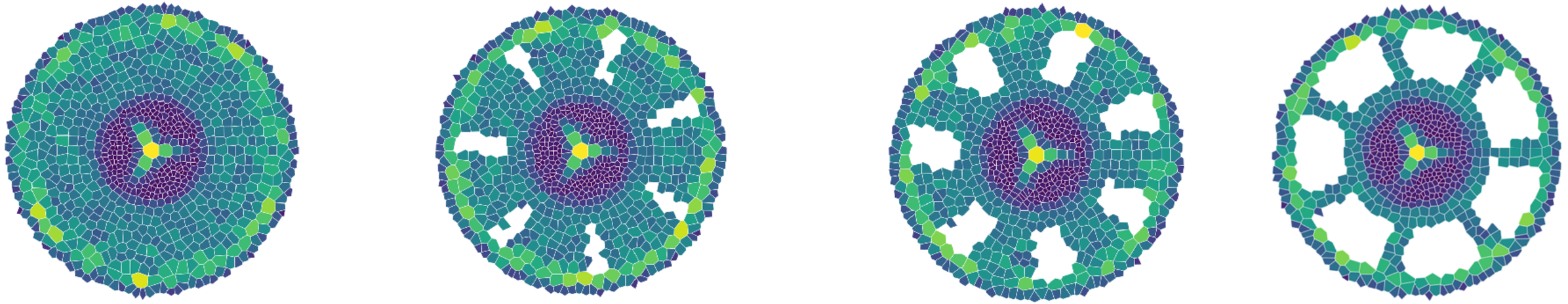


MODELLING WATER RELATIONS IN PLANTS

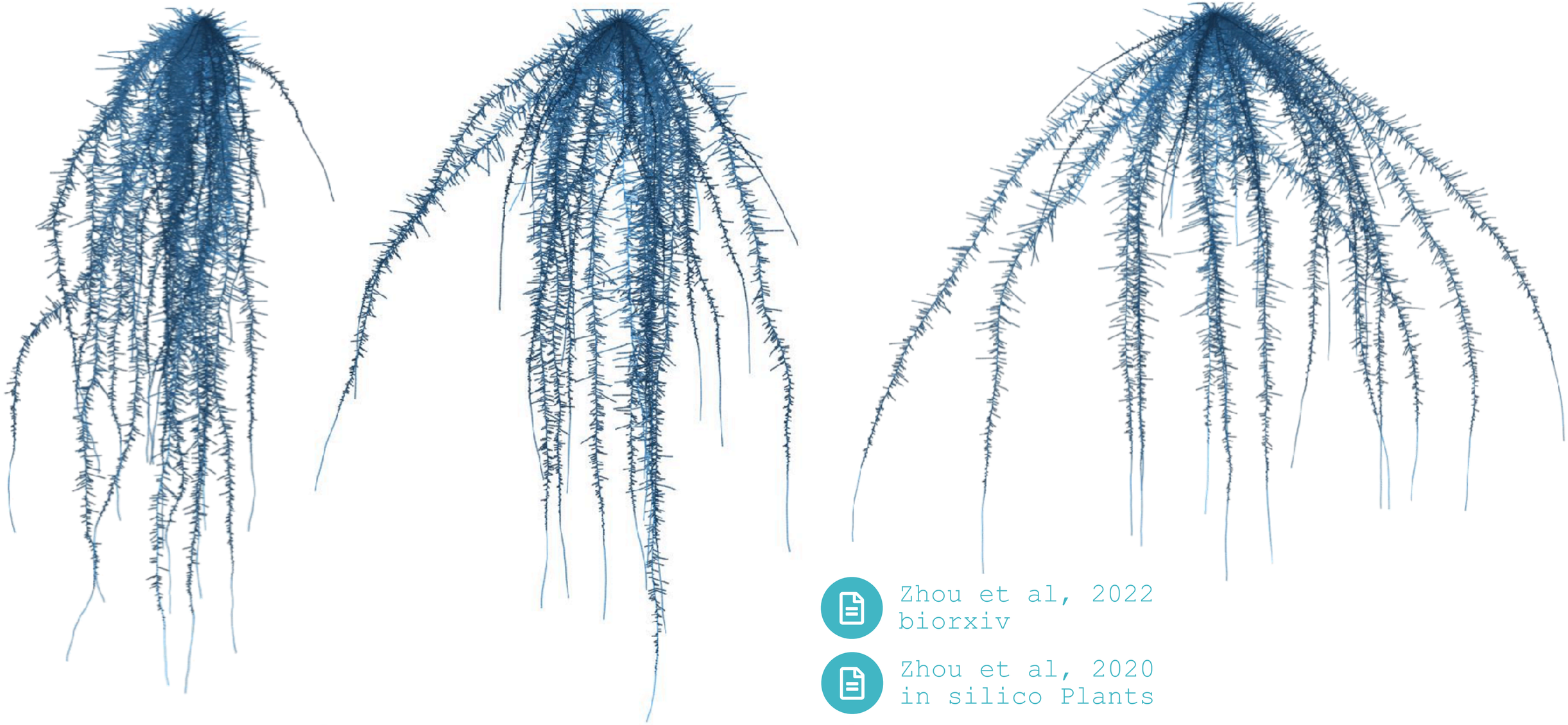
Guillaume Lobet, Valentin Couvreur, Xavier Draye, Adrien Heymans, Mathieu Javaux, Daniel Leitner, Félicien Meunier, Andrea Schnepf, Jan Vanderborght

