E-Dendro.

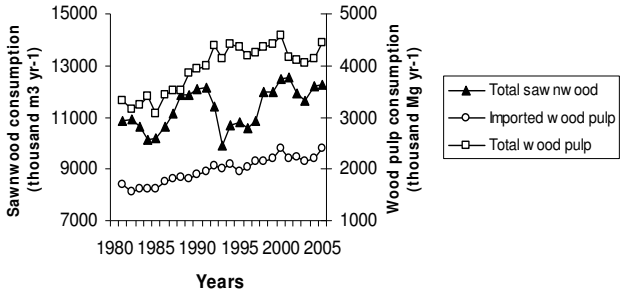
A soil-plant model operating at stand scale to assess the impact of sylviculture on the biogeochemical cycles of planted forest ecosystems.

Saint-André L.[1], Nouvellon Y.[1], Laclau J-P.[1], Gomat H.[2], Bikindou F.[2], Thongo M'Bou A.[2], Versini A.[1], D'Annunzio R.[1], Derrien D.[3], Zeller B.[3], Ranger J.[3], Levillain J.[1], Lemaire G.[1], Jourdan C.[1], Deleporte P.[1], Bouillet J-P[1].

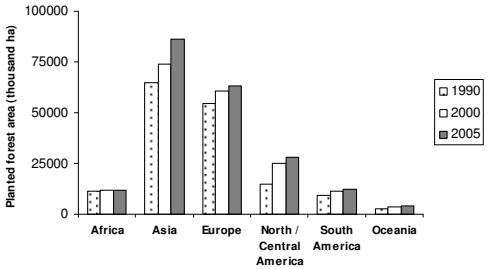
1 Cirad, France; 2 CRDPI, Republic of Congo; 3 INRA, France

Context: Sustainable management of fast growing species under the tropics. A crucial need.

For several decades a **continuous increase in the demand of ligneous products** has been observed worldwide



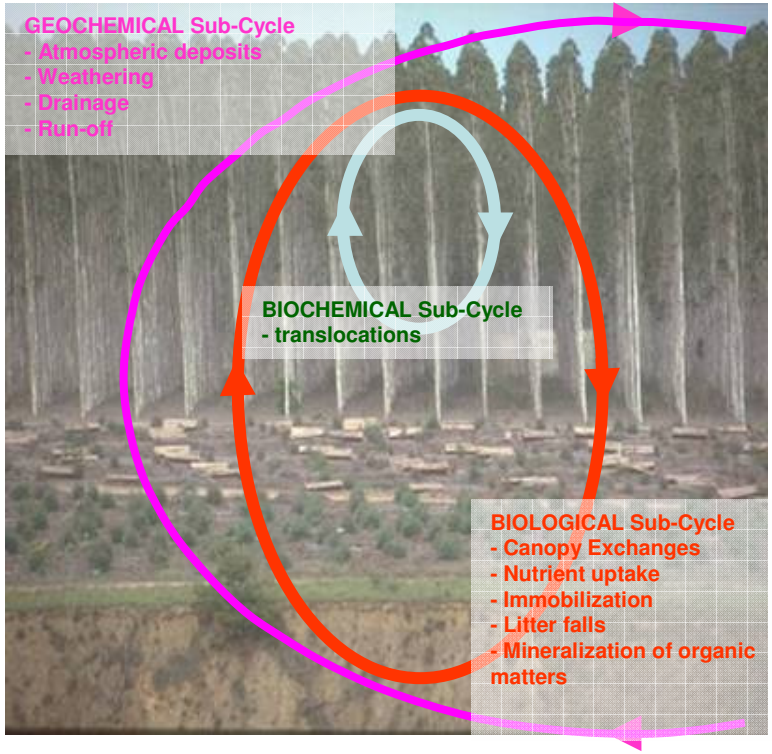
In the same time, the overall area of Forest Plantations increased dramatically during the last decades to reach 205 million ha in 2005



