

Abial – a growth simulator for pure even-aged stands of silver fir (*Abies alba* Mill.) in Vosges and Jura

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Objective

Reply to a demand by Office National des Forêts

- a model able to predict future growth of silver fir stands in NE France

mainly : pure and even aged natural stands
in Vosges + Jura / Morvan

model for mixed forests & Alpes in construction at Cemagref

- at low cost

using yet available data (INRA, ONF, IFN)

based on the Fagacées model for oak and beech
(by Jean-François Dhôte, Gilles Le Moguédec, Patrick Vallet)

implemented in the open Capsis platform
(<http://www.inra.fr/capsis>)

short development time (~ 2 months + data preparation)



Model overview

Distance-independent individual tree model

- initial data
 - stand data (fertility + location)
age, G, N (or inventory list of diameters)
- management scenario
- results
(at each step)
 - tree heights, diameters, volumes

Based on 5 core equations + volume

- stand level
 - self-thinning
 - dominant height
 - basal area increment
- tree level
 - tree radial increment
 - tree height
 - tree volume

$$\ln(N) \leq a + b \ln(Dg)$$

$$H_o = f(\text{age, fertility})$$

$$dG = f'(H_o, \text{silv}) \cdot dH_o$$

$$dg_i = f(g_{i,a-1}, dG, \dots)$$

$$h_i = f(d_i)$$

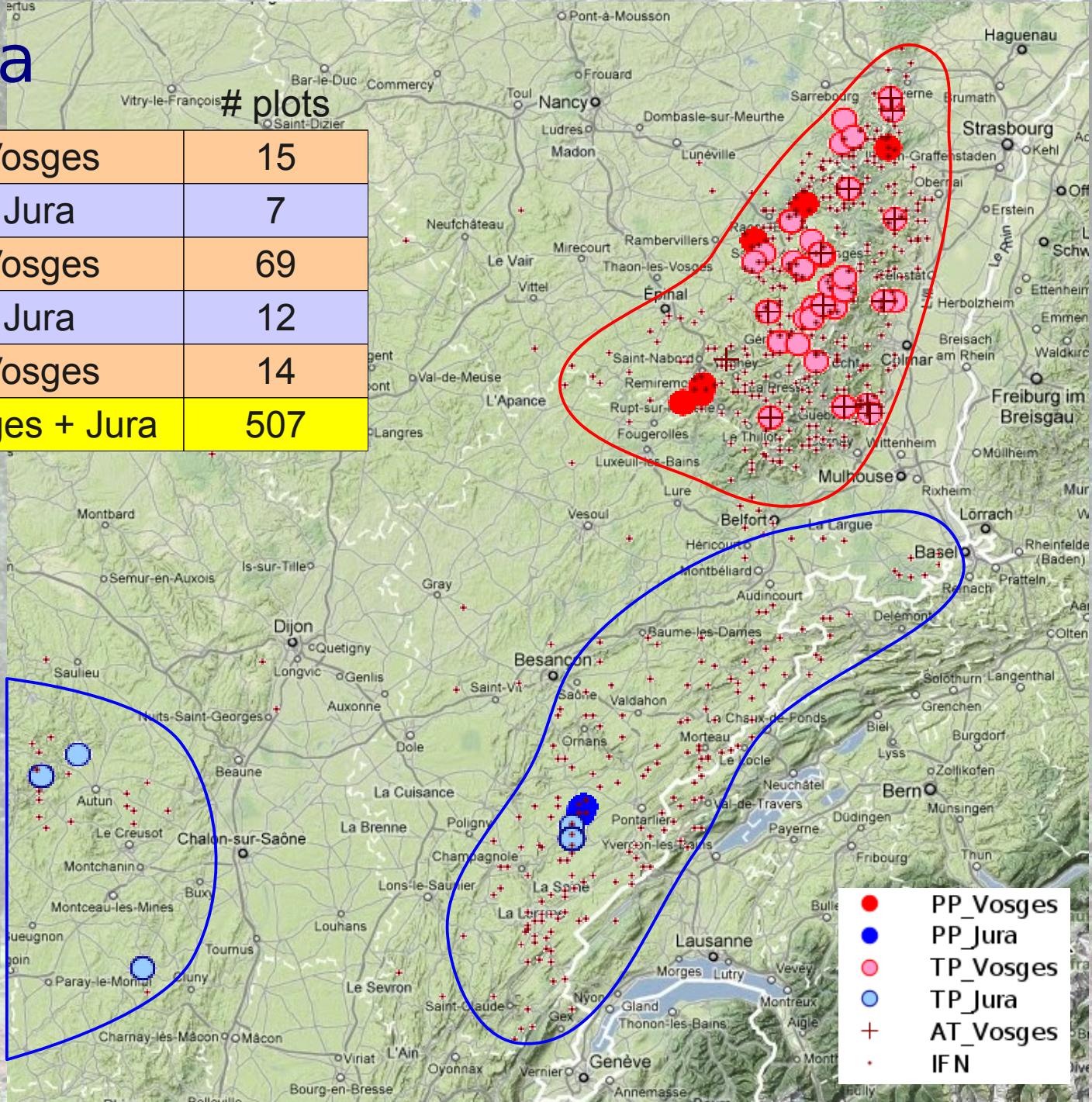
$$v_i = f(h_i, d_i)$$

Available data

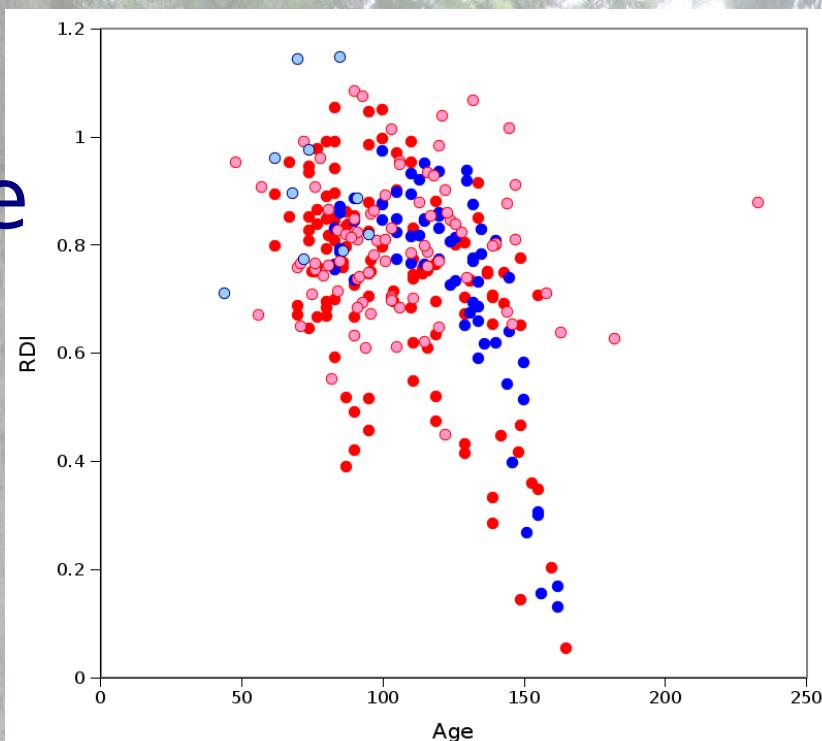
		# plots
permanent plots	Vosges	15
	Jura	7
temporary plots	Vosges	69
	Jura	12
height increments	Vosges	14
IFN inventory data	Vosges + Jura	507

→ good sampling for Vosges
few data in Jura + Morvan

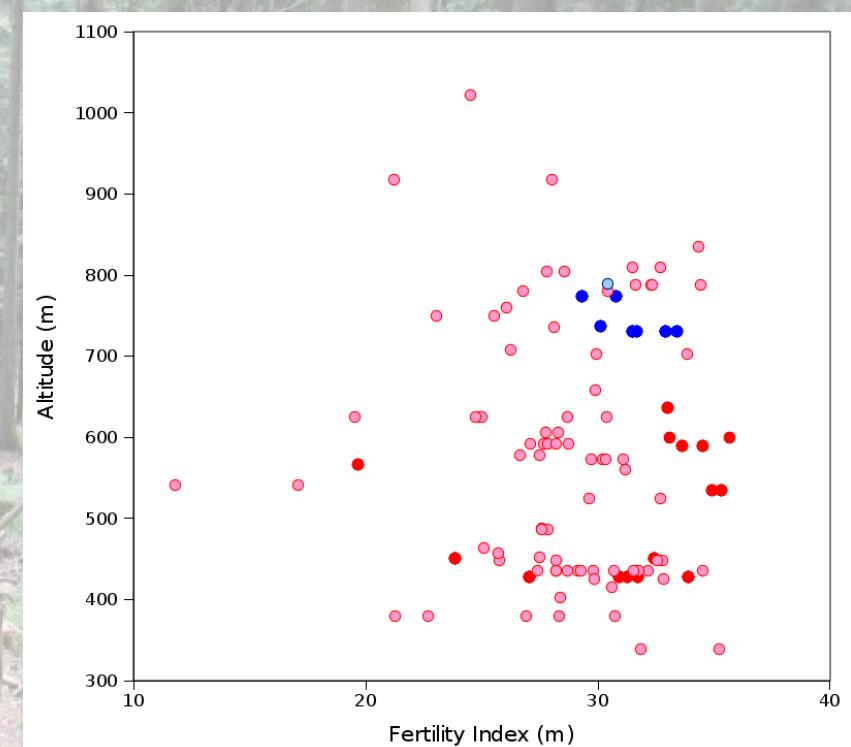
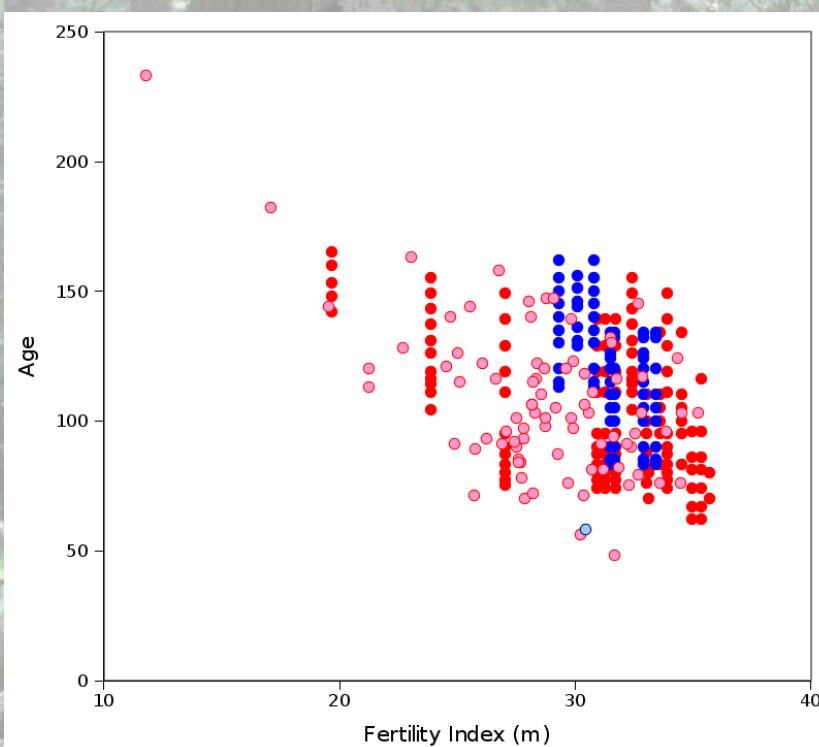
- data encoding
(Daniel Rittié et al)
- automatic verification & corrections
(Ingrid Seynave)
- altitude from GIS + digital terrain model
(Vincent Perez)



