Allometry und Biomass

Bildquelle J. Schuck

Prof. Dr. Thomas Seifert
Chair of forest Growth
and Dendrocology

thomas.seifert@wwd.uni-freiburg.de

What is Allometry?

Allometry is about measuring and comparing relationships between the dimension (body size) and their relationship to various biological quantities (source: Wikipedia)

$\mathbf{y = a \cdot x^b}$ Allometry equation

is based on the differential equation

$$\frac{dy}{y} = b \cdot \frac{dx}{x}$$

Otto Snell, Göttingen

Photo Wikipedia

thomas.seifert@wwd.uni-freiburg.de

Allometry for biomass determination

Application:
Allometries can be used to estimate the biomass (total AGB or biomass components from easily measurable tree sizes (usually BHD and height).

$$BM = a \cdot DBH^b$$

Classic nonlinear equation

$$\ln(BM) = a_0 + b \cdot \ln(DBH)$$

Ln-transformed linear equation

Advantage: can be parameterized with linear regression
Heteroscedasticity solved
Disadvantage: Must be corrected with variance in back-transformation must be corrected

If uniform stands with similar heights of all trees are used, the BHD is usually sufficient as the only parameter.

thomas.seifert@wwd.uni-freiburg.de

More complex multiple regressions

More complex equations use further independent variables

$$BM = a \cdot DBH^b \cdot H^c$$

Classic nonlinear equation

$$\ln(BM) = a_0 + b \cdot \ln(DBH) + c \cdot \ln(H)$$

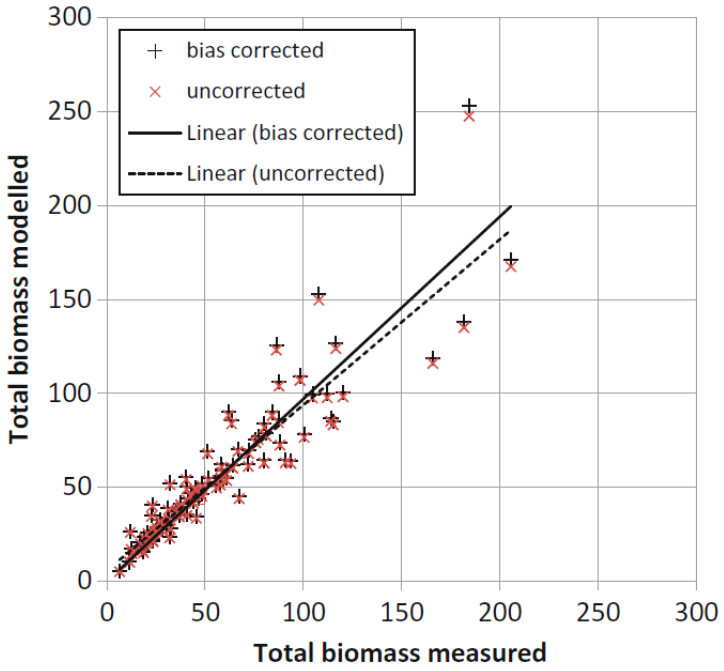
Linearised Equation

Advantage: can be parameterized with linear regressionDisadvantage: Must be bias-corrected with variance in back-transformation

thomas.seifert@wwd.uni-freiburg.de

Modelling

Caution: When using ln-transformed estimates, a bias correction is necessary! back-transformation correction (bias correction) is necessary!



