Reconstructing root system architectures from non-invasive imaging techniques for the use in functional structural root models

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Non-invasive imaging provides root architectures as input for functional-structural root models. However, root systems can often only be recovered partially using imaging, which affects the model results.

How much of a root system can we possibly recover from MRI and X-ray CT images and how can we overcome the problem of low root system recovery fractions?
ROOT DETECTION AND ROOT SYSTEM RECOVERY

Experimental setup

Exp 1: What is the minimum detectable root diameter?

Exp. 2: Which fraction of a root system can we possibly recover?

Water-filled capillaries of different diameters were emerged in soil and scanned with MRI and X-ray CT.

Lupine plants aged between 1 and 4 weeks were grown in soil-filled cylinders and scanned with MRI and X-ray CT.
ROOT DETECTION AND ROOT SYSTEM RECOVERY

Axial slices of the scanned sample with water-filled capillaries

Recovered roots from a subsample of a soil-grown lupine plant

**Root detection**
- **MRI:** Root detection below voxel size resolution
- **X-ray CT:** Root detection of ~3 x voxel size

**Root recovery**
- **MRI:** partly very low root system recovery fractions depending on root system density, soil type, water content
- **X-ray CT:** only subsample reconstruction, most roots could be recovered

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DEALING WITH LOW ROOT SYSTEM RECOVERY

Virtual completion of root systems → 'semi-virtual root systems'

- Root systems from non-invasive imaging are used as scaffolds onto which missing roots are virtually added using the root architecture model CRootBox.
- Model input parameters for CRootBox are derived both from WinRhizo measurements and the distribution of roots in the root scaffolds themselves.
SEMI-VIRTUAL ROOT SYSTEMS

How well do they represent the real root systems?

Comparison of total root lengths

Comparison of total root lengths extracted from semi-virtual root systems and WinRhizo measurements

Comparison of spatial distribution of root length within the soil volume

Goodness of fit (expressed by rRSME) between root length contained within sub-samples of semi-virtual root systems and X-ray CT – derived root systems as a function of the ratio between subsample and sample volume

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CONCLUSIONS

• Root recovery from MRI images is poor for older and denser root systems and is impeded by high water contents for certain soil types.

• Our virtual root completion approach allows generating semi-virtual root systems of which not only the total length, but also the length distribution within the soil domain resembles the actual root systems.

• Considering that the parameterization of virtual roots can be done with data from WinRhizo measurements, our virtual root completion approach is very simple and inexpensive.
Thank you for your attention!