Data structure



- large ranges:
 - elevation 350 to 1000 m
 - age 50 to 160 years
 - fertility 20 to 35 m at 100 years
 - RDI 0.1 to 1
- ~ good sampling for elevation, fertility, age
- lack of young stands with low density ($\text{RDI} < 0.6$)



Self-thinning model

self thinning

F. Longuetaud, F. Mothe

$$\ln(N) \leq a + b \ln(Dg)$$

- data

IFN points + permanent plots

- method

Stochastic frontier analysis (SFA)
(Zhang et al 2005)
using R package "Frontier"

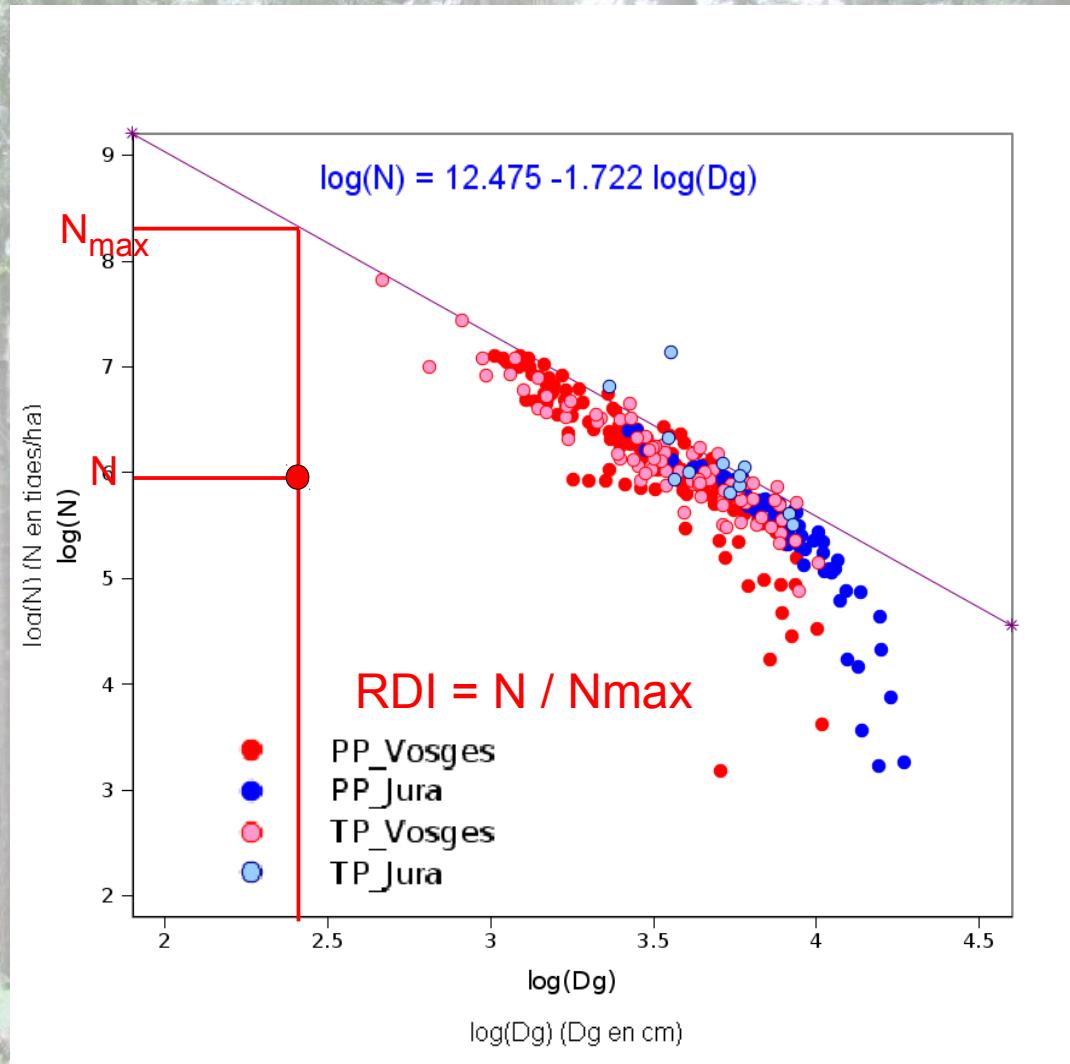
$$Y = \alpha + X\beta + (V - U)$$

V = normal distribution

U = half-normal distribution

plots with $Dg < 15$ cm or
 $Dg > 45$ cm were removed

- allows to compute the RDI
(Reineke|Relative Density Index)