Seifert and Seifert 2014

$$\ln(AGB_{total}) = a + b \ln(D\text{^}2H) + c \ln(H)$$

$$AGB_{total} = e^{(a + b \ln(D\text{^}2H) + c \ln(H) + \text{Varianz } 0.5)}$$

thomas.seifert@wwd.uni-freiburg.de

Modelling

Additivity

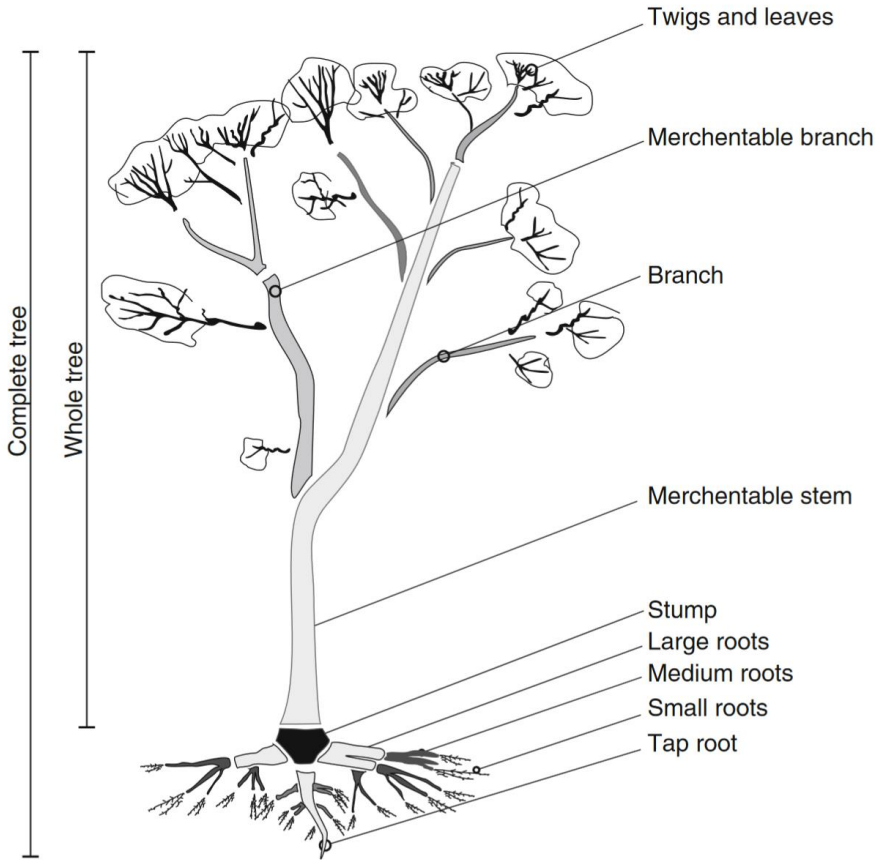
If there are several biomass components, the sums of the BM component models should equal the sum of the total biomass

Multivariate regressions:

Dirichlet regression (Schindler et al. 2023)
Seemingly unrelated regression (Vonderach et al 2019)
Proportionality estimation with the Aitchison copmplex (Seifrt & Seifert 2014).

thomas.seifert@wwd.uni-freiburg.de

Biomassekomponenten



Seifert und Seifert (2014)

Why biomass components?

- Biological statements about Allocation distribution
- Nutrient removals with the timber harvest
- Biomass production for thermal utilization

thomas.seifert@wwd.uni-freiburg.de

How to determine above ground dry mass?

I. Bulk method

1. Chip felled tree
2. Mix chips and weigh chips fresh
3. Dry sample of chips
4. Determine dry weight / fresh weight proportion
5. Scale up to the tree

Bundler, Foto Block

Remember
About 10-15 % branch/needle biomass remains in the stand and cannot be harvested without big effort

I. Bulk method

Advantage

- Delivers accurate estimations
- Fast and cheap for whole stands (biomass plantations)

Disadvantage

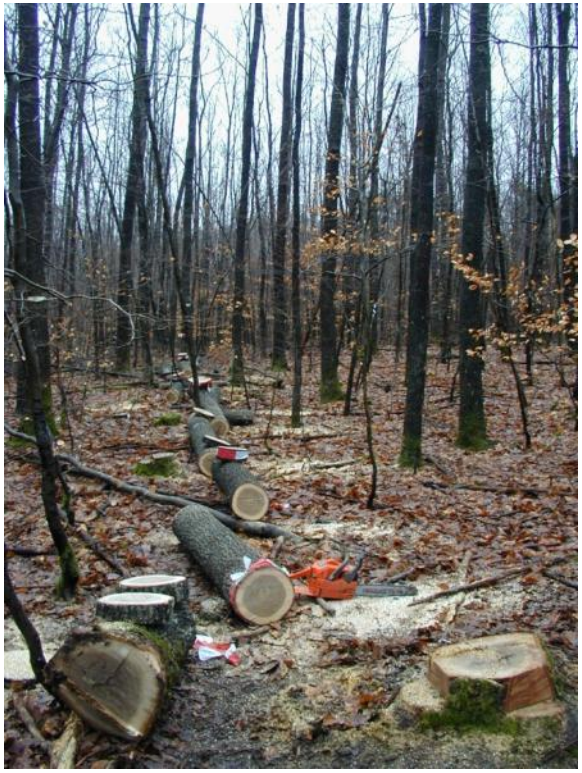
- not feasible at single tree level (mechanical losses)
- not able to split biomass in fractions within a tree (e.g. needles, bark, stemwood, branches, etc.)