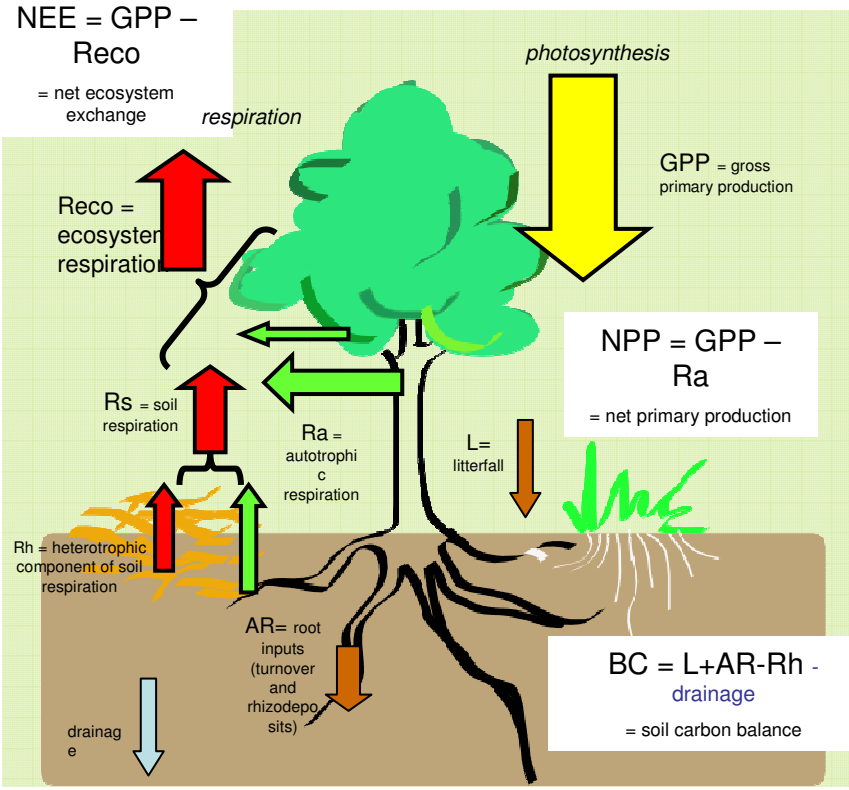
Tropical plantations are often established on poor soils

There are then concerns about the sustainability of such fast growing plantations because an intensive management is carried out (very short rotations) and leading to high risks of soil nutrient deficiencies.

Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM



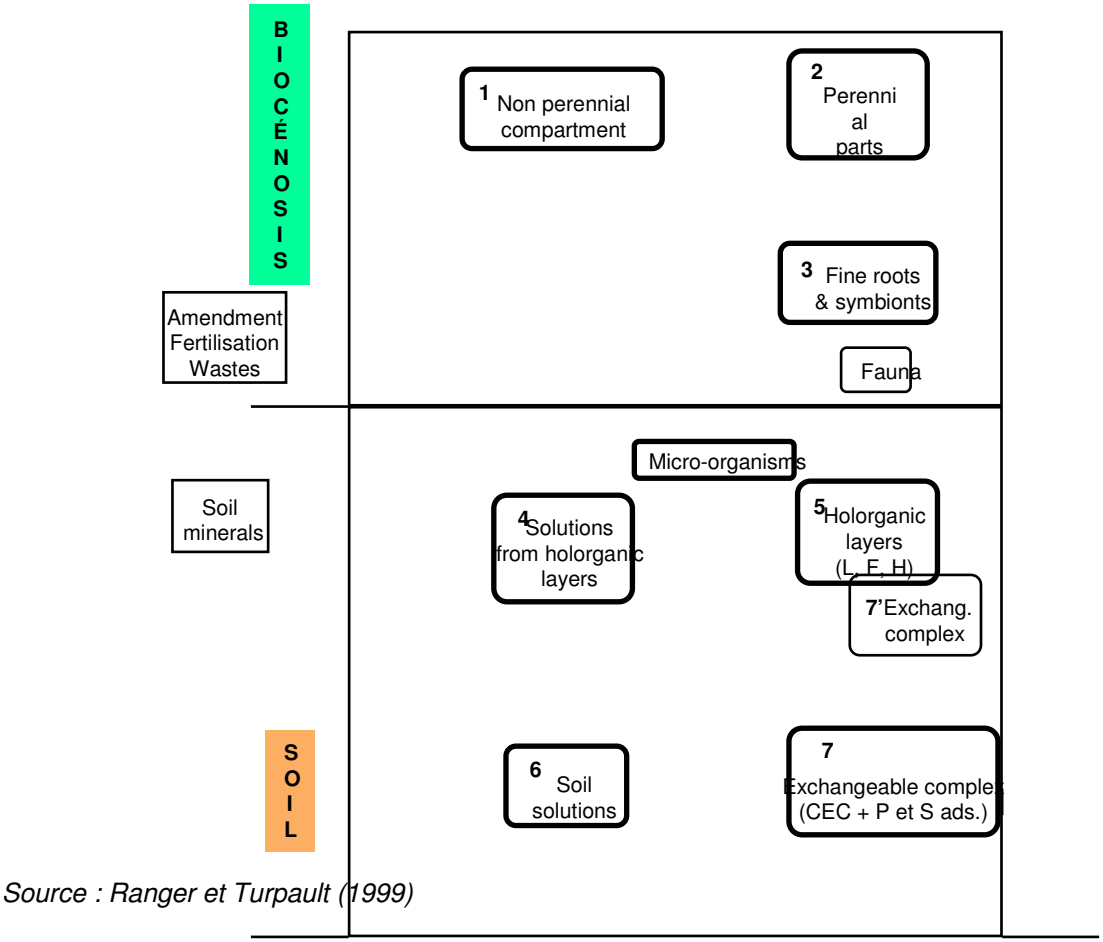
Nutrient and water cycles



Carbon cycle

Accounting for biogeochemical cycles, is a necessity for accurate forest management and a challenge for modeling work

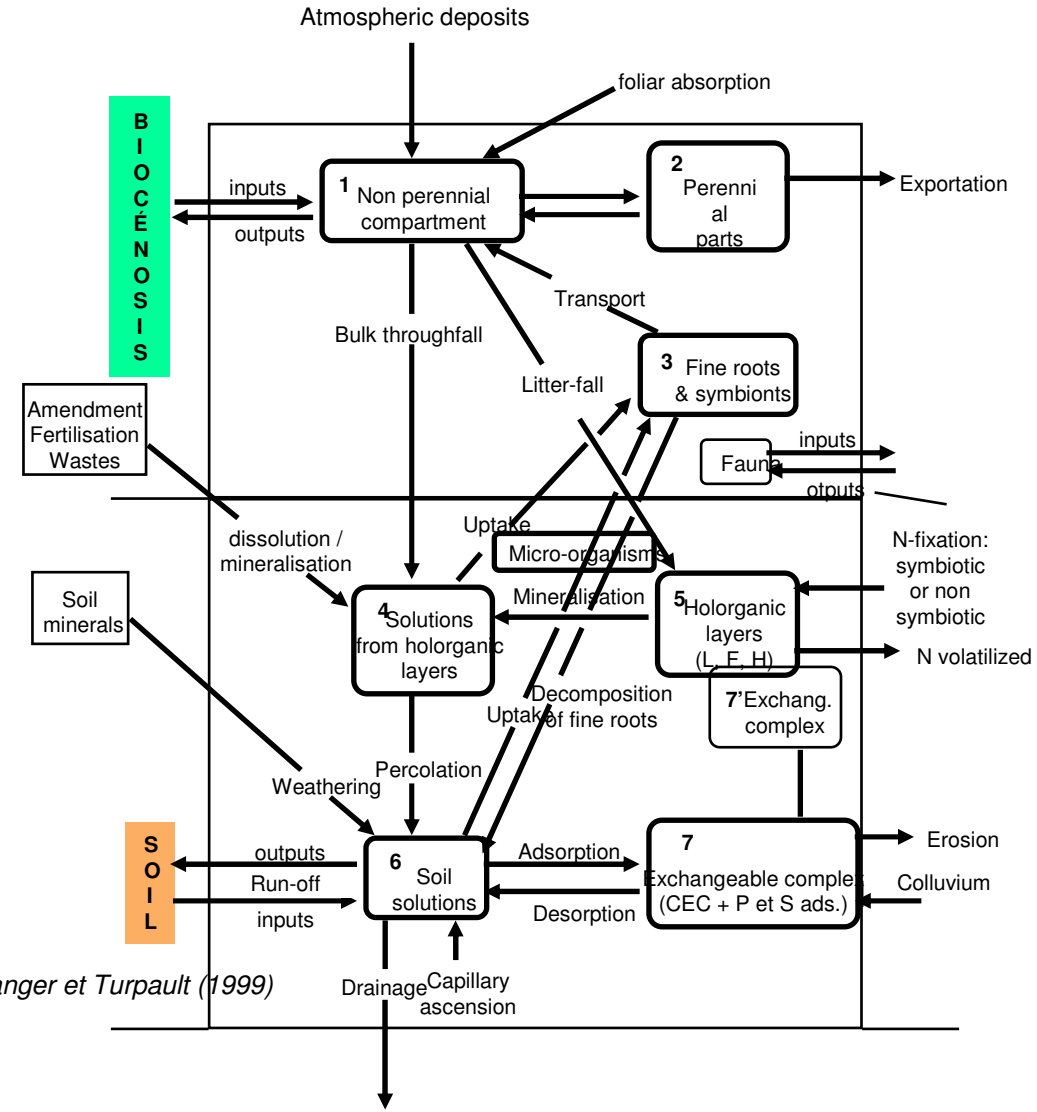
Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM



Source : Ranger et Turpault (1999)

A conceptual model with compartments and fluxes

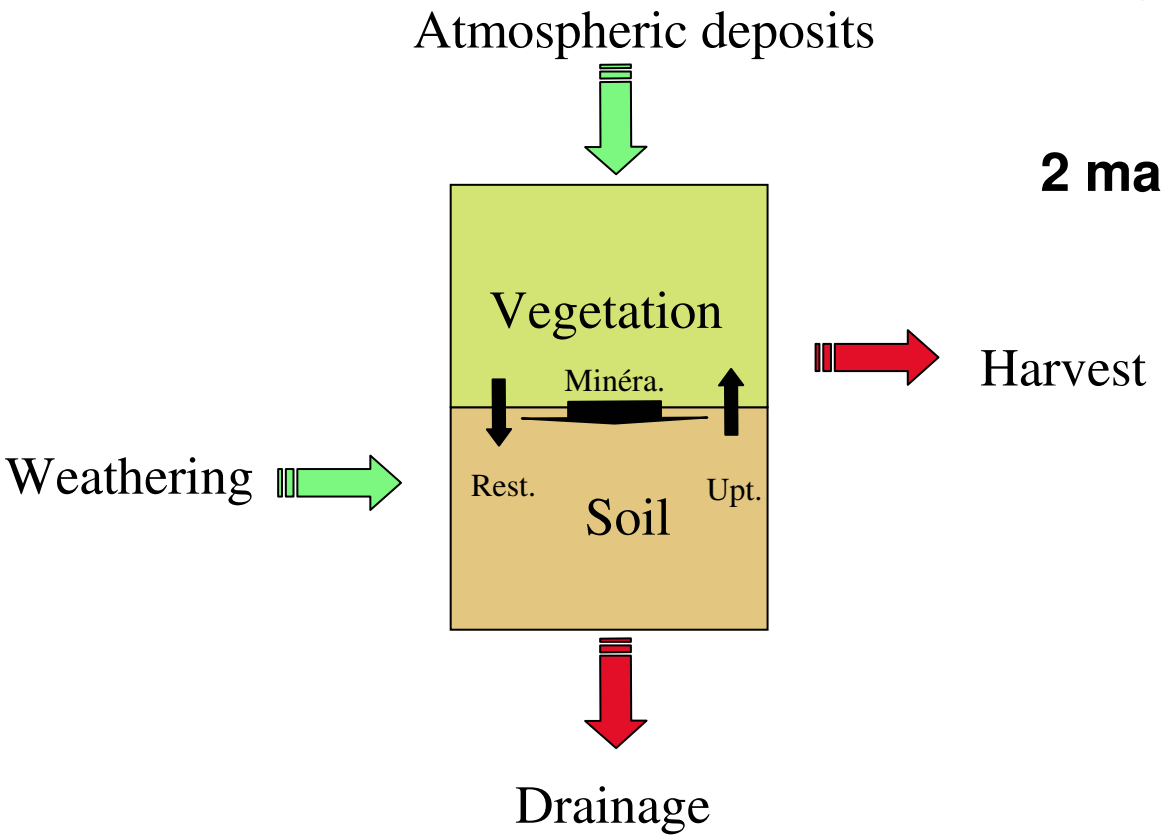
Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM



Source : Ranger et Turpault (1999)

A conceptual model with compartments and fluxes

Fortunately, simplifications can be made for nutrient I/O budgets of forest ecosystems :



2 main inputs =

Atmospheric deposits

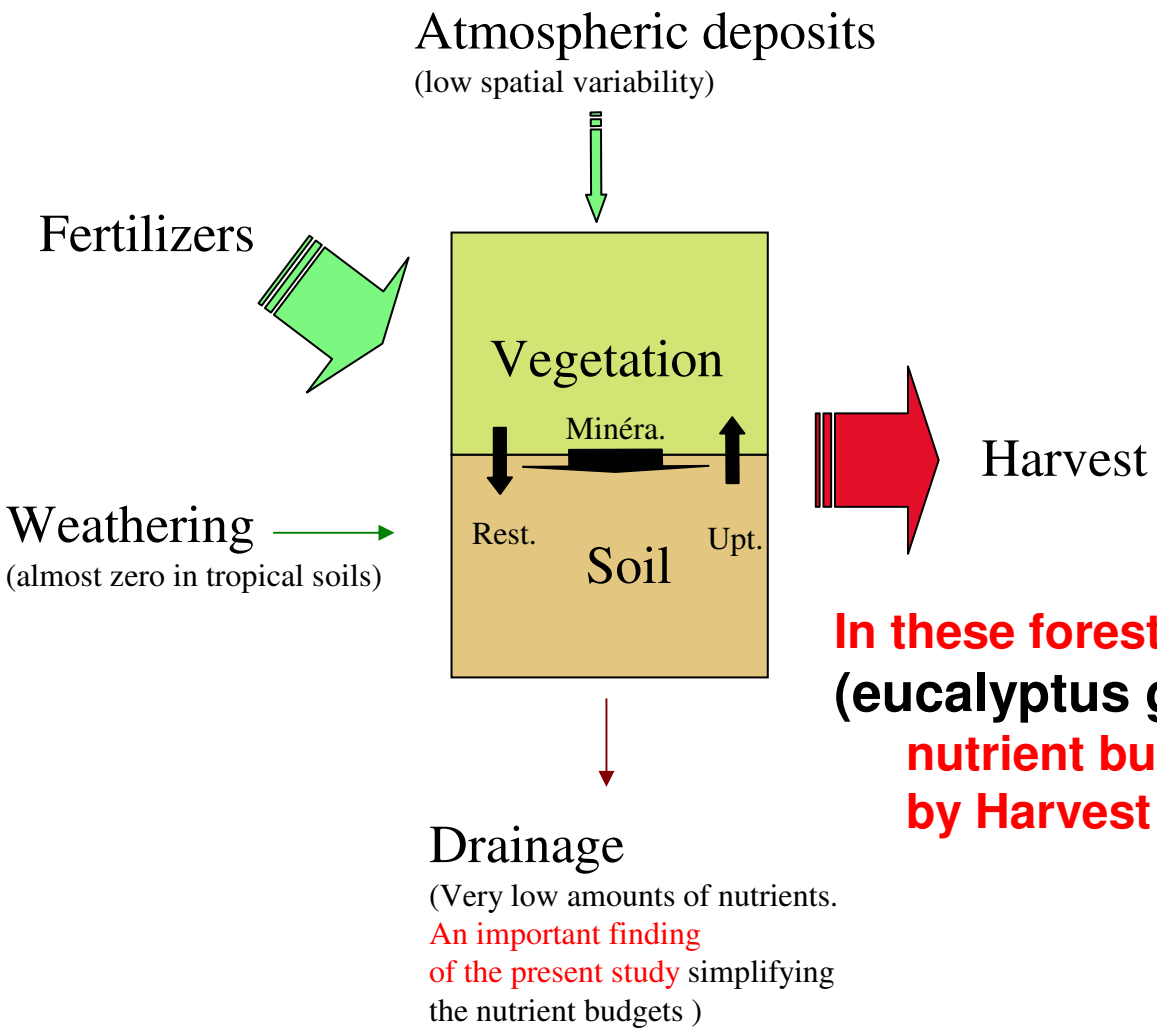
Weathering

2 main outputs =

Harvest

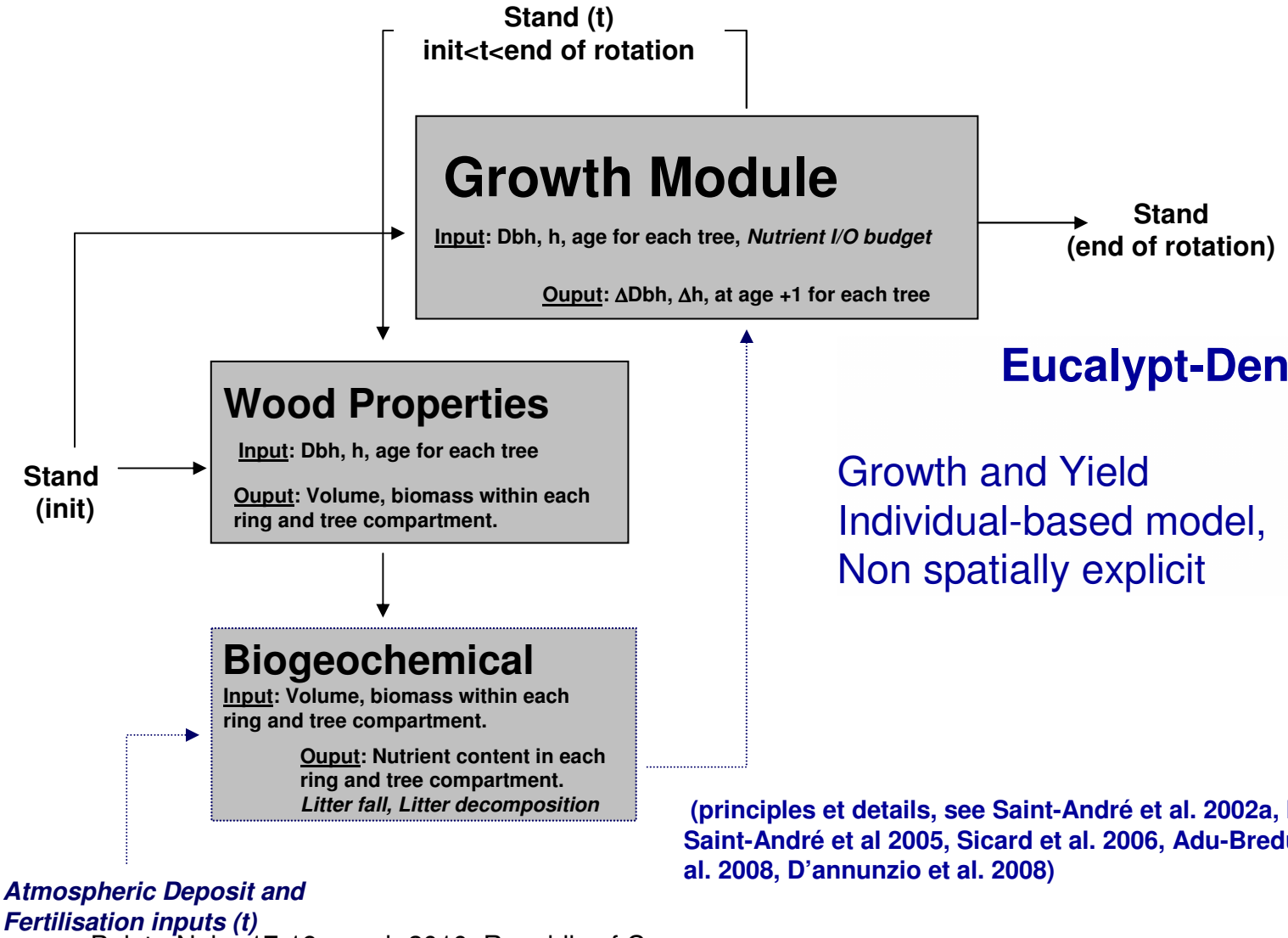
Drainage

What we learned from the comprehensive sites of Eucalyptus in Congo and in Brazil?



In these forest ecosystems
(eucalyptus growing on sandy soils),
nutrient budgets are mainly determined by Harvest and Fertilizer inputs

