
# Negotiation-support toolkit for learning landscapes

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# 13 | Functional branch analysis (FBA): Tree architecture and allometric scaling

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Functional Branch Analysis (FBA) is a tool to generate tree architecture and allometric scaling. It can be used as a non-destructive approach to develop allometric equations that are often used to estimate plot-level carbon stocks.

## Introduction

Trees come in various shapes and sizes, grow at different rates, and interact with their neighbours during development. However, many of the properties of an individual tree can be predicted by the diameter of its stem. The relationship between this diameter and properties such as tree height, tree biomass, leaf area and harvestable timber are called 'scaling rules' or allometrics.

Empirical allometric scaling equations for tree biomass—Y on the basis of stem diameter D—are often used in forest inventories and for assessments of carbon and nutrient stocks in vegetation. The most common form is $Y = aD^b$. The equations are based on cutting selected trees and obtaining destructive measurements that can then be related to the stem diameter. However, a non-destructive approach is sometimes used. In addition to reducing cost and time, it is particularly desirable when shifting from homogenous plantation forestry to mixed forestry or to multispecies agroforestry systems.

Certain regularities in the development of tree form are captured in 'fractal branching' models. Such models can provide a transparent scheme for deriving tree-specific scaling rules on the basis of easily observable, non-destructive methods. Apart from total tree biomass, the models can provide rules for total leaf area and the relative allocation of current growth to leaves, branches, stem or litter, or the ratio of green to brown projection area that modulates tree-crop interactions in a savannah.

## Objectives

The FBA protocol and program are designed to efficiently describe the architecture and key properties of a tree and to use the derived parameters to reconstruct trees with simple, repetitive ('fractal') rules. They are also used to derive scaling rules that relate stem and/or proximal root diameter to total biomass and to other properties. The allometric scaling relations derived with the FBA module can be directly used in the Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) model of tree–soil–crop interactions

## Steps

The model needs information about link diameter and length (that is, shoot or root segment) and about final structure (that is, leaves or fine roots). Not all, but at least 50 and preferably 100, successive links need to be measured to get a precise estimate of branch parameters. The elements of the model governing the branching pattern can be calculated using the FBA Help File. The independency of p (proportionality factor) and q (equity factor) to link diameter should be checked since independency is a requisite for the self-repetition rule.

Fractal branching models repeatedly apply the same equations to derive subsequent orders of the branching process ('self-repetition rule'). For practical applications, a rule is added for stopping when a certain minimum size is reached. The rules can refer to the diameter, length and/or orientation of the next order of branches. Figure 13.1 describes the elements of a functional branch analysis scheme, which can be applied to above- as well as belowground parts of trees. The combinations of the various parameters can be used to predict total size—weight, surface area, length, height, lateral extent—and the allometric scaling equations between these.