How to determine above ground dry mass?

II. Sampling method with full fresh weight record

1. Fell tree
2. Determine fresh weight of tree partitions:

   stem+bark, branch+needles
3. Sample partitions
4. Dry samples
5. Determine dry weight / fresh weight proportion
6. Scale up to the tree



Bundler, Foto Schuck

II Sampling method full fresh weight record

Fresh stem weight with bark

Fresh branch and needle weight

II Sampling method full fresh weight record

Advantage

- Delivers accurate estimations
- Allows for differentiation of tree partitions

Disadvantage

- Only feasible for smaller trees
- Bark and wood as well as branches and needles cannot be separated easily

III. Sampling method with a regression approach

Step 1: Sampling

1. Fell tree

stem

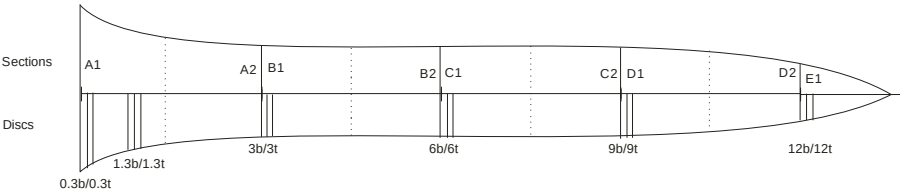
1. Cut stem discs
2. Measure green volume (with and without bark)
3. Dry discs
4. Determine basic density

branch

1. Measure branches in height and diameter at the stem
2. Sample branches for fresh weight (wood, bark, needles)
3. Dry branch samples and determine proportion for fresh / dry weight for wood, bark, needles separately

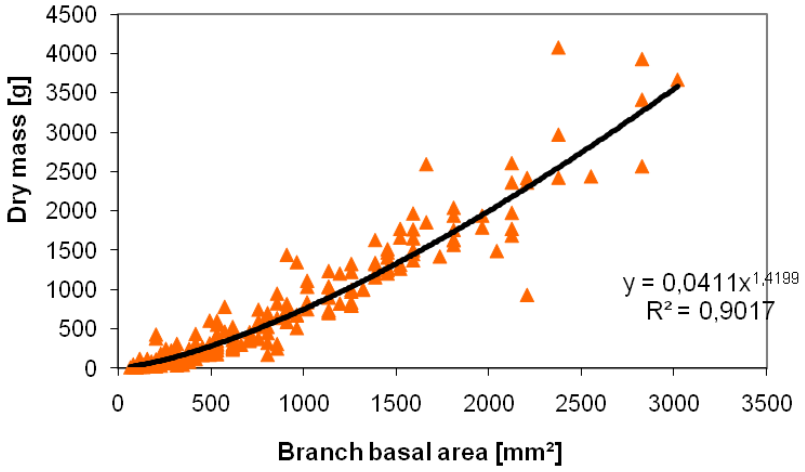
III. Sampling method with a regression approach

III. Compartment method based on regression



Biomass=Volume·Basic Density

$$BM = V \cdot R$$



Step 2: Upscaling

Allometric models $\ln(BMleaf) = a + b \cdot \ln(bba)$

1. Reconstruct stem and bark volume from discs to scale up
2. Model basic density along stem
3. Multiply density with volume
4. develop allometric models that relate biomass (wood, bark, needles) to branch area or diameter
5. Use model for each branch diameter of the tree to scale up to tree level

III. Sampling method with a regression approach

Step 1: Sampling

1. Fell tree

stem

1. Cut stem discs
2. Measure green volume (with and without bark)
3. Dry discs
4. Determine basic density

branch

1. Measure branches in height and diameter at the stem
2. Sample branches for fresh weight (wood, bark, needles)
3. Dry branch samples and determine a proportion for fresh to dry weight for wood, bark, needles separately

Step 2: Upscaling

1. Reconstruct stem and bark volume from discs to scale up
2. Model basic density along stem
3. Multiply density with volume

4. develop allometric models that relate biomass (wood, bark, needles) to branch area or diameter
5. Use model for each branch diameter of the tree to scale up to tree level

Here we are at tree level

What is Biomass?

