International Symposium "Root Research and Applications"
RootRAP, 2–4 September 2009, Boku – Vienna, Austria

Modelling rooting depth of trees in boreal forests

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ABSTRACT

We evaluated two nonlinear functions to estimate the tree rooting depth for incompletely sampled profiles. The functions were a hyperbolic curve, $Y = (Y_{max} X)/(K_d+X)$, and an exponential curve, $Y = Y_{max}(1-e^{-KX})$, where Y is the cumulative root biomass (g m^{-2}) at depth X (cm), Y_{max} the fitted maximum root biomass, and K_d and K parameters describing the form of the vertical root distribution curve. The functions were fitted to fine (<2 mm), coarse (2-10 mm) and total (<10 mm) tree root biomass data (g m^{-2}) from the organic, 0-5 and 5-20 cm layers of a Norway spruce dominated stand in eastern Finland (63° 51'N, 28° 58'E). Values for the mineral (till) soil layers were corrected for stone content (0.28 v/v) of the bulk soil. The fitted functions were used to calculate the depths at which 50% (D_{50}) and 95% (D_{95}) of maximum root biomass, Y_{max}, were achieved. Compared to the exponential model, the hyperbolic model gave higher R^2 (>0.9), D_{50} and D_{95} values for all three root diameter classes. D_{95} values with the hyperbolic model averaged 75.7 cm while those with the exponential model averaged 14.3 cm. With both functions, D_{50} and D_{95} values were greater for fine roots than for coarse roots (by 21% and 35% with exponential and hyperbolic models, respectively). Such models can be used not only to describe the vertical distribution of roots but also to objectively estimate maximum rooting depths.

KEYWORDS: root biomass, rooting depth, soil water use, curvilinear functions, modelling

1. INTRODUCTION

Most root studies deal with the amount of roots in the upper soil layer and do not provide information on rooting depths. However, for the purposes of studying and modelling ecosystem water fluxes it is necessary to know rooting depth since this largely determines the water storage capacity of the soil. Using incomplete profile sampling data, we evaluated two nonlinear functions which included an estimate of the total biomass of roots and then calculated the depths at which 50% (D_{50}) and 95% (D_{95}) of amount of roots occurred. Since water uptake is by the fine roots, we applied the functions to different root diameter size classes.

2. MATERIAL AND METHODS

Root biomass sampling was carried out in a Norway spruce dominated stand in eastern Finland (63° 51'N, 28° 58'E) (Palviainen et al., 2005). Replicated (n=20) soil cores were taken annually for seven years (1996-2003) from the organic layer (3 cm), and 0-5 cm and 5-20 cm mineral soil layers. Living roots tree roots separated from ground vegetation roots, divided into <1, 1-2, 2-5 and 5-10 mm diameter classes, and dry weight root biomass (g m^{-2}) calculated. Root biomass values for the mineral (till) soil layers were corrected for stone content of the bulk soil (0.28 v/v).

Two nonlinear functions were fitted to the annual average fine (<2 mm), coarse (2-10 mm) and total (<10 mm) tree root biomass data (g m^{-2}) (Table 1). The functions were a hyperbolic curve, $Y = (Y_{max} X)/(K_d+X)$ and an exponential curve, $Y = Y_{max}(1-e^{-KX})$, where Y is the cumulative root biomass (g m^{-2}) at depth X (cm), Y_{max} the fitted maximum root biomass, and K_d and K parameters describing the form of the vertical root distribution curve.

3. RESULTS

The fitted cumulative depth distribution curves for the fine and coarse root biomass fractions are presented in Figure 1.

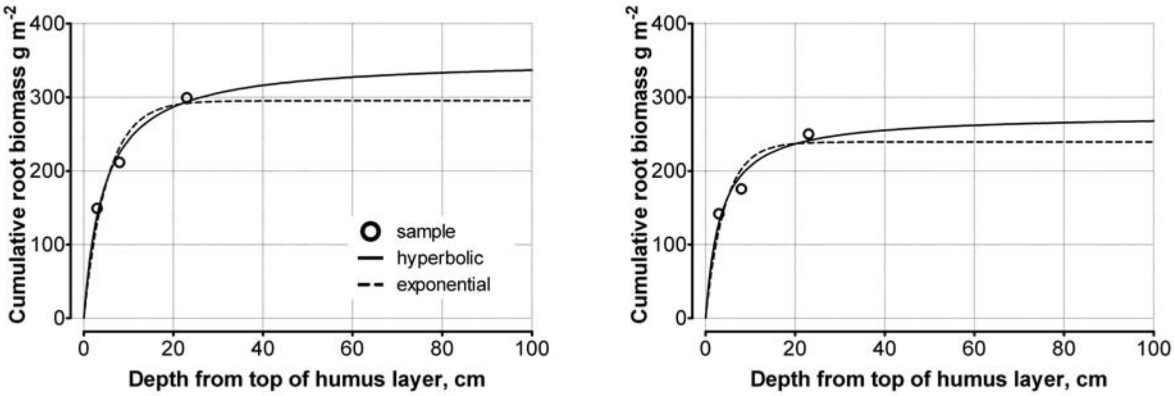

Figure 1. Modelled and measured fine (left) and coarse (right) root biomass depth distributions

Compared to the exponential model, the hyperbolic model gave higher R^2, D_{50} and D_{95} values for all three root diameter classes (Table 1). D_{95} values with the hyperbolic model averaged 75.7 cm while those with the exponential model averaged 14.3 cm. With both functions, D_{50} and D_{95} values were greater for fine roots than for coarse roots (by 21% and 35% with exponential and hyperbolic models, respectively).

Table 1. Rooting depths (cm) at which 50% (D_{50}) and 95% (D_{95}) of maximum root biomass was achieved according to the two studied nonlinear models.

Root diameter	Hyperbolic model (1)			Exponential model (2)		
class	R^2	D_{50}	D_{95}	R^2	D_{50}	D_{95}
Fine	0.98	4.6	86.6	0.92	3.6	15.6
Coarse	0.91	3.4	64.4	0.79	3.0	12.8
Total	0.95	4.0	76.0	0.87	3.3	14.4

4. CONCLUSIONS

Such models can be used not only to describe the vertical distribution of roots but also to objectively estimate maximum rooting depths.

REFERENCES

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