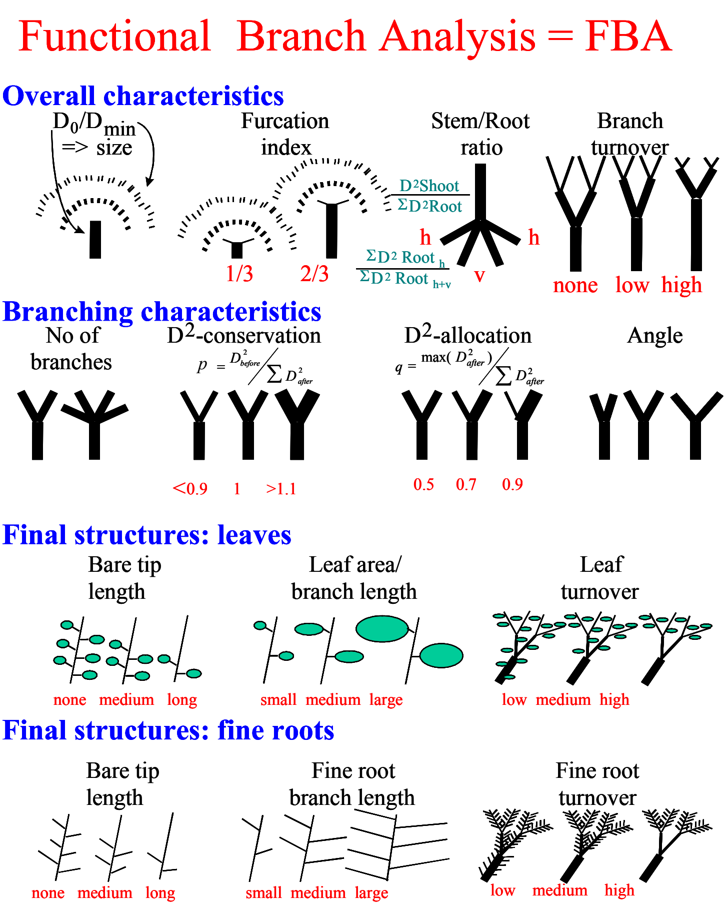


**Figure 13.1.** Elements of the functional branch analysis model for deriving allometric scaling equations between above- or belowground tree parts

## Example of application

A comparison between model estimation and real observation of tree biomass aboveground and its components was carried out for four tropical tree species in the Philippines: *Shorea contorta*, *Vitex parviflora*, *Pterocarpus indicus* and *Artocarpus heterphyllus* (Figure 13.2). Total aboveground tree biomass, as calculated with the allometric equations from the FBA model, fit well with the biomass measurements obtained from destructive methods (Figure 13.2A). Slight differences were found for the tree components: wood ( Figure 13.2B) and leaf biomass (Figure 13.2C) for all four tree species.

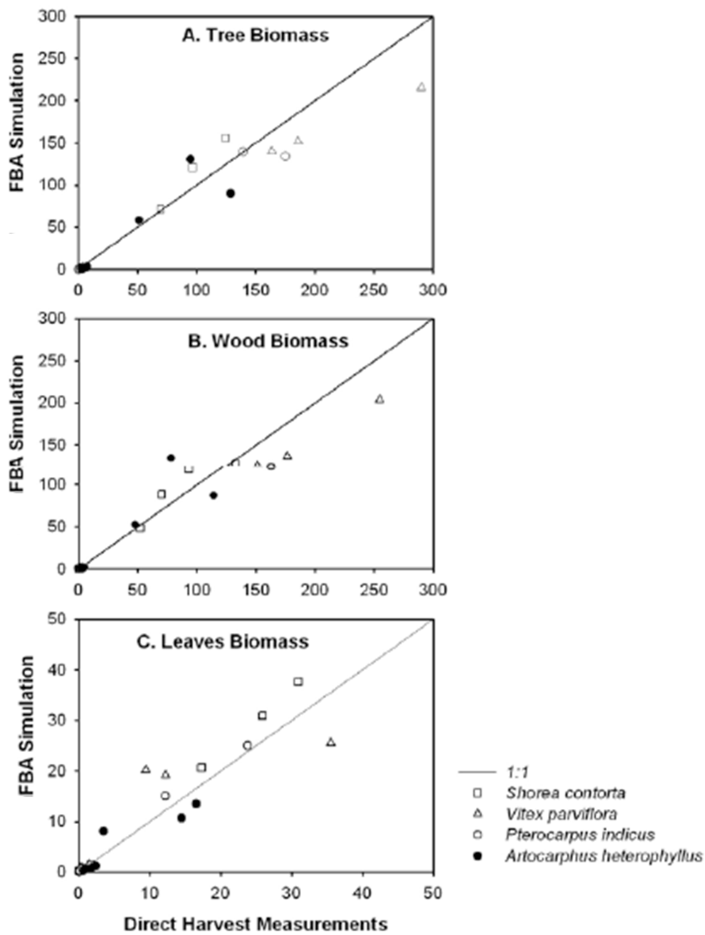


**Figure 13.2.** Comparison between FBA estimation and direct harvest biomass values of tree biomass

**Note:** (A) wood biomass; (B) and leaves biomass; (C) for four tropical tree species in the Philippines: *Shorea contorta*, *Vitsex parviflora*, *Pterocarpus indicus* and *Artocarpus heterphyllus*. Points along the 1:1 line means that values simulated by the FBA exactly match the actual measured values. Source: Martin 2008

FBA is also equipped with visualization tools that can be used if the angles between branches are also measured (figures 13. 3 and 13.4).

