How to better describe spatial heterogeneity of root distribution in tree ecosystems?

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1 INTRODUCTION For a better understanding of processes affecting underground biodiversity in forest ecosystems, a reliable characterisation of root spatial distribution is indispensable. This work aims to introduce a set of methodologies, which are (1) statistically based, (2) easy to use in conjunction with conventional root sampling techniques (e.g. root trench, coring) and (3) generic and suitable to describe the spatial heterogeneity of root distribution in European forests.

Spatial heterogeneity of root distribution

Objective to describe

Abundance

Horizontal gradient

Modelling tree root density (RD) as a function of tree species, position and size, understorey richness and presence of stones.

Example of method

***ChaMRoots* model**

Root production efficiency (E) at a given point due to its surrounding trees differing in root provision potential (p):

$$E = \frac{\mathrm{d}RD}{\mathrm{d}p} \qquad p = \sum_{s=1}^{N_s}\sum_{e=1}^{N_e} p_{e,s} = \sum_{s=1}^{N_s}\left(\sum_{e=1}^{N_e} \frac{g_{e,s}^{\lambda_s}}{\beta + (D_{e,s}^{\alpha})^{\varphi_s}} O_{e,s}\right)$$

where, N_s – number of tree species around the target point ($N_s \geq 0$, $s \in [0, N_s]$); N_e – number of tree individuals of a given species s around the target point ($N_e \geq 0$, $e \in [0, N_e]$); $p_{e,s}$ – the potential of tree root provision contributed by the tree (e, s); $g_{e,s}$ – basal area at a height of 1.3 m of an individual tree e of species s (m²); $D_{e,s}$ – horizontal distance from the centre of the tree (e, s) to the target point (m) and $D_{e,s} \geq 0$; $O_{e,s}$ – the absence of emerged obstacles on the ground between the target point and the tree e of species s.

We can use either a power function or a logistic function to model the relationship between E and p.

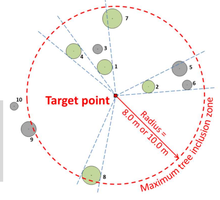
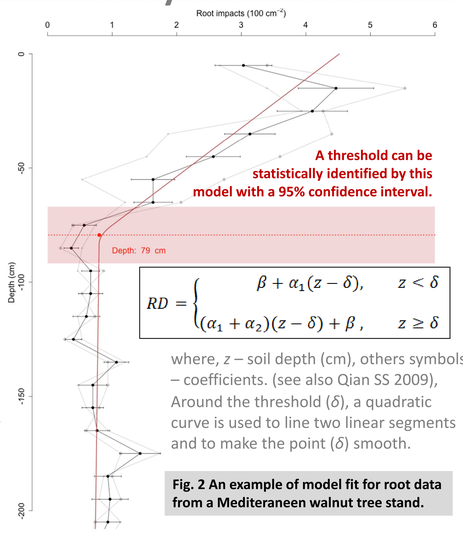


Fig. 1 Each eligibile tree (in light green) considered in p should have a stem centre that is within the maximum tree inclusion zone and not hidden by other tree stems.

Vertical gradient

Modelling root density (RD) along a soil profile by identifying a threshold that might be used to split shallow and deep roots.

Hockey stick model



$$RD = \begin{cases} \beta + \alpha_1(z-\delta), & z < \delta \\ (\alpha_1+\alpha_2)(z-\delta) + \beta, & z \geq \delta \end{cases}$$

where, z – soil depth (cm), others symbols – coefficients. (see also Qian SS 2009), Around the threshold (δ), a quadratic curve is used to line two linear segments and to make the point (δ) smooth.

Fig. 2 An example of model fit for root data from a Mediteraneen walnut tree stand.

Biological gradient

Modelling cumulative frequency of root density (C_d) along root diameter (d).

Low parameter functions

$$C_d = 1 - e^{-\zeta d} \qquad C_d = 1 - \exp\left(-\frac{\eta}{\delta}\left(e^{\delta d} - 1\right)\right)$$

$$C_d = 1 - e^{-(d/\gamma)^{\kappa}} \qquad C_d = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{\ln d - \mu}{\sigma\sqrt{2}}\right)\right]$$

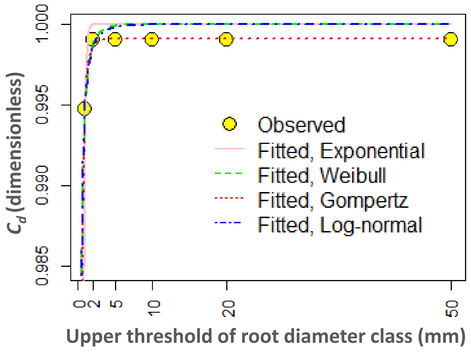


Fig. 3 Comparison of model fit between four types of low parameter functions.

Evenness

Patchiness

Determining if roots grow in cluster or evenly in soil as a function of environmental gradients, i.e. soil depth and distance to tree trunks.

Geostatistics

Synergic strategies

Quantifying synergies of root distribution among different root sizes that are associated to contrasted traits, functioning and ecosystem services.

Probability theories

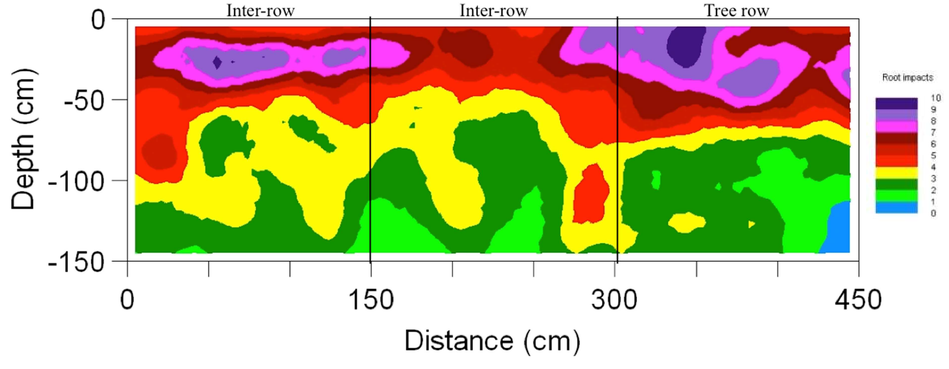


Fig. 4 An example of Kriged map of tree fine root (d ≤ 2 mm) intercepts within a root trench in a Mediteraneen walnut stand.

Reference: **[1]** Mao Z, Saint-André L, Bourrier F, Stokes A, Cordonnier T. Modelling and predicting spatial distribution of tree root density in heterogeneous forest ecosystems. Annals of Botany, submitted in 09/2014;
[2] Cardinael R, Mao Z, Prieto I, Stokes A, Dupraz C, Jourdan C. Competition with winter crops induces deeper rooting of walnut trees in a Mediterranean alley cropping agroforestry system. Plant and Soil, submitted in 10/2014;
[3] Mao Z, Cardinael R, Prieto I, Stokes A, Dupraz C, Jourdan C. Characterisation of evenness of root distribution in a Mediterranean alley cropping agroforestry system. (*in prep*. for Forest Ecology and Management).