Zhang L., Bi H., Gove J.H., Heath L.S., 2005. A comparison of alternative methods for estimating the self-thinning boundary line. *Canadian Journal of Forest Research* 35: 1507-1514.

Dominant height curve

J.D. Bontemps

dominant height curve

$H_0 = f(\text{age, fertility})$

- data

29 permanent plots + height increments for Vosges

7 permanent plots for Jura

- method

Vosges : Lundqvist-Matern model (Zeide 1993)

$$H_0(t) = K \cdot \exp \left[- \left(\frac{R \cdot m \cdot C_m}{K} \cdot (t - t_0) + \ln \left(\frac{K}{H_0(t_0)} \right)^{-m} \right)^{-1/m} \right]$$

with: $C_m = \exp((1+m) \cdot (1 - \ln(1+m)))$

$t_0 = 15$ years $H_0(t_0) = 1.30$ m

R = fertility index m, K = constants

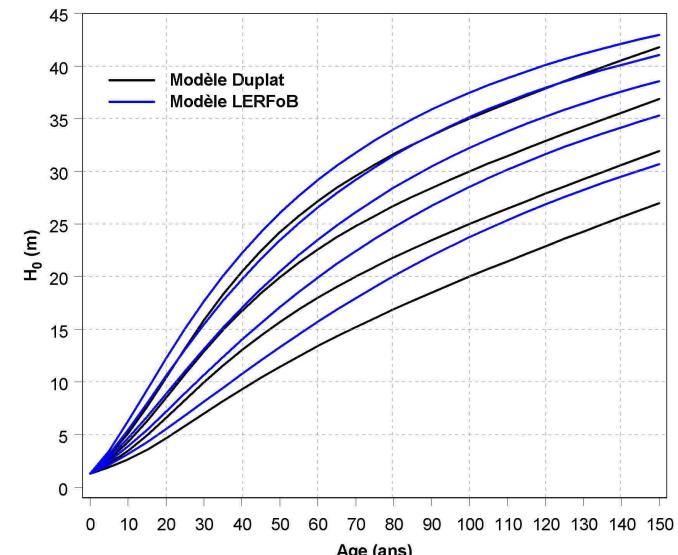
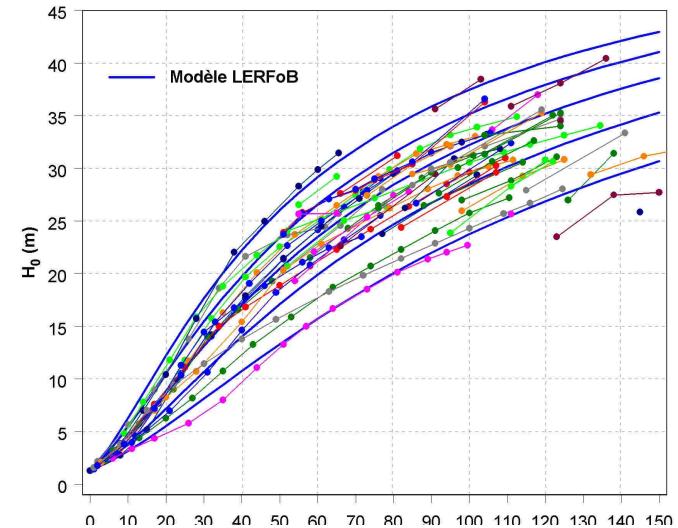
Zeide, B. (1993). Analysis of growth equations.
Forest Science 39:594-616

Jura : existing Duplat (1980) model

Duplat P. (1980). Tables de production de référence pour le sapin du Jura.

Bulletin Technique de l'ONF, 11:13-26.

Journée Capsis – 22 juin 2010 – Montpellier



Stand basal area increment

basal area
increment

$$dG = f' (H_0, \text{silv}) \cdot dH_0$$

J.D. Bontemps

- data

15 permanent plots for Vosges
7 permanent plots for Jura
exploratory analysis using IFN data