Modeling approach, a dedicated tool for forest managers



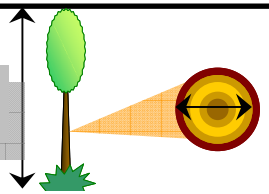
Eucalypt-Dendro

Growth and Yield
Individual-based model,
Non spatially explicit

(principles et details, see Saint-André et al. 2002a, b, Saint-André et al 2005, Sicard et al. 2006, Adu-Bredu et al. 2008, D'annunzio et al. 2008)

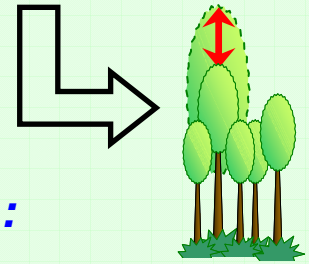
Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM

Stand inventory, real or virtual, at an age A

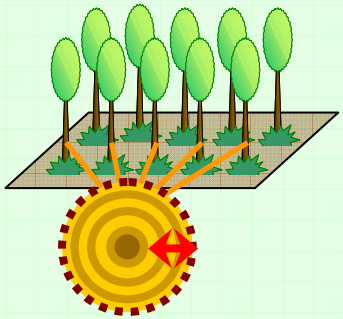


1. Growth Module

Site fertility evaluation (constant in time)



Stand growth in *dominant H*