Biomasse von Holz = Volumen · Basic density

Unitzs	kg	m^3	kg/m^3

Example:

Biomasse:

A tree species has a basic density of 420 kg/m^3 and we want to determine How much biomass 2 fm (m^3) wood of this species have.

420 kg/m^3 · 2m^3 = 840 kg

thomas.seifert@wwd.uni-freiburg.de

How much carbon is in a tree?

$$\text{Carbon} = \text{Biomass} \cdot 0.5$$

Units	kg	kg

Example Calculation:
Biomass:
A tree species has a basic density of 420 kg/m³, and we want to determine how much biomass (weight) 2 solid cubic meters (fm) of this tree species contain.
420 kg/m³·2 m³=840 kg420kg/m³·2m³=840kg

Carbon Content:
840 kg·0.5=420 kg C840kg·0.5=420kg C

thomas.seifert@wwd.uni-freiburg.de

Ho are the carbon dioxide equivalents calculated (CO_2e)?

$$CO_2 = Carbon \cdot 3.67$$

Einheiten	kg	kg

Example

A tree species has a basic density of 420 kg/m³ and we woudl lik et o know the C content

420 kg/m³ · 2 m³ = 840 kg

Carbont: 840 kg · 0,5 = 420 kg (C)

CO_2 = Kohlenstoff · 3,67 = 420 kg (C) · 3,67 = 1541,4 kg(CO_2)

thomas.seifert@wwd.uni-freiburg.de

How to calculate C->CO_2

Reacztion equation: C + 0_2 --> CO_2

1) From 1 Mol(CO_2) we will lget 1 Mol(C) entsteht

2) Basic equation

m = M · n

Mass = molare Mass · Anount

´The molar Masse of C ist M(C) = 12 g/mol

n(C) = m(C) / M(C) = 1000 g / 12 g/mol = 83,333 mol

Im Periodensystem

12,0	16,0
$_6$C	$_8$O

3) Molar Mass of a CO_2 Molecule is calculated the following way:
C: 12, O_2: 16, CO_2 a mulecule consists of 1 C and 2 O
equals M (CO_2) = 12+16+16= 44 g/mol

4) Jetzt Gleichung 2 und 3 zusammenführen und lösen
m(Kohlenstoffdioxid = n(CO_2) · M(CO_2) =83,333 mol · 44 g/mol = 3666,66 g = **3,67 kg**

Ergebnis: 1 kg Kohlenstoff im Holz entspricht 3,67 kg Kohlendioxid

thomas.seifert@wwd.uni-freiburg.de

Carbon in forets stands

C in Forest stands

AGB + BGB + NM + litter+ SOC

AGB Above Ground biomass

BGB below ground biomass

NM necromass

Litter

SOC Soil organic carbon

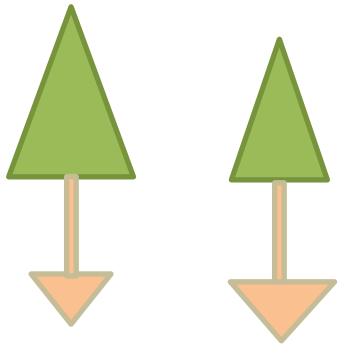
thomas.seifert@wwd.uni-freiburg.de

AGB vs BGB

Die Datenlage bei unterirdischer Biomasse ist schlecht

On avreage 25% of the theal tree biomass is BGB

Lichtlimitierung



H_2O bzw. Nährstofflimitierung

Influenec of H_2O und Nutrient on Proportions of AGB and BGB

thomas.seifert@wwd.uni-freiburg.de

Wieviel Holz kommt denn aus dem Wald?

Erntefestmeter = Vorratsfestmeter · 0,8

Standing Volume (Vfm) is usually measured with bark included. It refers to coarse wood (>7 cm in diameter). This is used to describe the stock of standing wood in the forest, and the harvest rate is also expressed in terms of Vfm.
Harvest Volume (Efm) is used when wood is harvested. Depending on the tree species, it typically involves a deduction of about 10% for bark and 10% for harvesting losses. Species-specific conversion factors are available for this. "Dameter under bark." means that the bark deduction has already been applied (coarse wood without bark).

Even during the harvesting of branches and limb material, about 15–20% usually remains in the forest as harvesting losses.

thomas.seifert@wwd.uni-freiburg.de

How much wood is used for structural purposes?