- method

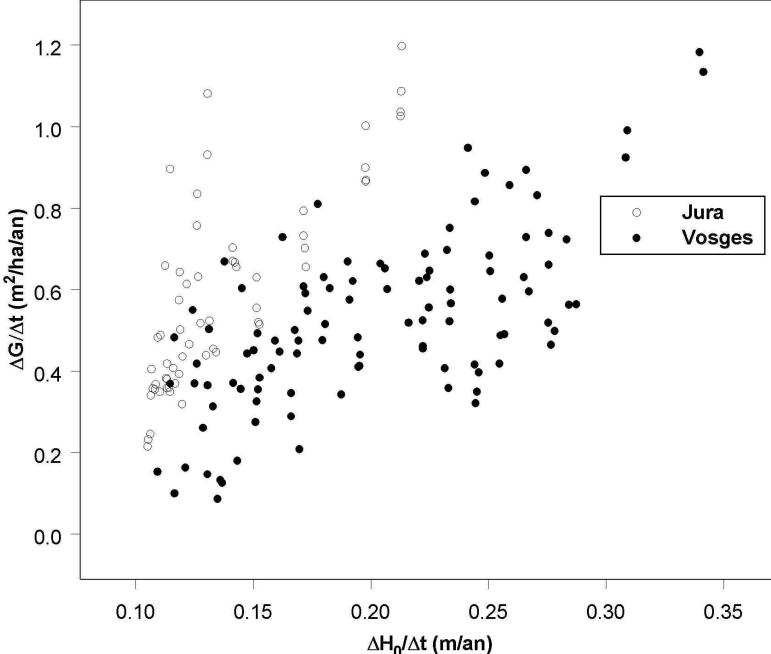
Eichorn relation: $G = f (H_0, \text{silv.})$

Differential form:

$$\Delta G / \Delta t = f' (H_0, \text{silv.}) \cdot \Delta H_0 / \Delta t$$

In practical:

silviculture effect = RDI
elevation and region effect



$$\frac{\Delta G}{\Delta t}(t) = RDI^a \cdot \exp \left[b \cdot ALT + (c_0 + c_{ma} + d_{ma} \cdot H_0(t)) \right] \cdot \exp \left(\frac{\sigma^2}{2} \right) \cdot \frac{\Delta H_0}{\Delta t}(t)$$

with: a, b, c_0, σ = constants

c_{ma}, d_{ma} = region dependant constants

Tree radial increment

L. Saint-André

- data

15 permanent plots for Vosges
7 permanent plots for Jura
+ remeasured temporary plots

- method

Deleuze et al 2004 model

$$\Delta g(t) = p \cdot \Delta G(t) \cdot \left(c_t - m \cdot A + \left((m \cdot A + c_t)^2 - 4 \cdot A \cdot c_t \right)^{1/2} \right)$$

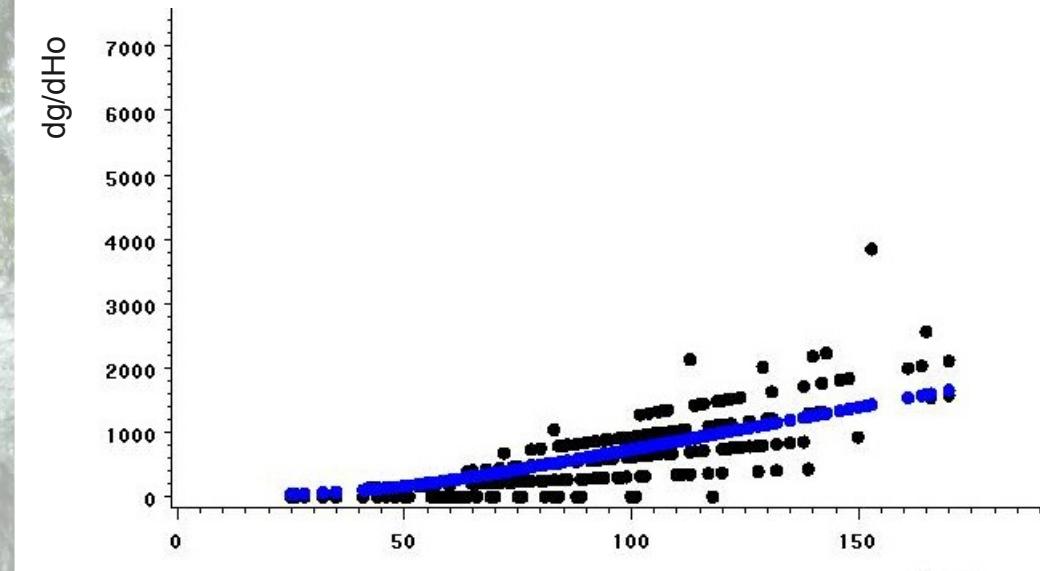
with: c_t = circumference

$$p = p_0 \left[RDI_t^{p_1} + p_2 \cdot \ln(0.002 + \Delta RDI_t) \right]$$

p_0, p_1, p_2, m, A = constants

tree diameter increments

$$dg_i = f(g_{i,a-1}, dG, \dots)$$



Deleuze C., Pain O., Dhôte J.-F., Hervé J.-C. (2004). A flexible increment model for individual trees in pure and even-aged stands. *Annals of Forest Science*, 61:327:335.