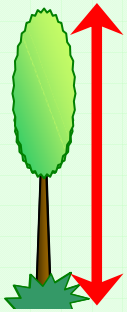


Stand growth in *basal area*

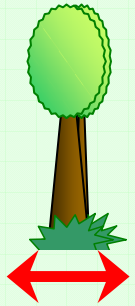
Depends on :

- ***clone***
- ***stand density (competition)***

Individual tree growth in Height



Individual tree growth in *basal area*

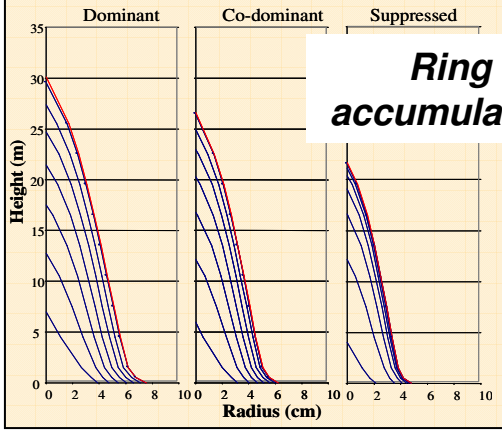


Inventory at A + 1 month

Inventory at A + 1 month

2. Wood Properties Module

Stem taper equation

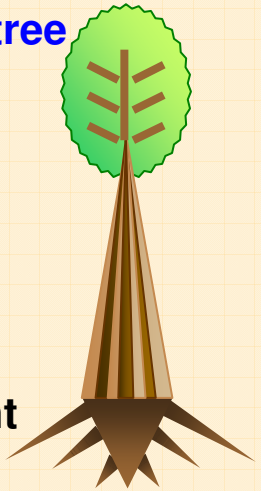


Ring accumulation

Volume for each tree

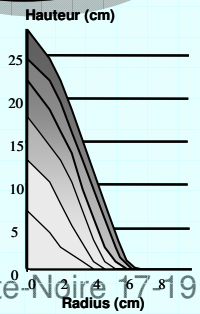
Set of biomass equations for each part of the tree