UCLouvain

JÜLICH Forschungszentrum

PlantComp - 2022

MODELLING **ROOT ARCHITECTURE** WITH CPLANTBOX



Open Source bit.ly/crootbox

Zhou et al, 2022
biorxiv

Zhou et al, 2020
in silico Plants

Schnepf et al, 2018
Annals of Botany

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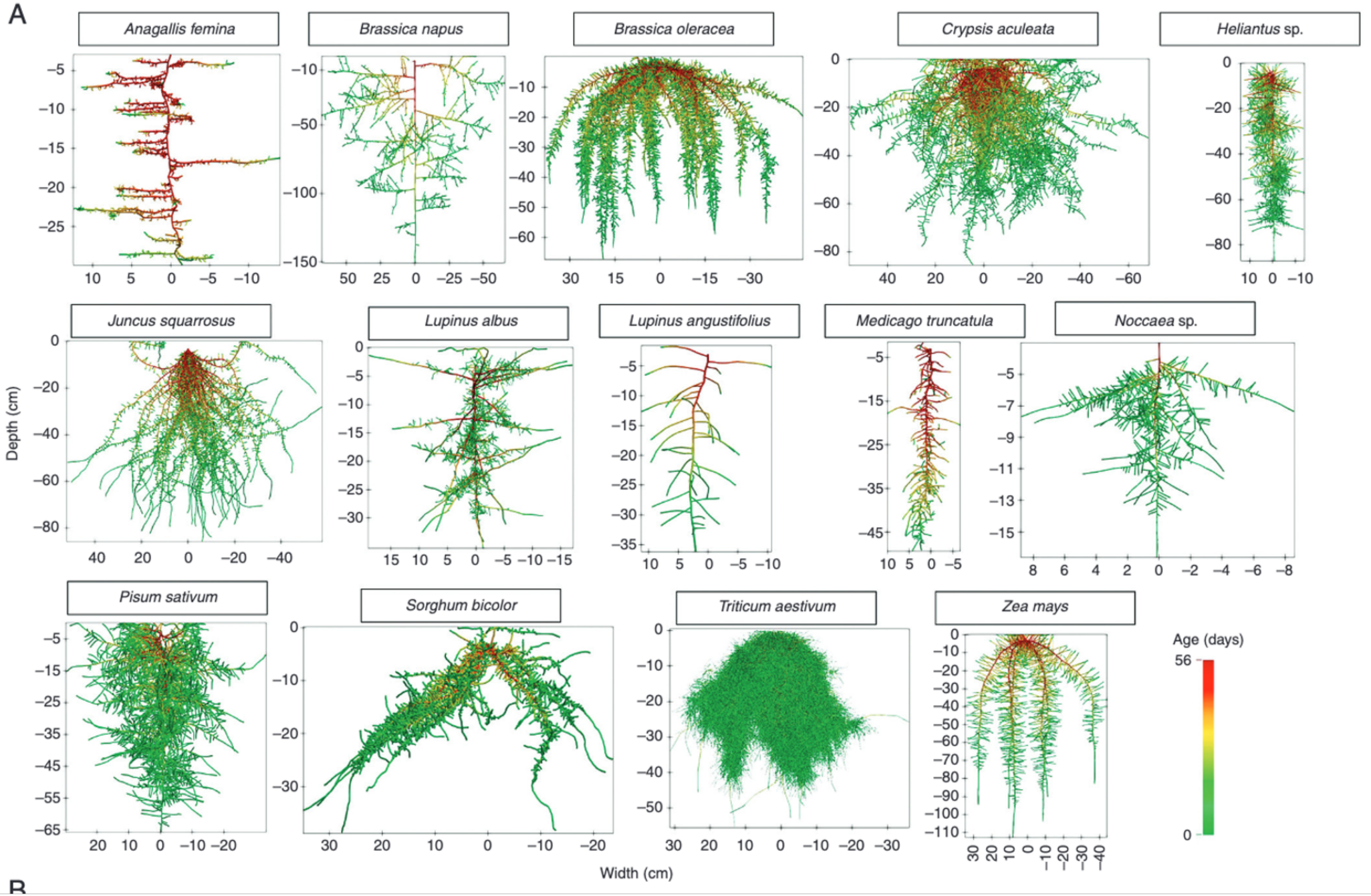
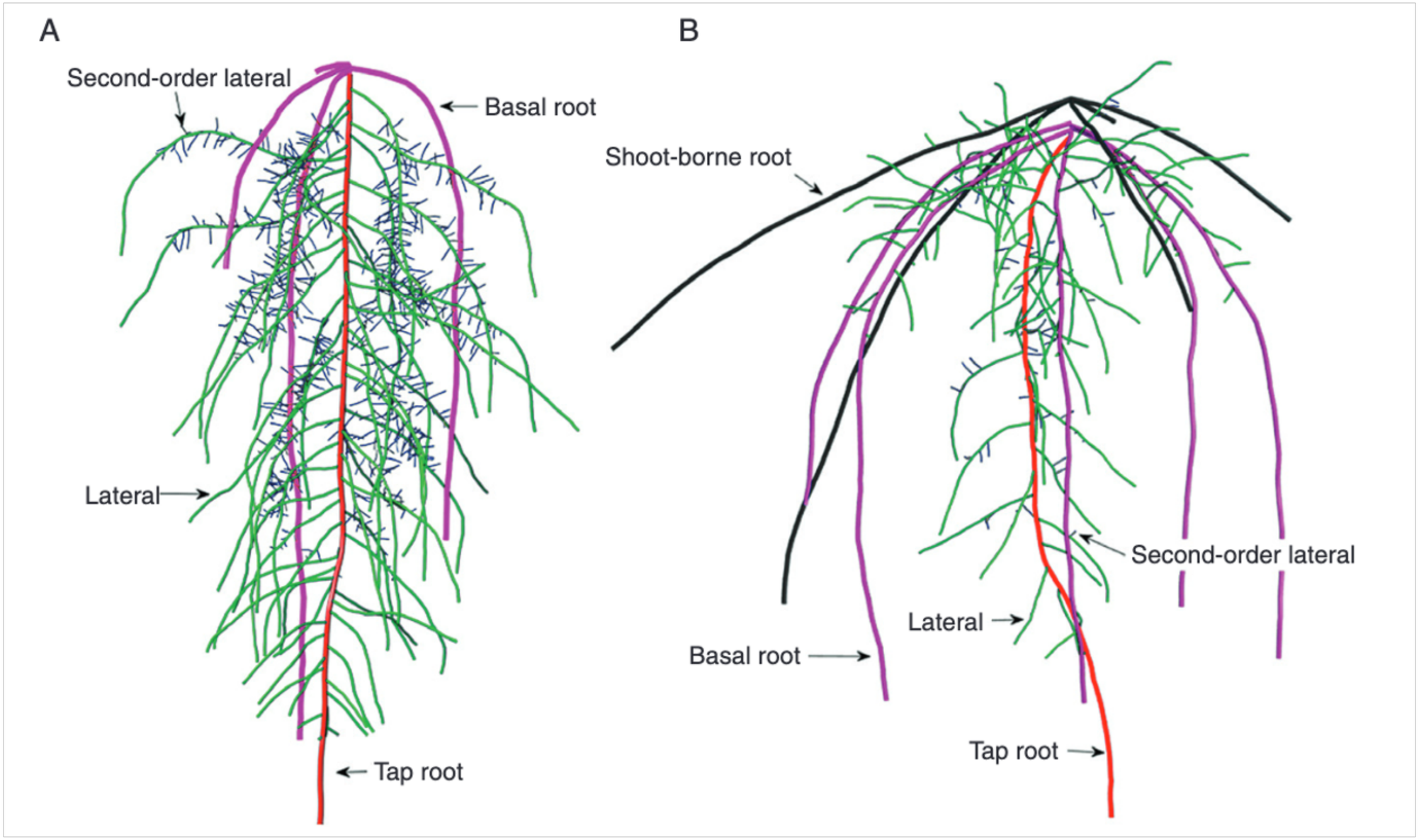
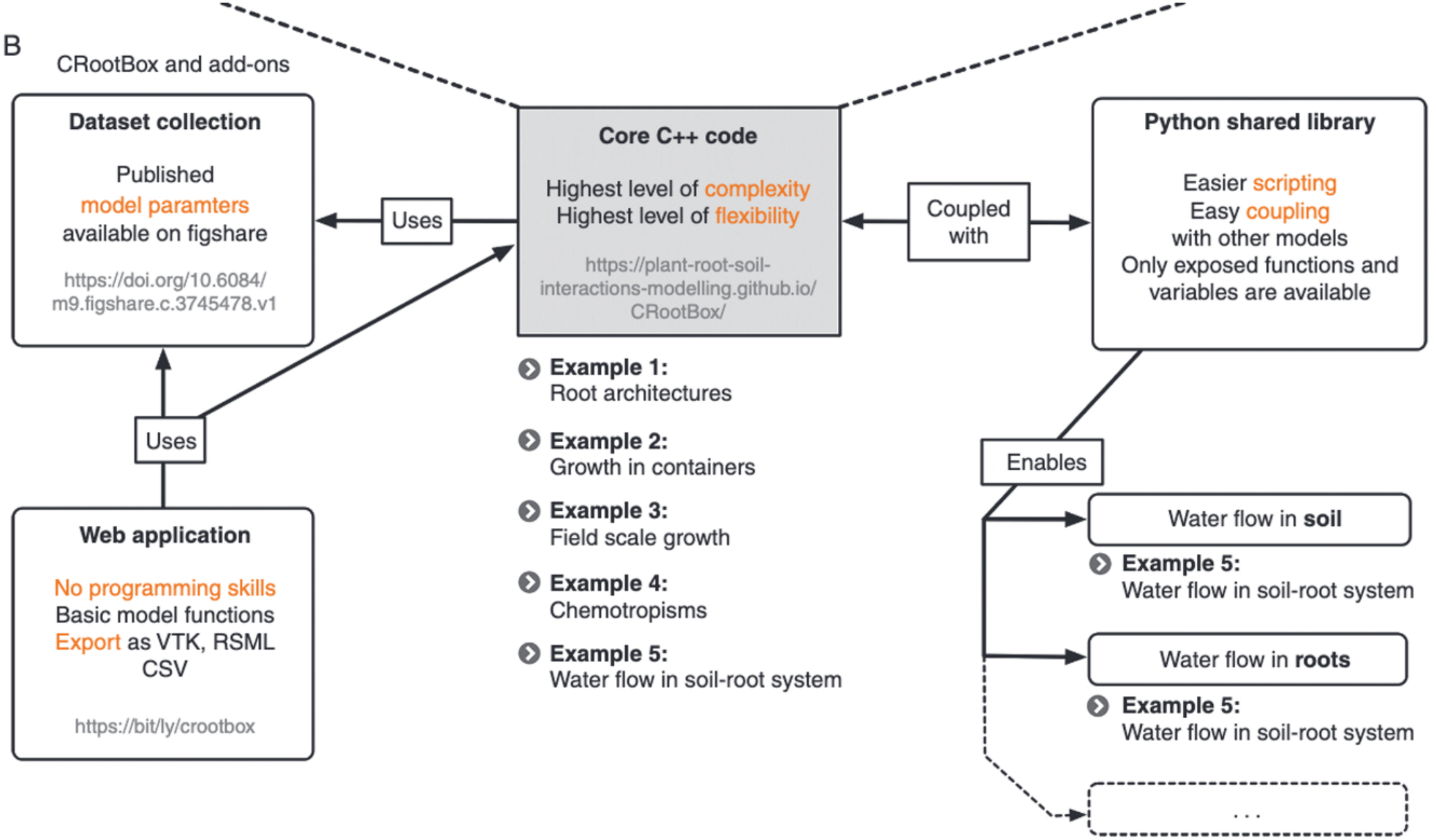