Tree height

tree heights

F. Longuetaud, F. Mothe

$$h_i = f(d_i)$$

- data

84 permanent + temp plots for Vosges
19 permanent + temp plots for Jura

- method

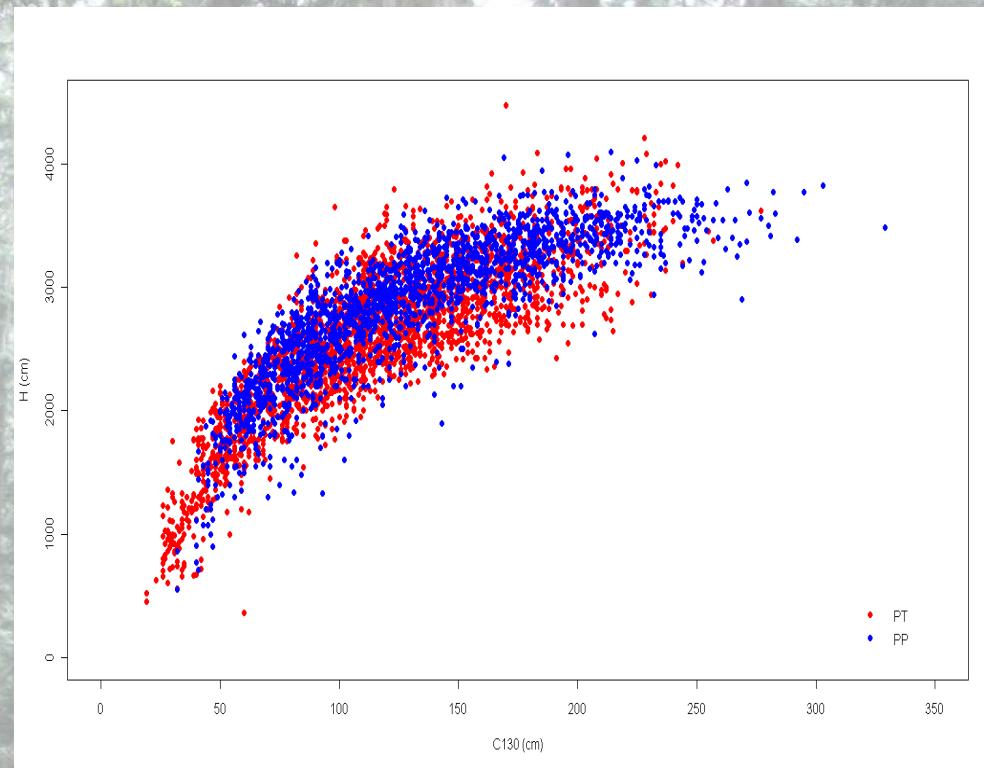
Height vs diameter relation:

$$h_t = 1.30 + m_1 \left(1 - \exp \left(-(b_0 + b_1 \cdot m_1) \cdot c_t \right) \right)$$

with: c_t = circumference

$$m_1 = a_0 + a_1 H_0 + a_2 FI + a_3 Age + a_4 ALT$$

a_i, b_i = constants



Tree volume

literature models

- total aboveground volume

$$v_t = \frac{c^2 \cdot h_t}{40000 \pi} \cdot \left[a + b \cdot c_t + \frac{c \cdot \sqrt{c_t}}{h_t} \right]$$

with: c_t = circumference

h_t = height

a, b, c = constants

- commercial volume > 7 cm

$$v_t = a + b \cdot d_t^2 \cdot h_t + c \cdot h_t + d \cdot d_t^3 \cdot h_t + e \cdot d_t$$