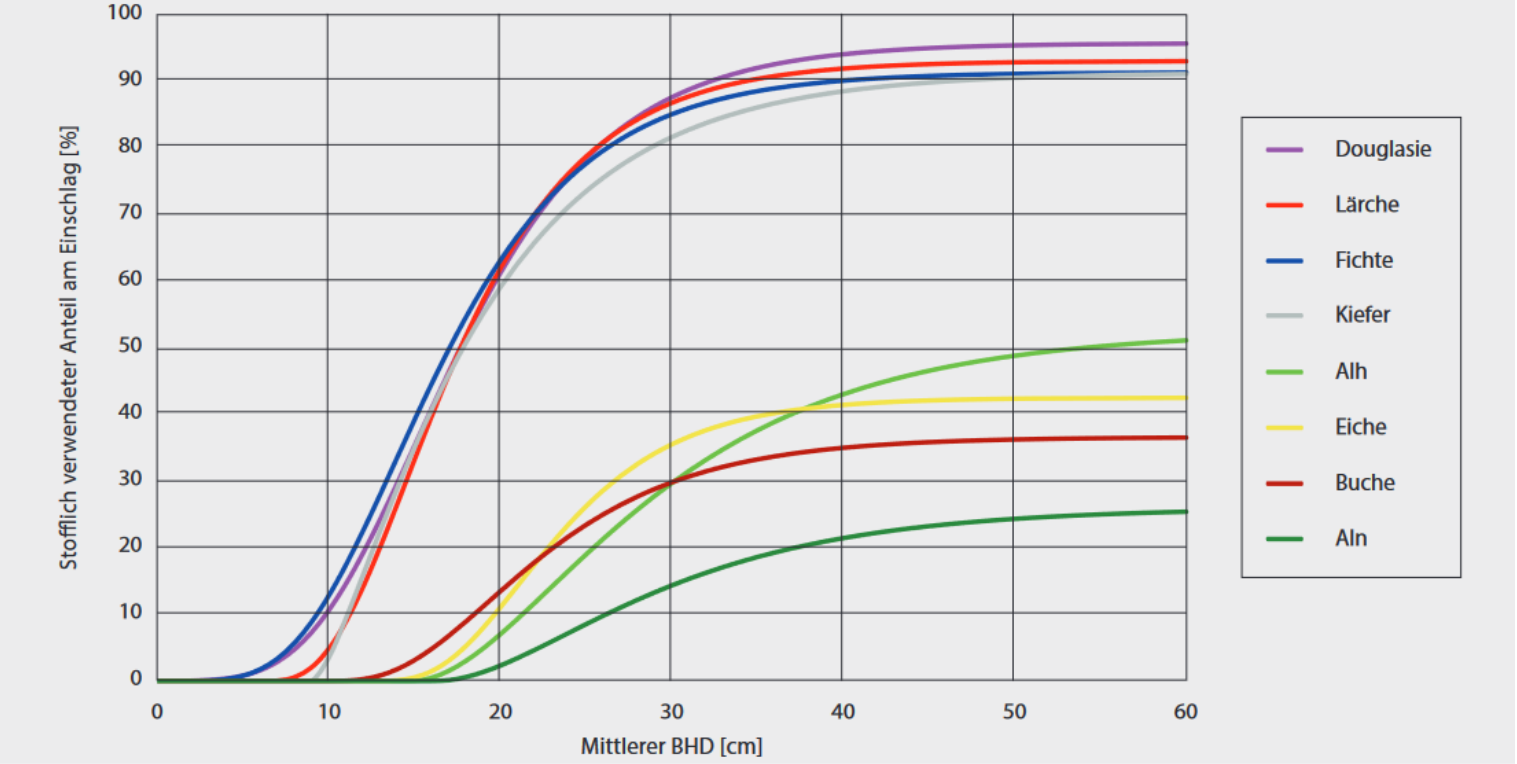


Abbildung 3
Anteil der stofflichen Verwendung in Abhängigkeit des mittleren BHD getrennt nach Baumartengruppen

thomas.seifert@wwd.uni-freiburg.de

How much sawing residues are lost from roundwood in Sawmills?

About 50%

Typically used for energy production for the sawmill or as pellets.

thomas.seifert@wwd.uni-freiburg.de