A
Anagallis femina
Brassica napus
Brassica oleracea
Crypsis aculeata
Heliantus sp.
Juncus squarrosus
Lupinus albus
Lupinus angustifolius
Medicago truncatula
Noccaea sp.
Pisum sativum
Sorghum bicolor
Triticum aestivum
Zea mays
Depth (cm)
Width (cm)
Age (days)
56
0
B





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]

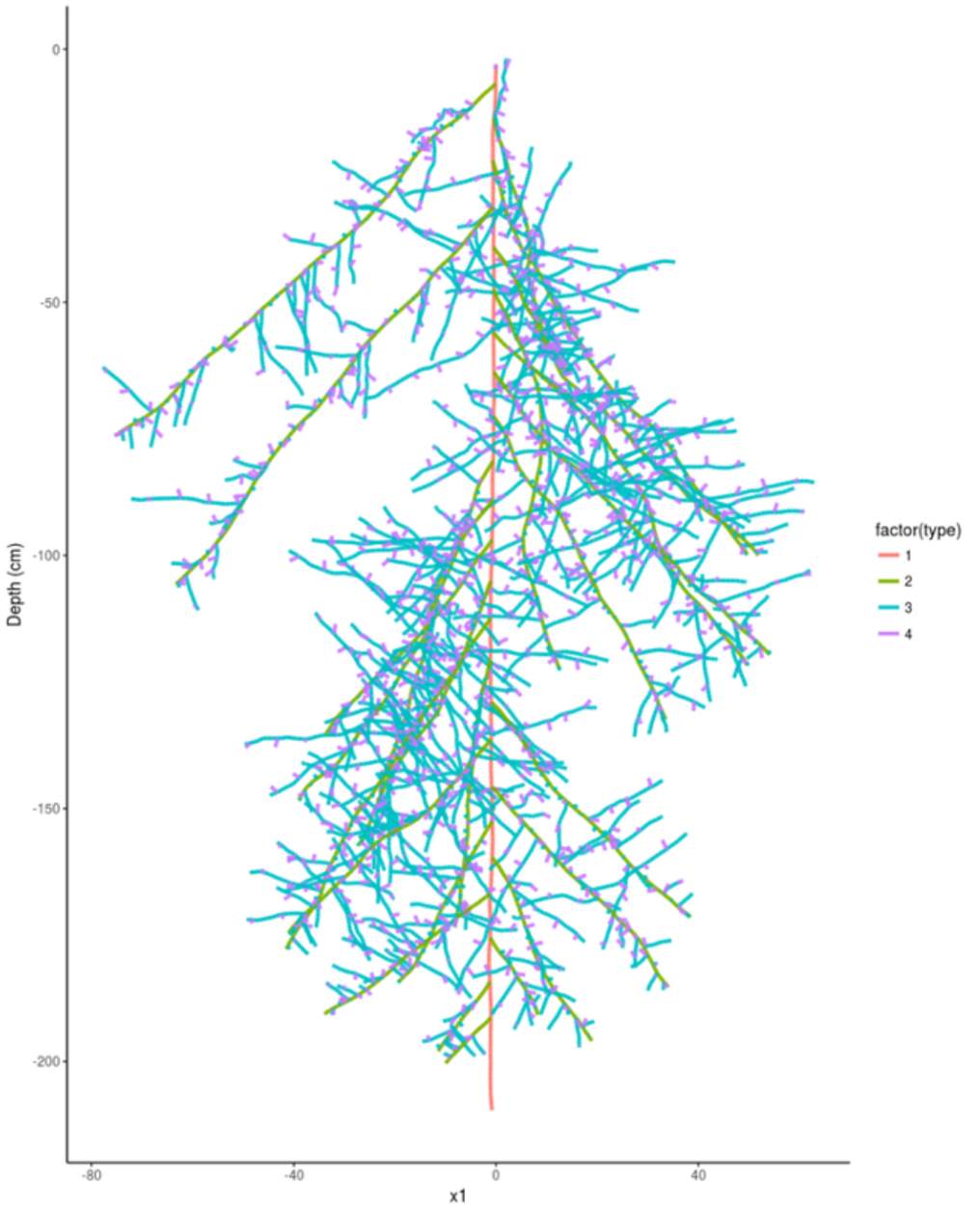
Parameter value:

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



bit.ly/RootBox/

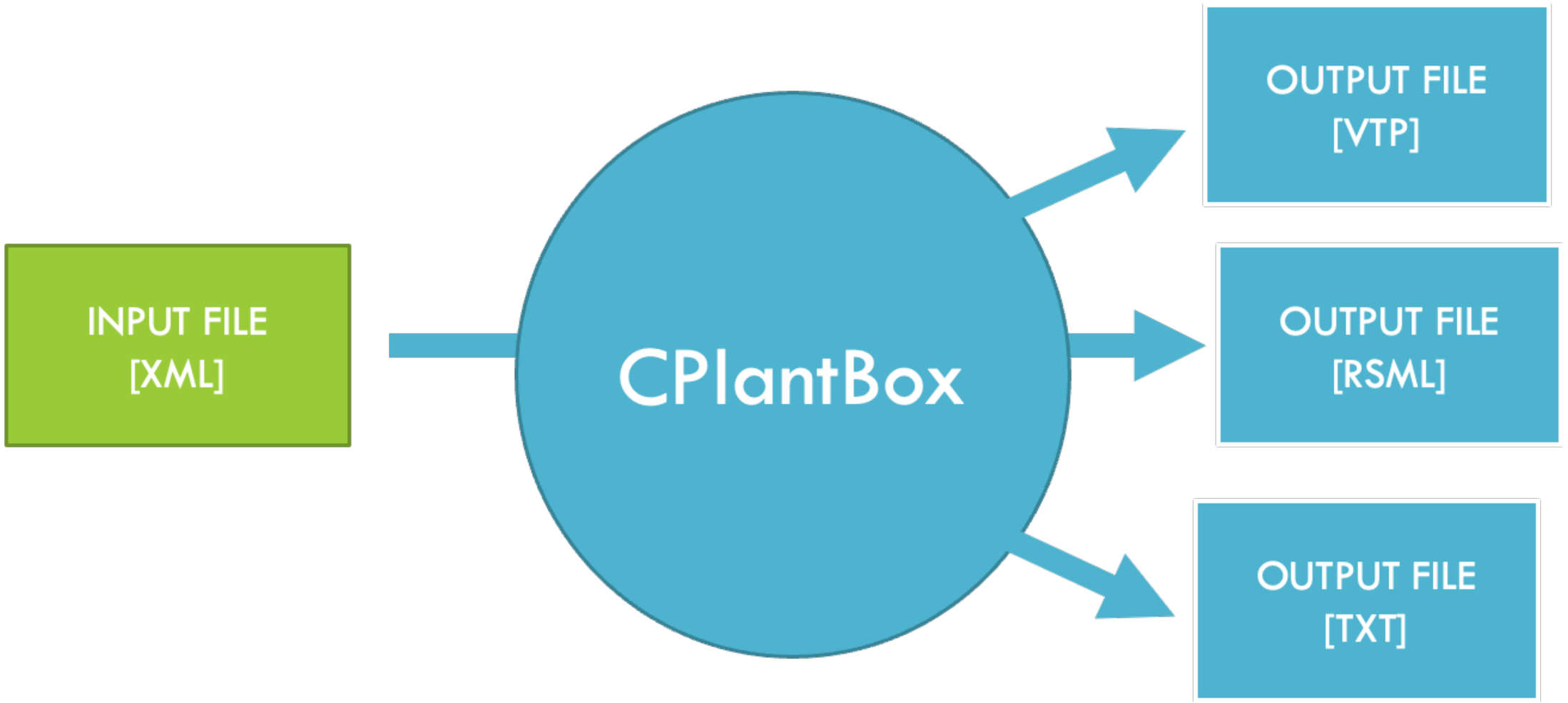


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TABLE 3. *Complete list of parameters used by CRootBox for each root type*

Description	Parameter name	Units
Root radius	a	cm
Initial elongation rate	r	cm d^{-1}
Insertion angle	θ	rad
Length of basal zone	l_a	cm
Length of apical zone	l_b	cm
Length between lateral branches	l_n	cm
Maximal root length	l_{max}	cm
Tropism type	*type*	{0,1,2,3}[1]
Number of trials (tropism strength)	N	1
Standard deviation of random angular change	σ	cm^{-1}
Root successor types	*successor*	[type, probability; …]
Name of the root type	*name*	String
Root colour	*colour*	RGB
Resolution along root axis	*dx*	cm
Root life time	*rlt*	day
Type of root elongation	*gf*	{1,2}[2]
Scale elongation	*se*	Function[3]
Scale branching probability	*sbp*	Function[3]
Scale branching angle	*sa*	Function[3]

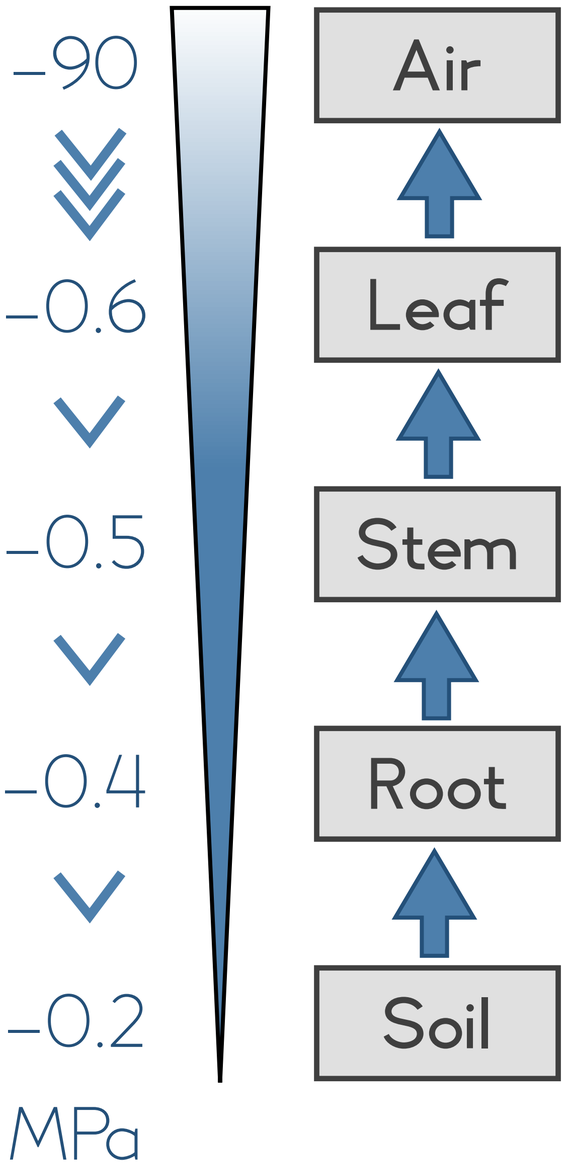
TABLE 2. *List of plant parameters needed for the root architecture development of dicotyledonous and monocotyledonous plants*

