Allometric relations between roots and shoots based on the root atlases

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ABSTRACT

The data gathered by Kutschera and coworkers as presented in different volumes of the rootatlas suggest a number of analyses. One of the more straightforward is to analyze relations between the shoot height, maximum root depth and maximum lateral root system extension which are constant descriptors in all the quoted Atlases. In another step these parameters can be correlated to soil profile descriptions, and location parameters also described in the Atlases. Results of these analyses will be presented, and allometric coefficients discussed in the light of theoretical considerations regarding shoot-root partitioning

KEYWORDS: allometry, root-shoot, image analysis

INTRODUCTION

The theory of functional equilibrium as described by e.g. France and Thornley (1984) allows to define a relationship between the aboveground and the belowground matter of vegetation. We wanted to test the consequences of this asumption using data gathered by Kutschera and coworkers (op. cit.).

THEORY

The total growth of a plant or homogeneous vegetation is assumed to be the minimum of two growth processes: one determined by growth resources aboveground (A: light, CO2); the other by growth resources belowground (B: nutrients, water):

$$\frac{\Delta W_T}{\Delta t} = \min\left(c_A W_A A \quad , \quad c_B W_B B\right)$$

where c is the conversion efficiency for the respective organs, W the weight of the aboveground or belowground matter capturing resources; A, B the available above(below)ground resource. Using a number of assumptions (growth proportional to shoot and root weight balanced growth, introducing volume fractions θ, and volumetric mass density ρ,) allows to write the above equation in terms of volumes, where the volumes V_A and V_B contains all above(below)ground biomass. The volume fractions are the relative space occupied by the biomass above- and belowground within these hulls. If the volume is characterized by a height, a length and a width, and if the growth has no preferred direction in the horizontal plane (l_A=w_A) the resulting equation can be rewritten as:

$$\frac{A}{B}\frac{h_A l_A^2}{\alpha} = h_B l_B^2$$

The only way we can simplify this equation further is by assuming a relation between the height and the length scale of the aboveground volume:

$$l_A = b h_A^c$$

Substitution and rewriting yields:

$$\beta \frac{A}{B} h_A^{2c+1} = h_B l_B^2$$

Rewriting in terms of geometric variables is convenient because these can be measured non-destructively and in fact have been presented consistently in the different root atlases. This equation shows that given functional equilibrium the scale parameter of the allometric function should be modified by the resource ratio (aboveground over belowground).

METHODS

We used the result of equation to describe the data of the Atlases published by Kutschera et al (1960,). To include information regarding aboveground and belowground resources the database was extended with the Ellenberg indicator values modified for Austria (Karrer, 2009). Using Ellenberg numbers for water and nutrients (belowground) and light (aboveground) introduces a regressor with indicator levels. Fitting a power function for the specific values should yield parallel lines, with intercept values increasing with the Ellenberg ratio of L over min(F,N).

RESULTS AND DISCUSSION

Based on log-linear regression of the H-T-S data in the different Root Atlases we find the exponent in the allometric description (2c+1) to be equal to 1.91±0.05 (n=905;Percentage variance explained 61.), suggesting c=0.45±0.03 (c≈0.5), so

$$l_A \approx b h_A^{\frac{1}{2}}$$

This is a result which can be tested in the field, or for which literature results can be analyzed. The analysis of the estimated intercepts as a function of the ratio of Ellenberg numbers could be described by an increasing function (linear, parameters statistically significant, n=25, Percentage variance explained: 0.20), as suggested by the above theory. In addition we could not show that the exponent is a function of this ratio (slope not significant from 0). The observational data therefore show some support for the functional equilibrium between shoot and root.

REFERENCES

France. J., and Thornley J.H.M. 1984. Mathematical models in agriculture. A quantitative approach to problems in agriculture and related sciences. Butterworths, London etc. 335 pp.

Karrer, G. 2009. http://statedv.boku.ac.at/zeigerwerte/ (accessed june 2009)

Kutschera, L. 1960. Wurzelatlas mitteleuropäischer Ackerunkräuter und Kulturpflanzen. DLG, Frankfurt am Main

Kutschera, L., E. Lichtenegger. 2002. Wurzelatlas mitteleuropäischer Waldbäume und Sträucher. Leopold Stocker Verlag Graz, Stuttgart.

Kutschera, L., E. Lichtenegger, M. Sobotik, D. Haas. 1997. Die Wurzel das neue Organ. Ihre Bedeutung für das Leben von Welwitschia mirabilis und anderer Arten der Namib sowie von Arten angrenzender Natur mit Erklärung des geotropen Wachstums der Pflanzen. Pflanzensoziologisches Institut, Klagenfurt.

Kutschera, L. and Lichtenegger E. 1982. Wurzelatlas mitteleuropäischer Grünlandpflanzen. Bd. 1: Monocotyledoneae. G. Fischer, Stuttgart, New York

Kutschera, L. and Lichtenegger E. 1992. Wurzelatlas mitteleuropäischer Grünlandpflanzen. Bd. 2: Pteridophyta und Dicotyledoneae (Magnoliopsida). Teil 1: Morphologie, Anatomie, Ökologie, Verbreitung, Soziologie, Wirtschaft. G. Fischer, Stuttgart, New York