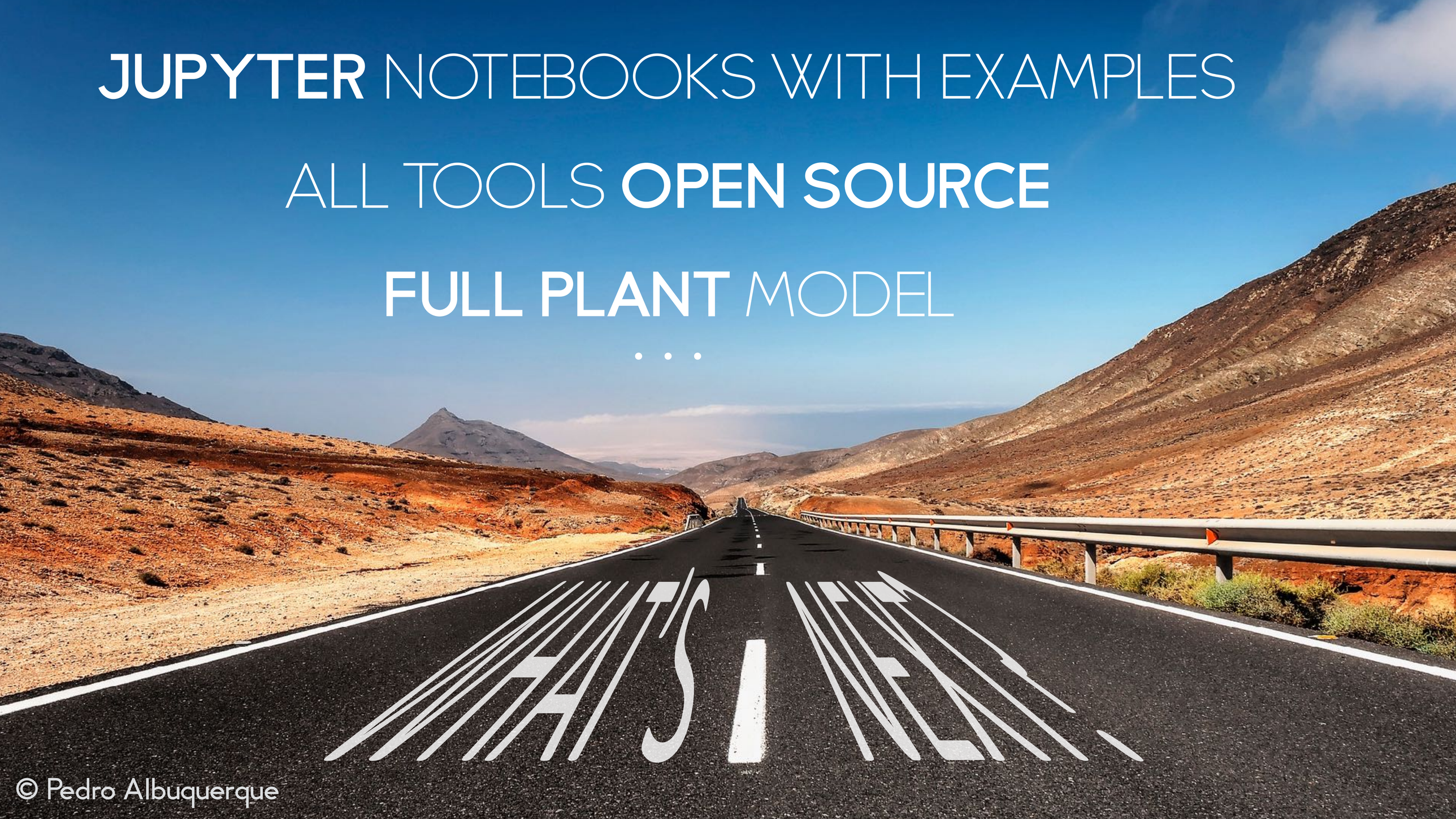
Passot, Couvreur, Meunier et al 2018
DOI: 10.1101/312918

JUPYTER NOTEBOOKS WITH EXAMPLES

ALL TOOLS **OPEN SOURCE**

FULL PLANT MODEL

• • •

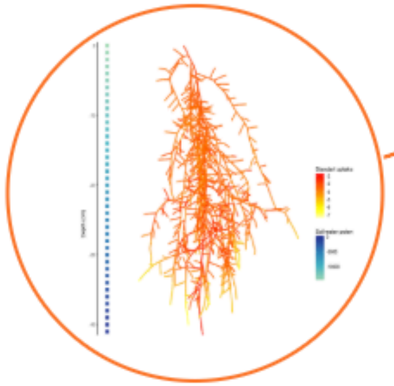


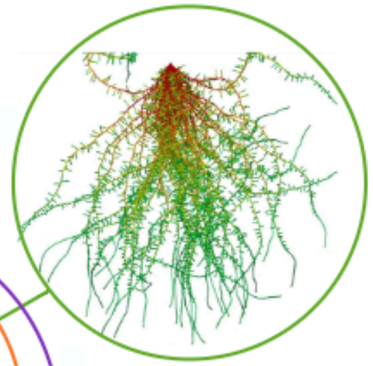
MODELS AS **TEACHING** TOOLS IN PLANT PHYSIOLOGY

MARSHAL

Modèle permettant de simuler l'architecture hydraulique, ainsi que le potentiel de transpiration dans des environnements contrastés

Voir le modèle

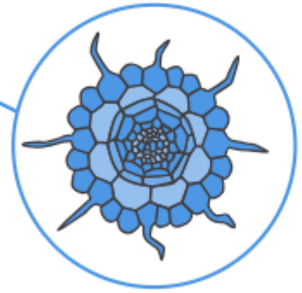




CRootBox

Modèle générique d'architecture racinaire, capable de simuler n'importe quelle plante.

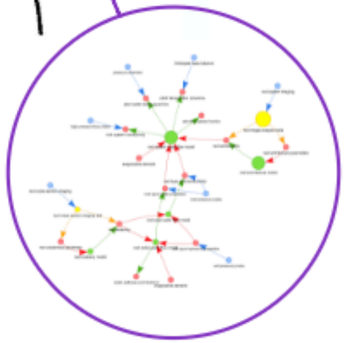
Voir le modèle



MECHA

Modèle de résolution des flux d'eau au sein d'une coupe racinaire

Voir le modèle



Water Network

Pas un modèle, mais une interface reliant entre eux les différents outils informatiques utiles pour l'étude des relations hydrique dans le système sol-plante.

Voir l'interface

www.botalgorithme.be
(in french)

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