Manual for tree allometric equations
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Expert meeting on tree volume, biomass allometric equations

- Manual for tree allometric equations

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May 26, 2014
KFRI, INDIA
What is Allometry?

Broad definition: within a given population, there is a statistical relationship between the size of an organism and the size of any part of it (Gould, 1966)

For example: between height and diameter; diameter and crown size; biomass and diameter; etc.

Can be used to predict some difficult-to-measure tree characteristics from easily collected data.

Volume prediction

Biomass prediction

Nutrient content prediction

Volume tables

Biomass equations

Nutrient content equations
What is Allometry?

More restrictive definition: proportionality between the relative increments of two metrics measured on an organism (Huxley, 1924)

\[ \frac{dB}{B} = a \frac{dD}{D} \]

Which gives by integration

\[ B = b \times D^a \]

And by extension

\[ B = c + b \times D^a \]

Where \( a \) gives the proportionality between the relative increments, \( b \) gives the proportionality between biomass and diameter (given \( a \)) and \( c \) is the biomass of the tree when \( D = 0 \) (if \( D \) was measured at a height different from zero).
From the idea… (in 2005)

- Students are not familiar with the appropriate and up-to-date fitting techniques
- The “magic” R2 is usually preferred to the biological meaning of the equations
- Models are fitted without considering the structure in the data set (source of variations)
- Outliers are too easily removed from the data set while they can bring information on the structure of the dataset

And so on ….

There was then a strong need to make a new review on the methods to build tree allometric equations

Including biological concepts, up-to-date statistical procedures and training examples
……To the result (2012)


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Available in French, English and Spanish

Content, 7 steps

G. Validation of the model and prediction of trees volume or biomass

A. Selection of trees biomass explanatory variables and the area of validity of the equation

B. Design of the sampling and selection of the trees to be measured

C. Preparation and implementation of field and laboratory measurements

E. Graphic exploration of the dataset

F. Fitting of the allometric equation

D. Data entering and shaping
1. Tree growth, biomass partitioning and biomass allocation - Biological concepts

Tree and stand growth: case of even-aged and monospecific forests

- **Stand production**

  **Eichhorn's rule**

  Wood production (volume) of a given tree species at a given stand mean (or top) height should be identical for all site classes.

  - Soil fertility (site index) determines the time need to attain this height and volume.

- **Assmann's yield level theory**

  - There are some range of variations of wood production at a given top height (variations related to the stockability issue)

- **Langsaeter Hypothesis**

  - Losses in productivity if the standing stock is too low
2 Sampling strategy and stratification

Sampling strategy

Some theoretical considerations, case study relating tree volume to $D^2H$

Taking $E=5\%$, a tree volume of $2m^3$, $\mu=5m^3$ and $\tau=1m^3$...... $n=98$ trees

Is there a way to lower this number of trees, ie, to optimize the sampling?

$1 + E \approx \sqrt{1 + \frac{1}{n} + \frac{(D^*H^* - \bar{D}^2H_e)^2}{\sum_{i=1}^{n}(D_i^2H_i - \bar{D}^2H_e)^2}}$

$(1 + E)^2 - 1 \approx \frac{1}{n}$

Minimize this value (but difficult to do in practice on the field)

Maximize this value = sampling the extreme trees....

And $n=10$ trees
3 Field work

Step 2

× Above-ground biomasses

Sampling of cross-sections regularly along the trunk. The width of the cross-sections should be fixed for all heights within the trees. For multi-stem trees, take cross-sections in all stems.

Mixing leaves before taking a sample.

Stump:
Top limit = above-ground point where the tree was cut
Down limit = where the roots could be clearly individualized

Example, Rubber tree in Thailand
4 Data recording and checking

How data resulting from inventory and monitoring efforts will be acquired, managed, processed, checked, analyzed, distributed, and archived.