with: c_t = circumference

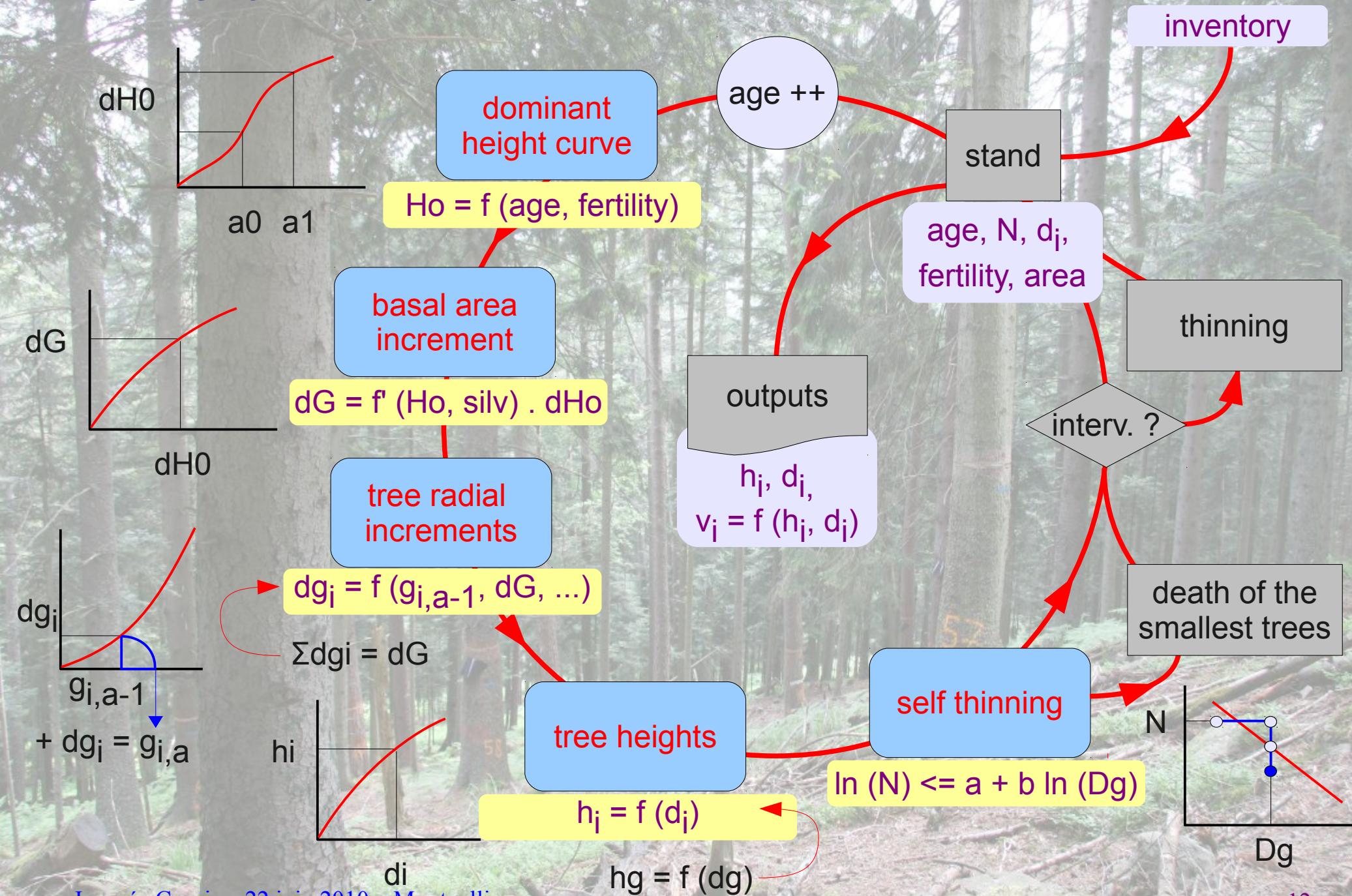
h_t = height

a, b, c, d, e = constants

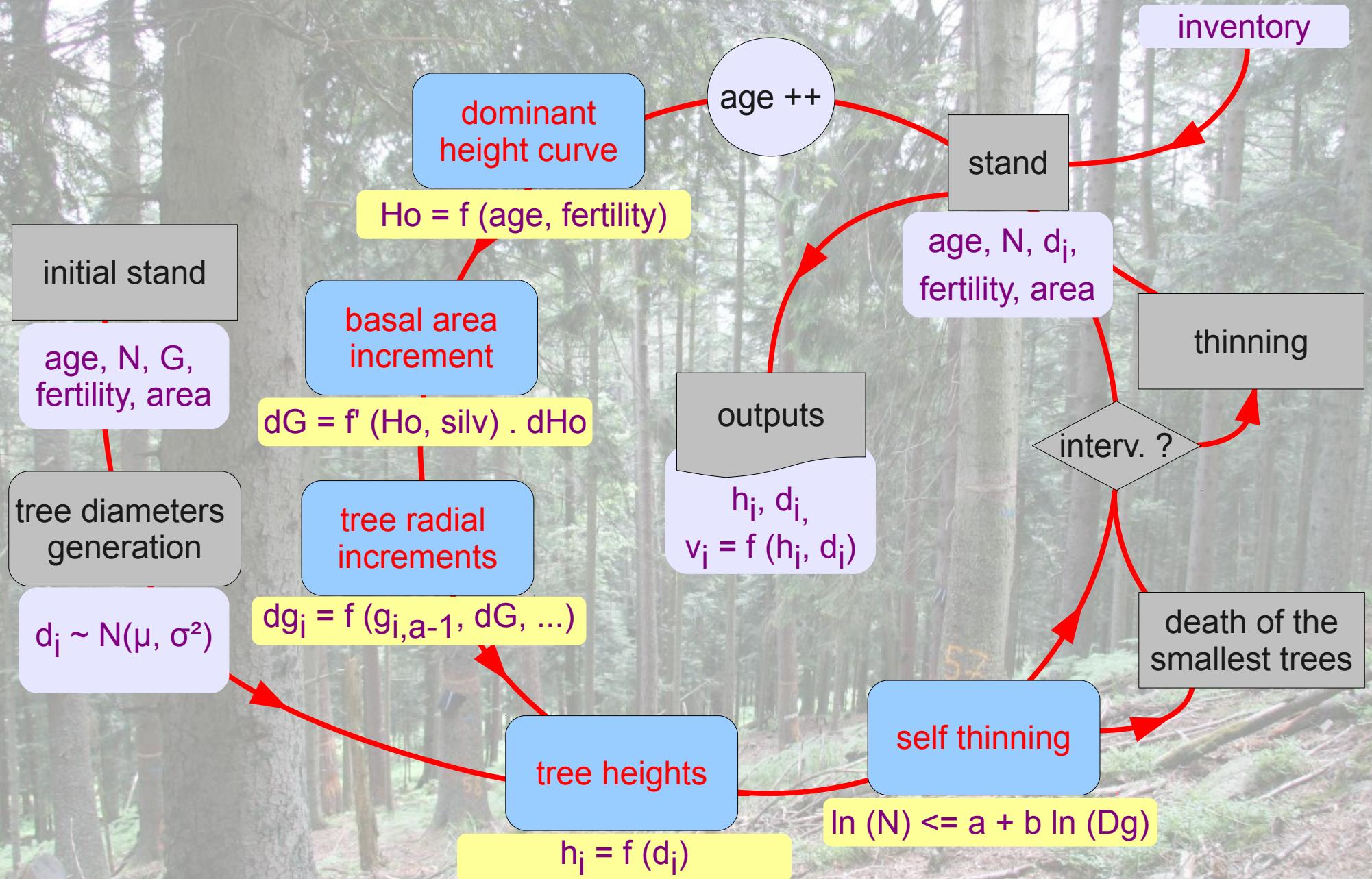
Vallet P., Dhôte J.-F., Le Moguedec G., Ravart M., Pignard G. (2006). Development of total aboveground volume equations for seven important forest tree species in France. *Forest Ecology and Management*. 229:98-110

Duplat P. (1980). Tables de production de référence pour le sapin du Jura.
Bulletin Technique de l'ONF, 11:13-26.

