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Quantification of root growth patterns from the soil perspective via root distance models

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The rhizosphere is a dynamic domain that changes with root growth and depends on local interactions between root and soil and the spatial arrangement of the root system in the soil volume. Traditional approaches to quantify root distribution are very limited in estimating this transient extent of the rhizosphere. In the present paper we advocate the analysis of root growth patterns from the soil perspective. This change of perspective addresses more directly how certain root system architectures facilitate the exploration of soil. For the first time we propose a parsimonious root distance model with only four parameters which is able to describe root growth patterns throughout all stages in the first three weeks of growth of Vicia faba captured with X-ray computed tomography. Using this model, which is fitted to the frequency distribution of root distances in soil, it is possible to estimate the rhizosphere volume, i.e. the volume fraction of soil explored by roots, and adapt it by specific interaction distances, for water uptake, rhizodepostion, etc. Furthermore, through 3D time-lapse imaging and image registration it is possible to estimate root age dependent rhizosphere volumes, e.g. for young roots only. Thus, our root distance models is a useful abstraction of complex root growth patterns that provides complementary information on root system architecture unaddressed by traditional root network analysis, which is helpful to constrain deterministic root growth models in order to achieve more realistic results.