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Functional branch analysis as tool for fractal scaling above- and belowground trees for their additive and non-additive properties

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Abstract

Empirical allometric scaling equations ($Y = aD^b$) for tree biomass on the basis of stem diameter D are often used in forest inventories and for assessment of carbon and nutrient stocks in vegetation. When shifting from plantation forestry to mixed forestry or multi-species agroforestry systems, however, short-cuts to the empirical approach for establishing such equations are desirable. Fractal branching models provide a transparent scheme for deriving tree-specific scaling rules (especially, the b parameter) on the basis of easily observable, non-destructive methods. The relation between link (section of stem or branch between two branching points) length and link diameter has a direct influence on the b parameter of the allometric equation in the range 2–3.5, providing substantial variation around the claims of a universal value of 8/3. Apart from the total tree biomass, the models can provide rules for total leaf area; relative allocation of current growth to leaves, branches or stem. The power of the allometric scaling relation (b) necessarily has the same value, for a given tree, for all properties that are dominated by the endpoints of the branching process, and that are thus 'additive'. Below ground, similar descriptions hold for individual root axes, where the proximal root diameter can be used for predicting total length or biomass of all its branches. Sampling error was analyzed to derive rules for the number of branching points that should be observed for reliable estimates of the fractal branching parameters. For the inherent parameter variability that was chosen as default setting a minimum number of 50 branching points should be observed. A spreadsheet model (functional branch analysis, FBA) is made available through the WWW that allows users to derive results for new parameter combinations and/or seek new applications.

Keywords: Allometrics; Fractal dimension; Root biomass; Tree architecture; Tree biomass

1. Introduction

Trees cover a broader range of scale in their size than any other organism (Thomas, 2000) and the concept 'tree' needs a scalar before any meaningful statements about biomass, nutrient stocks or uptake, water use, carbon sequestration, pro-

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