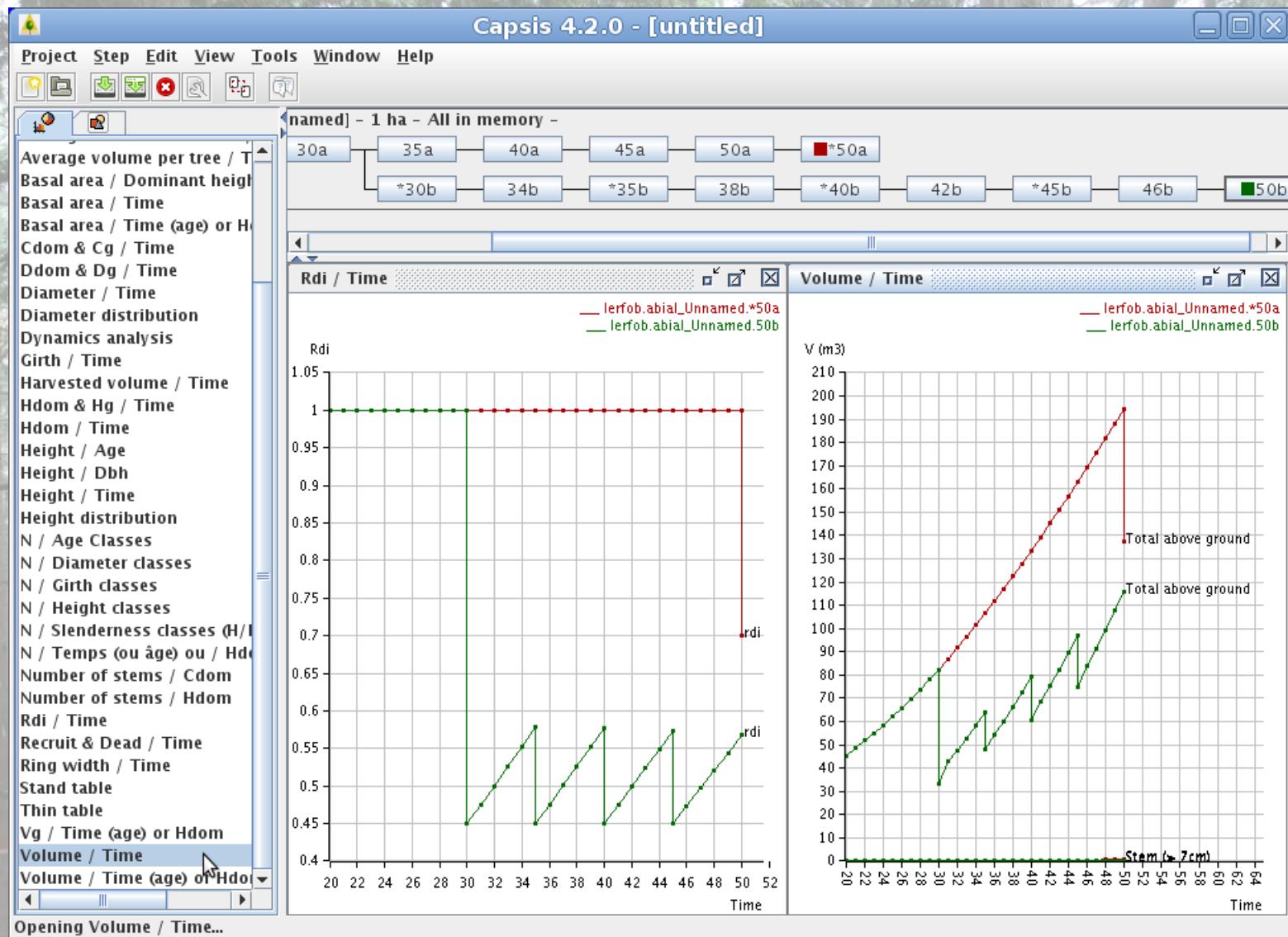
General work-flow



General work-flow



Abial 2.0 software



Conclusions

- the model seems to satisfy ONF request...
- ... but there are strong limitations:
 - * pure and even aged stands
 - * not accurate for the juvenile phasis
 - * understory not considered
 - * mortality only due to competition and concerning smallest trees
 - * outputs limited to yield (no stem profile, no wood quality...)
 - * restricted to the validity domain:
 - Vosges and Jura mountains
 - elevation 350 to 1000 m
 - age 50 to 160 years
 - fertility 20 to 35 m at 100 years
 - RDI 0.6 to 1