**Objective:**
To transfer field data into ONE electronic database

Different types of software:
- Microsoft Office
- Access
- MySQL

http://science.nature.nps.gov/im/datamgmt/index.cfm
5 Data analysis and graphical exploration of the structure in the data sets

Different relations between two variables $X$ and $Y$

(a) Linear relation and constant variance of the residue,
(b) Non linear relation and constant variance
(c) Linear relation and non constant variance of the residue
(d) Non linear relations and non-constant variance of the residue
6 Model fitting

**Goodness of fit**

- How to assess the goodness of fit (for linear and non-linear models)

Example errors with heteroscedasticity
5 Use of harmonised definitions of tree components

- Crown diameter (m)
- Crown area (m²)
- Tree height (m)
- Log height (m)
- Tree volume (m³)
- Branch volume (m³)
- Leaf volume (m³)
- Basal area (m²)
- Basal circumference or diameter (cm)
- Circumference or diameter (cm) at 1.3m

- Bark (B)
- Gross branches: D>7cm (Bg)
- Thin branches: D<7cm (Bt)
- Leaves (L)
- Large roots (Rb)
- Medium roots (Rm)
- Fine roots (Rf)
- Stump (S)
- Trunk-underbark (T)
- Dead branches (Bd)
- Gross branches: D>7cm (Bg)
- Large roots (Rb)
- Fine roots (Rf)
- Stump (S)
- Trunk-underbark (T)
- Fruit/seed (F)
7 Model use and biomass prediction

Using a biomass/volume equation

- Confidence intervals for the predictions

General case for linear and non-linear regression, utilization of the delta-method (Serfling, 1980)

Confidence interval for the mean

\[
Y(X) \pm t_{(1-\alpha/2)} \cdot \sqrt{\frac{s^2_y}{n}}
\]

Confidence interval for an individual prediction

\[
Y(X) \pm t_{(1-\alpha/2)} \cdot \sqrt{\frac{s^2_y}{n} + \hat{\sigma}_\varepsilon^2 \cdot X^2}
\]

with:

\[
\begin{aligned}
\sigma_y^2 &= \left( \frac{\partial Y}{\partial \beta} \right) \Sigma \left( \frac{\partial Y}{\partial \beta} \right) \quad \text{The variance for } Y \\
\left( \frac{\partial Y}{\partial \beta} \right) &= \text{The matrix of the derivative of } Y \text{ toward the model parameters} \\
\left( \frac{\partial Y}{\partial \beta} \right)^T &= \text{The transposed matrix of } \left( \frac{\partial Y}{\partial \beta} \right) \\
\Sigma &= \text{The covariance matrix of the parameters} \\
\end{aligned}
\]

- \(\hat{\sigma}^2\): The variance of errors of the given compartment

- \(\hat{\sigma}_\varepsilon^2\): The variance of errors of the given compartment regarding the whole system of equation

- \(X^2\): The weighting function
Training courses

- Fourth set in Sri Lanka after Ecuador (Ecuador, Panama, Paraguay), Vietnam (Vietnam and Indonesia) and Zambia (Zambia and Tanzania)
- 107 persons from more than 25 institutions
Objectives

- to present the current and up-to-date knowledge for building allometric equations including courses on the related theory, field operations, fitting and use of the allometric equations,
- to propose technical exercises aiming at identifying gaps (knowledge, allometric equations and raw data) to report carbon stocks and carbon stock changes at the country level,
- to propose practical works on raw data to get familiar with the statistical software and to build allometric equations from their own data sets,
- to help participants in elaborating their road map at national level (general scheme illustrating the required information and data fluxes from the forest stratification to the carbon stock assessments, identification of the existing raw data and allometric equations, bringing to light the gaps, quality control procedures, elaboration of a preliminary road map),
- to elaborate a translational network of experts on allometric equations.
Validation of the model and prediction of trees volume or biomass

A. Selection of trees biomass explanatory variables and the area of validity of the equation

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Complexity of tree growth and biomass allocation

Sampling strategy and stratification

Field work: example from case studies

Data entering, data management and QC

Graphical analysis and first data interpretation

Practical cases and issues related to model fitting

Identification of the data to be used for the exercise

Use and prediction
<table>
<thead>
<tr>
<th><strong>Planning</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAY 1: Overview of the current status of the development of allometric equations in the countries</strong></td>
</tr>
</tbody>
</table>