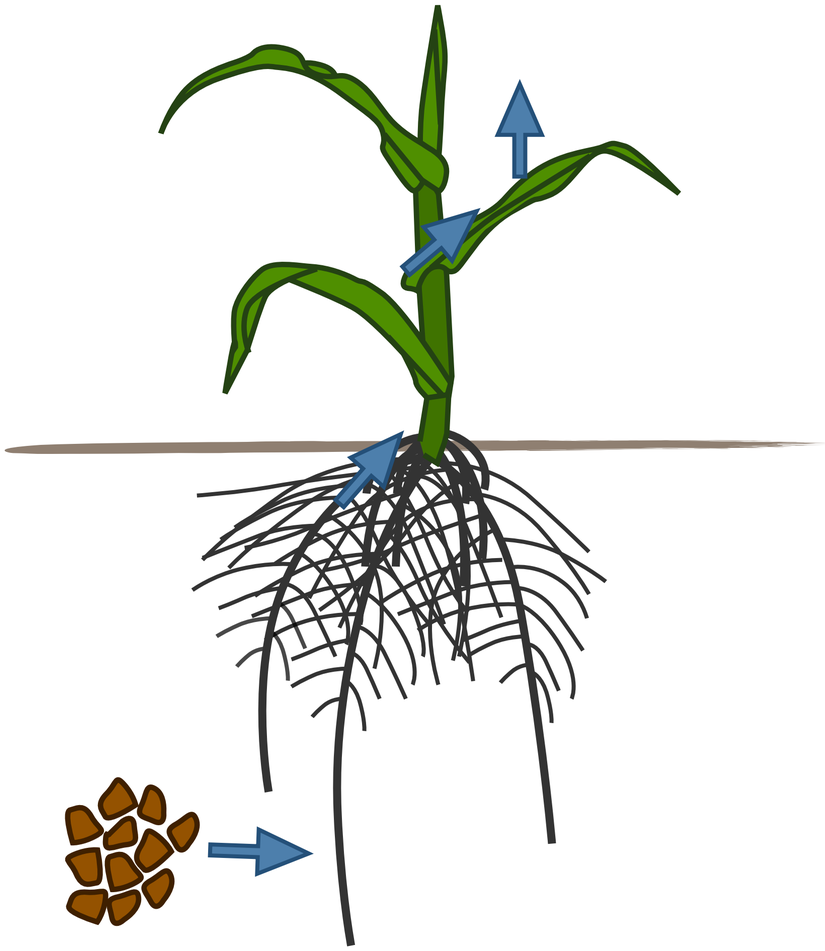
Description	Parameter name	Unit	Plant type
Planting depth	*depth*	cm	Dicot and monocot
First emergence of basal roots	$first_B$	day	Dicot and monocot
Time period between basal roots	$delay_B$	day	Dicot and monocot
Maximal number of basal roots	max_B	1	Dicot and monocot
First occurrence of shoot-borne roots	$first_S$	day	Monocot
Time period between shoot-borne roots	$delay_S$	day	Monocot
Number of shoot-borne roots per root crown	n_S	1	Monocot
Distance between root crowns along the shoot	dz_S	cm	Monocot

https://github.com/guillaumelobet/plantcomp

https://plantmodelling.shinyapps.io/shinyRootBox/

-Try to web interface to play with the parameters
-Run the jupyter notebook in colab
-Try modifying the parameters directly in the input files





