Fractal dimensions of rooting systems – the case of the Wurzelatlas mitteleuropäischer Ackerunkräuter und Kulturpflanzen

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ABSTRACT

The drawings in the Wurzelatlas mitteleuropäischer Ackerunkräuter und Kulturpflanzen (Root atlas of central European Weeds and Crops, and also in other Atlases by Kutschera and others) offer a unique opportunity to analyze rooting patterns of very different crops and herbs determined using a consistent methodology. Using 203 drawings, the fractal dimension of the drawings are determined. Results are presented and suggest that the fractal dimension of a rooting system increases with the length scale characterizing the root volume.

KEYWORDS: fractal, image analysis, rooting system

INTRODUCTION

The self-similarity of patterns in nature is a well-known phenomenon. Fractal descriptions of rooting systems have been presented in literature (e.g. Eghball et al. 1993; Tatsumi et al. 1989), and have been used to characterize response to nutrient stress. Tatsumi (1995) determined the spatio-temporal changes in fractal dimension of a rooting system.

THEORY

In the box counting method, the fractal dimension of an object is determined from the log-log plot of the number of boxes required to completely cover the object against the size of the box. It is a measure of how completely the object appears to fill the dimensions in which it is located. For two dimensional root system drawings a fractal dimension of 2 would suggest that the root systems completely fills the drawing; a fractal dimension of 1 suggests that the root system consists of a straight line.

METHODS

After digitizing, thresholding and skeletonizing, we used the box counting method to characterize the root drawings of the Atlas published by Kutschera et al (1960). The fractal dimension was then correlated with a number of variables defined in the Atlas, among which the height of the plant H, the maximum rooting depth T, and the lateral extension of the root system S. An equivalent depth of the rooting system was also calculated as the cubed root of the rooting volume TS^2. To include information regarding aboveground and belowground resources the database was extended with the Ellenberg indicator values modified for Austria (Karrer, 2009). Some exploratory regression analyses were executed to analyze possible relations between fractal dimension and the variables

RESULTS AND DISCUSSION

All relations between single Ellenberg numbers and fractal dimension were non-significant. Multivariate regression between fractal dimension and all Ellenberg numbers (excluding invariant species "x") also was non-significant. Relations between the fractal dimension and the size of the plant or its' rooting system showed a weak but statistically significant linear trend (r^2=0.11; n=175). Figure 1 shows the correlation between equivalent root system scale and fractal dimension. Based on an analysis of two-dimensional drawings this result suggests that the deeper the rooting system, the more intensive its' exploration of the area encompassing it. This adds to the study by Tatsumi (1995), who found that the fractal dimension increases when a root system develops.

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Figure 1: Relation between fractal dimension of the rooting system and the equivalent depth of the rooting system. Results suggest fractal dimension increases with equivalent depth.