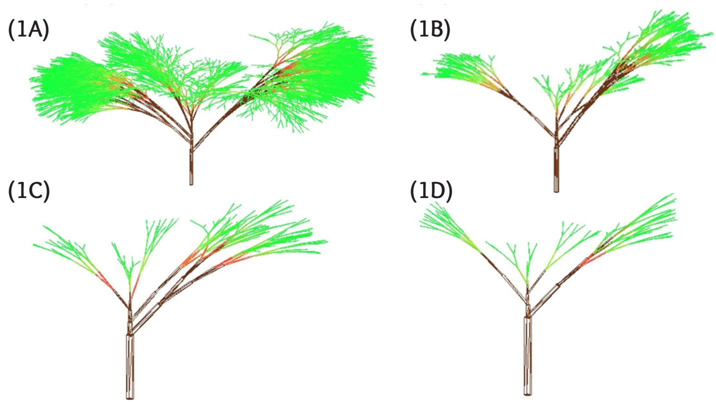


**Figure 13.3.** Example of tree shapes by varying just one parameter in the fractal branching routine

**Note:** In the example above, variation of the proportionality factor, p, for change of stem diameter at a branching point, has the values 0.8, 1.0, 1.2, and 1.4 respectively, in figures A–D. Trees with low p value are endowed with more branches and leaves; those with high p value have fewer branches and leaves owing to more significant branch tapering

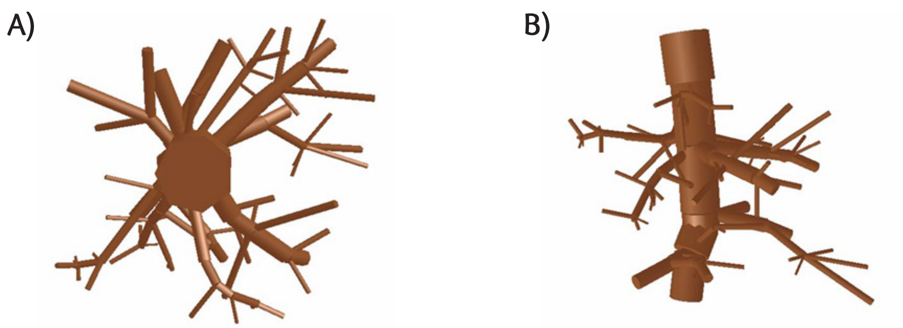


**Figure 13.4.** An example of tree root architecture produced by the FBA model as seen from the top (A) and from the side (B).

## How to get the FBA model

The FBA model, embedded in an Excel worksheet, can be downloaded from the World Agroforestry Centre website: http://www.worldagroforestry.org/sea/Products/AFModels/WaNulCAS/downloadc.htm.

The model allows users to derive results for new parameter combinations and/or to seek new applications.

## Key references


Van Noordwijk M, Mulia R. 2002. Functional branch analysis as tool for fractal scaling above- and belowground trees for their additive and non-additive properties. *Ecological Modelling* 149:41–51.

Smiley G, Kroschel J. 2008. Temporal change in carbon stocks of cocoa–gliricidia agroforests in Central Sulawesi, Indonesia. *Agroforestry Systems* 73:219–231.

The landscape scale is a meeting point for bottom–up local initiatives to secure and improve livelihoods from agriculture, agroforestry and forest management, and top–down concerns and incentives related to planetary boundaries to human resource use.

Sustainable development goals require a substantial change of direction from the past when economic growth was usually accompanied by environmental degradation, with the increase of atmospheric greenhouse gasses as a symptom, but also as an issue that needs to be managed as such.

In landscapes around the world, active learning takes place with experiments that involve changes in technology, farming systems, value chains, livelihoods' strategies and institutions. An overarching hypothesis that is being tested is:

> Investment in institutionalising rewards for the environmental services that are provided by multifunctional landscapes with trees is a cost-effective and fair way to reduce vulnerability of rural livelihoods to climate change and to avoid larger costs of specific 'adaptation' while enhancing carbon stocks in the landscape.

Such changes can't come overnight. A complex process of negotiations among stakeholders is usually needed. The divergence of knowledge and claims to knowledge is a major hurdle in the negotiation process.

The collection of tools—methods, approaches and computer models—presented here was shaped by over a decade of involvement in supporting such negotiations in landscapes where a lot is at stake. The tools are meant to support further learning and effectively sharing experience towards smarter landscape management.


World Agroforestry Centre

ASB Partnership for the Tropical Forest Margins

AARD

Federal Ministry for Economic Cooperation and Development

Norad

IFAD Enabling poor rural people to overcome poverty

CGIAR Research Program on Forests, Trees, and Agroforestry