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

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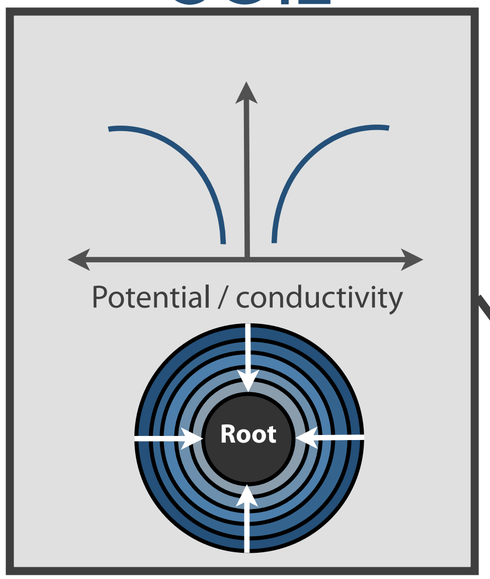
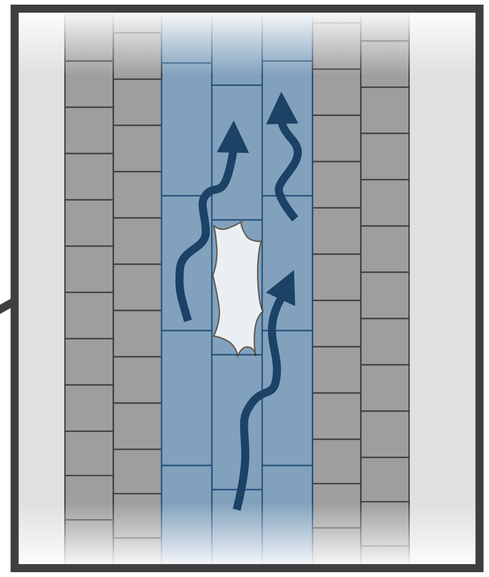
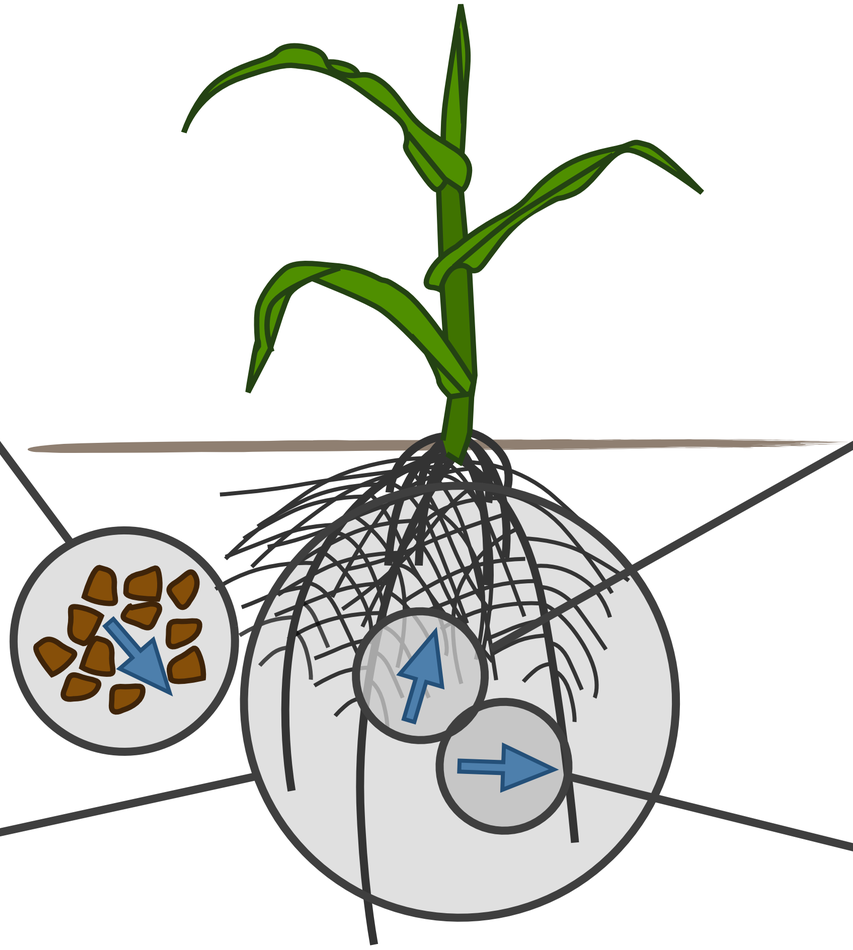
CONDUCTIVITIES CAN BE **REGULATED**

SOIL

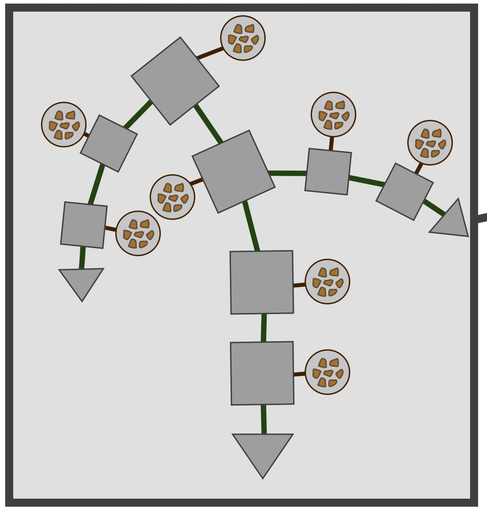


AXIAL CONDUCTIVITY

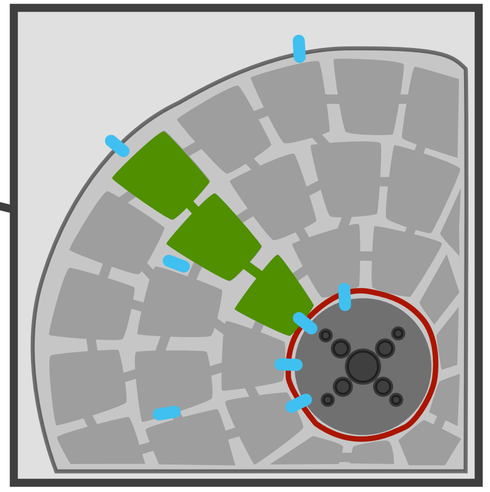




ARCHITECTURE



RADIAL CONDUCTIVITY



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MODELLING **ROOT ARCHITECTURE** WITH CPLANTBOX

Zhou et al, 2020 in silico Plants

Schnepf et al, 2018 Annals of Botany

Open Source

bit.ly/crootbox

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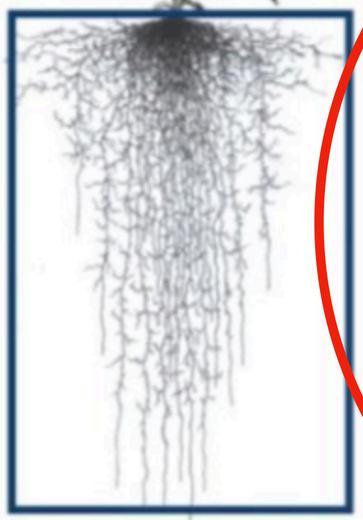
ELECTRICAL ANALOGY FOR WATER FLOWS IN THE PLANT