| Presentation of the content of the training | Matieu | https://dl.dropbox.com/u/6896677/Content%20of%20the%20training-web.pdf |
| Forest types and ecological stratification of Vietnam (Including presentation on the structure of the forest based on data from previous NFI cycles) and AE development plan under UN-REDD Vietnam | Vietnam Study Team (including 20 min presentation by Phuong, RCFEE) | https://dl.dropbox.com/u/6896677/2012_VTP_Forests%20and%20AE%20development.pdf |
| Current status of knowledge on volume and biomass assessment (including description of the database, methodology used, sources, quality of the raw data, wood density, etc.) | Vietnam Study Team (including 20 min presentation by Hung, FIPPI) | https://dl.dropbox.com/u/6896677/Current%20status%20of%20knowledge%20on%20volume%20and%20biomass.pdf |
| Forest types and ecological stratification of Indonesia (Including presentation on the structure of the forest based on data from previous NFI cycles) | Indonesia | https://dl.dropbox.com/u/6896677/presentation%20in%20Vietnam-revised.pdf |
| Current experiences from destructive measurement field work and identified gaps overall | Indonesia | https://dl.dropbox.com/u/6896677/Experiences%20from%20destructive%20measurement%20fieldwork%20in%20Indonesia.PDF |
| Development of allometric equations for estimating forest carbon stocks based on field measurement (ground based forest carbon accounting): | http://www.dephut.go.id/files/SNI%207725%202011%20_(English%20version)%20Development%20of%20allometric%20equations%20for%20estimating%20forest%20car_0.pdf |
| 1. What are the steps and procedures for estimating national forest carbon stocks? | | https://dl.dropbox.com/u/6896677/DSCN0995.JPG |
# Planning

## DAY 2: Development of allometric equations “state of the art”

<table>
<thead>
<tr>
<th>Topic</th>
<th>Speaker</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building tree allometric equation to assess volume and biomass</td>
<td>Matieu</td>
<td><a href="https://dl.dropbox.com/u/6896677/Building%20tree%20allometric%20equation%20to%20assess%20volume%20and%20biomass%20%5BAutosaved%5D.pdf">Building%20tree%20allometric%20equation%20to%20assess%20volume%20and%20biomass%20state%20of%20the%20art.pdf</a></td>
</tr>
<tr>
<td>Complexity of tree growth and biomass allocation</td>
<td>Laurent</td>
<td><a href="https://dl.dropbox.com/u/6896677/Biomass%20TrainingMaterial%20FromBiologyToAE.pdf">Biomass%20TrainingMaterial_FromBiologyToAE.pdf</a></td>
</tr>
<tr>
<td>1. Which are the forest stratum without AE in your country?</td>
<td>discussions</td>
<td><a href="https://dl.dropbox.com/u/6896677/Presentation_Table_1_Day2.pdf">VN%20table%201.pdf</a></td>
</tr>
<tr>
<td>2. Do those forest strata contribute significantly to emissions?</td>
<td>discussions</td>
<td><a href="https://dl.dropbox.com/u/6896677/Presentation.pdf">VN%20table%202.pdf</a></td>
</tr>
<tr>
<td>3. What is the max and min tree diameter sampled? How many tree sample per diameter class?</td>
<td>discussions</td>
<td><a href="https://dl.dropbox.com/u/6896677/AE%20and%20N%20-%20TNU.pdf">VN%20TNU.pdf</a></td>
</tr>
<tr>
<td>Field work: example from case studies</td>
<td>Laurent / Matieu</td>
<td><a href="https://dl.dropbox.com/u/6896677/Field%20work_example%20from%20case%20studies%20%5BAutosaved%5D.pdf">Field%20work_example%20from%20case%20studies.pdf</a></td>
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<tr>
<td>Practical cases and issues related to model fitting</td>
<td>Laurent</td>
<td><a href="https://dl.dropbox.com/u/6896677/Indon-Question%202.pdf">Indon-Question%202.pdf</a></td>
</tr>
<tr>
<td>Use and prediction</td>
<td>Laurent</td>
<td><a href="https://dl.dropbox.com/u/6896677/Biomass%20TrainingMaterial_ModelUse.pdf">Biomass%20TrainingMaterial_ModelUse.pdf</a></td>
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</table>
Planning

DAY 3-4: Exercises on development of allometric models

- Installation of the statistical software
- Graphic exploration (different set of data)
- Model fitting with and without heteroscedasticity by tree compartment
- Model fitting for total aboveground biomass (with or without additivity)
- Biomass assessment using existing data and models (development of decisional trees)

1. Which are the different equation forms (the main commons)?
2. Which are the inputs in your equations?
3. Which are the statistical information you collected to describe those equations?
   (exercise done on database)

- By group
- SAS software installed per group (for the training only)
- Exercise using sample data

Indonesia 1:
https://dl.dropbox.com/u/6896677/Answers%20Group%201-Model%20fitting.docx

VN 1:
https://dl.dropbox.com/u/6896677/PP_Huong.pptx