Plant-soil Modeling with CPlantBox: Bridging Structure and Function

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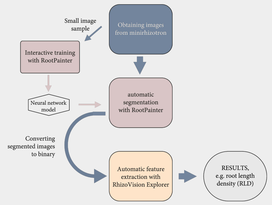
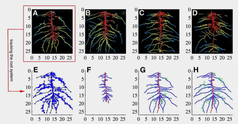
Sharing is encouraged

Parameterization: Feature extraction & Root tracking

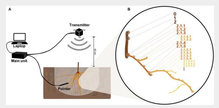
Deep Learning Based Automated Minirhizotron Image Analysis Pipeline

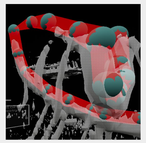


From images using Root System Analyzer



In situ 3D digitization

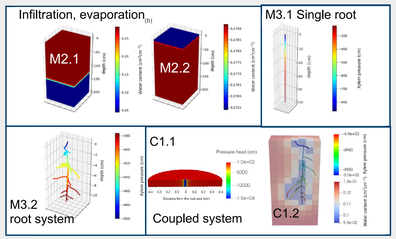




Interactive using VR tracking

Fichtl L. et al. **(2024)** A Field-to-Parameter Pipeline for Analyzing and Simulating Root System Architecture of Woody Perennials: Application to Grapevine Rootstocks. Plant Phenomics 6
Baker, D. N. et al. **(2024)** Hands-On Plant Root System Reconstruction in Virtual Reality. In Proceedings of the 30th ACM Symposium on Virtual Reality Software and Technology Selzner, T. et al. **(2023)** 3D U-Net segmentation improves root system reconstruction from 3D MRI images in automated and manual virtual reality work flows. Plant Phenomics, 5
Bauer, F. M., et al. **(2022)** Development and validation of a deep learning based automated minirhizotron image analysis pipeline. Plant phenomics.
Leitner D., et al. **(2014)** Recovering root system traits using image analysis exemplified by two-dimensional neutron radiography images of lupine. *Plant physiology 164 (1)*

Model benchmarking



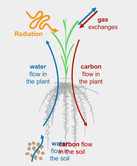
Schnepf et al. **(2023)** Collaborative benchmarking of functional-structural root architecture models: Quantitative comparison of simulated root water uptake. *in silico Plants, 5(1)*

Schnepf et al. **(2020)** Call for participation: collaborative benchmarking of functional-structural root architecture models. The case of root water uptake. *Frontiers in Plant Science, 11:316*

CPlantBox

DuMux-Rosi

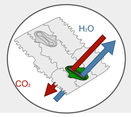
Functional aspects



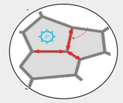
$\psi_t = \psi_p + \psi_g + \psi_o$

Water and carbon flow
PDE, mass balance

Carbon and water flow

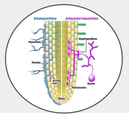


Water release and carbon uptake

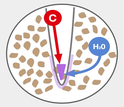


Plant leaf growth and maintenance carbon use

Rhizosphere dynamics



Plant mycorrhizal associations increase water and nutrient uptake for carbohydrates



Water uptake, carbon release and microbial carbon use

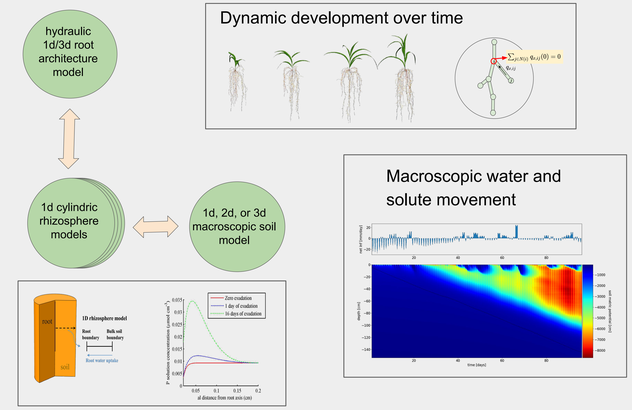
Giraud M. et al. **(2025)** In silico analysis of carbon stabilisation by plant and soil microbes for different weather scenarios. EGUsphere 2025, 1-76
Giraud et al. **(2023)** CPlantBox: A fully coupled modelling platform for the water and carbon fluxes in the soil–plant–atmosphere continuum. in silico Plants 5 (2)
Landl, M. et al. **(2021).** Modeling the impact of rhizosphere bulk density and mucilage gradients on root water uptake. Frontiers in Agronomy, 3, 622367.
Schnepf A. et al. **(2016)** L-System model for the growth of arbuscular mycorrhizal fungi, both within and outside of their host roots. Journal of The Royal Society Interface 13

CPlantBox - Outlook

- Handbook
- WebApp
- Better tools for easier parameterizations

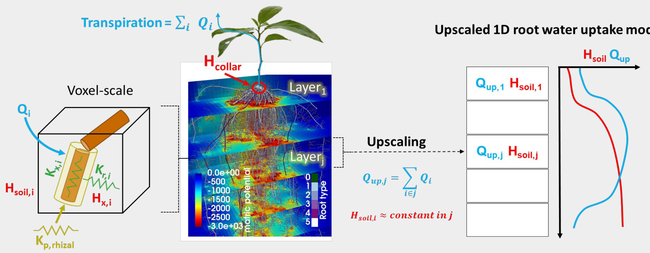
Giraud et al. **(2023)** CPlantBox: A fully coupled modelling platform for the water and carbon fluxes in the soil–plant–atmosphere continuum. *in silico Plants 5 (2)*
Zhou et al. **(2020)** CPlantBox, a whole-plant modelling framework for the simulation of water-and carbon-related processes. *in silico Plants 2 (1)*
Schnepf et al. **(2018)** CRootBox: a structural–functional modelling framework for root systems. *Annals of botany 121 (5)*
Leitner et al. **(2010)** A dynamic root system growth model based on L-Systems: Tropisms and coupling to nutrient uptake from soil. *Plant and soil 332*

Multi-scale implementation



Giraud et al. **(2023)** CPlantBox: A fully coupled modelling platform for the water and carbon fluxes in the soil–plant–atmosphere continuum.
Koch T. et al. **(2021)** DuMux 3–an open-source simulator for solving flow and transport problems in porous media with a focus on model coupling. *Computers & Mathematics with Applications, 81*
Leitner, D. et al. **(2014)** Recovering root system traits using image analysis exemplified by two-dimensional neutron radiography images of lupine. *Plant physiology, 164(1)*

Model development & upscaling



Leitner D. et al. **(2025)** From hydraulic root architecture models to efficient macroscopic sink terms including perirhizal resistance. *Hydrology and Earth System Sciences 29 (6)*
Vanderborght et al. **(2024)** Mechanistically derived macroscopic root water uptake functions: The α and ω of root water uptake functions. *Vadose Zone Journal 23 (4)*
Vanderborght et al. **(2024)** Combining root and soil hydraulics in macroscopic representations of root water uptake. *Vadose Zone Journal 23 (3)*

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