SHOOT

AIR

Kst

Ka

Kx

$J = K * (\Psi 1 - \Psi 2)$

Δψ

Kr

Ks

ROOT

SOIL

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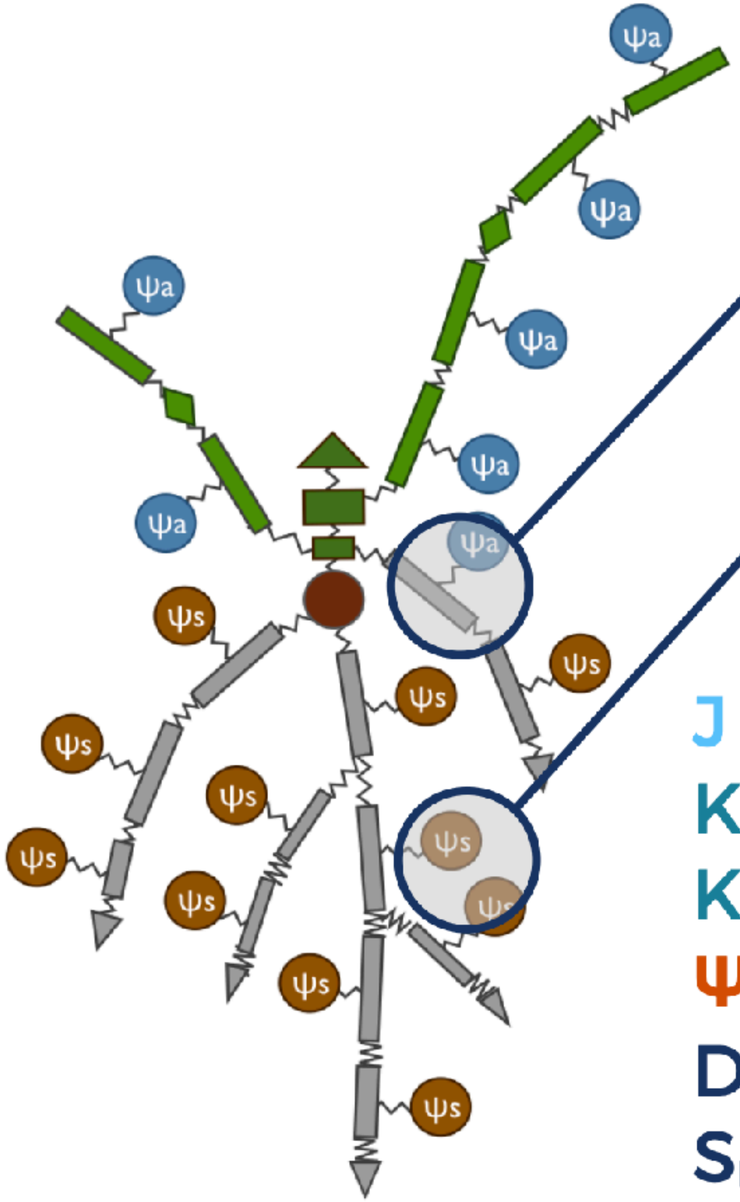
ELECTRICAL ANALOGY FOR WATER FLOW



Axial flux

$$J = K_x \cdot \frac{(\Psi_{r1} - \Psi_{r2})}{D_{r2\text{-}r1}}$$

Radial flux

$$J = K_r \cdot (\Psi_{r1} - \Psi_{soil}) \cdot S_{r1}$$

ROOT SYSTEM CONDUCTIVITY [Krs]

J = water flux [$m^3\ s^{-1}$]

K_r = radial conductivity [$m^4.s^{-1}.MPa^{-1}$]

K_x = radial conductivity [$m.s^{-1}.MPa^{-1}$]

Ψ = water potential [MPa]

$D_{r2\text{-}r1}$ = distance between nodes [m]

S_{r1} = surface [m^2]

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Model

Tutorial

About

Use simplified root system

Run model

Report a bug

Architecture | Conductivities | Environment

Select root type

Taproot

Select parameter to change

Length of basal zone [cm]

Parameter mean:

0 2 4

0 0.4 0.8 1.2 1.6 2 2.4 2.8 3.2 3.6 4

Parameter deviation [%]:

0 10 50

0 5 10 15 20 25 30 35 40 45 50

Length of basal zone [cm]

Length of the unbranched basal zone of the root

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

What to display

Water potential

Taproot LongLateral Basalroot Shootborneroot Lateral

Display range:

-15,000 -383.12

-15,000 -12,076.62 -9,153.25 -6,229.87 -3,306.5 -383.12

Depth (cm)

0 -10 -20 -30

Soil water po

0 -5000 -10000 -15000

Water poten

-5000 -10000 -15000

– MARSHAL –

Open Source

marshal-root.github.io

Meunier et al, 2020
In silico Plants

HOW TO **MAXIMISE** THE **WATER UPTAKE CAPACITY** OF THE PLANT, WITH ONLY **2 MODIFICATIONS** ?

WHICH **ARCHITECTURAL PARAMETER** HAS THE MOST IMPACT ON THE **KRS** ?

WHICH **PARAMETER** HAS THE MOST IMPACT ON THE **UPTAKE DEPTH** ?

marshal-root.github.io