Biomass
- **by tree compartment**
- **by ring**



3. Biogeo-chemical Module

Model for nutrients evolution in rings



N P K concentrations in each ring

Set of nutrient content equations

Nutrient content N, P, K, Ca, Mg

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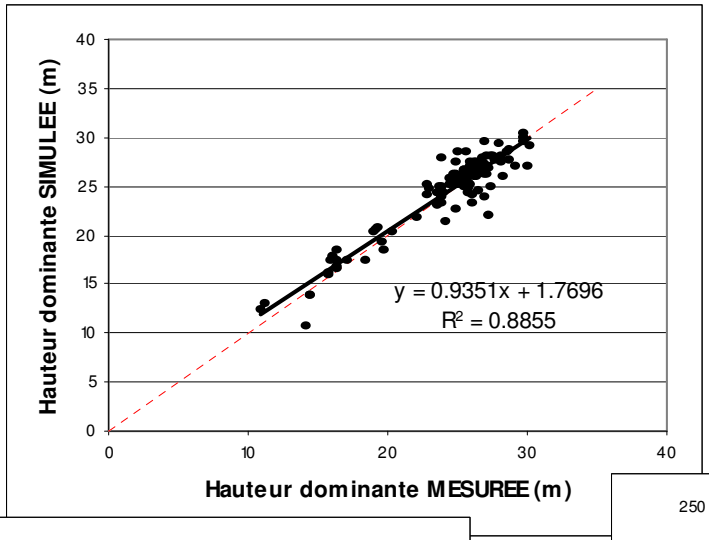
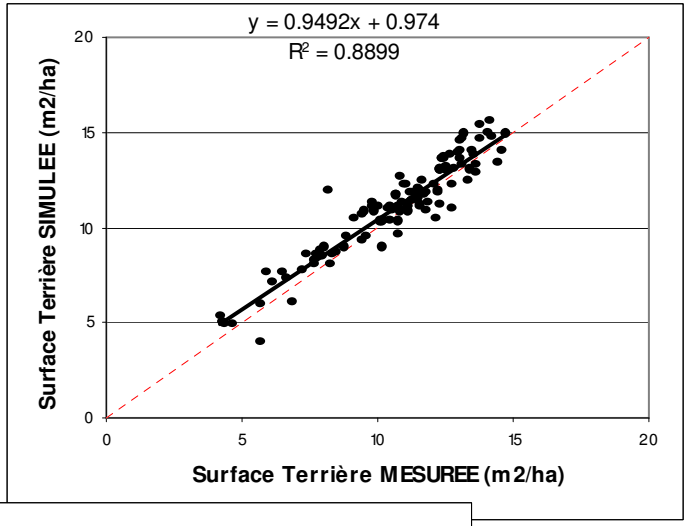
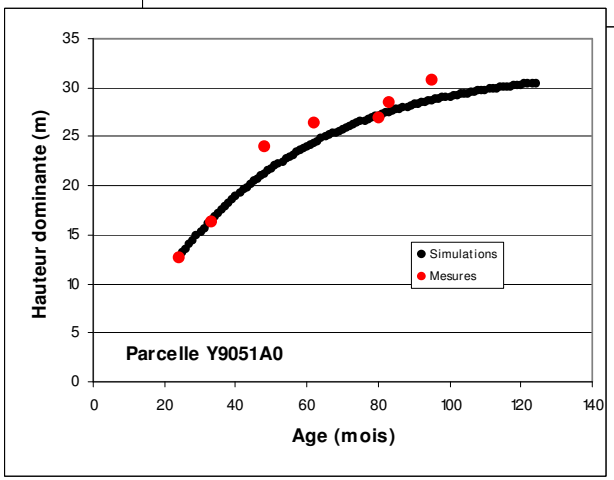
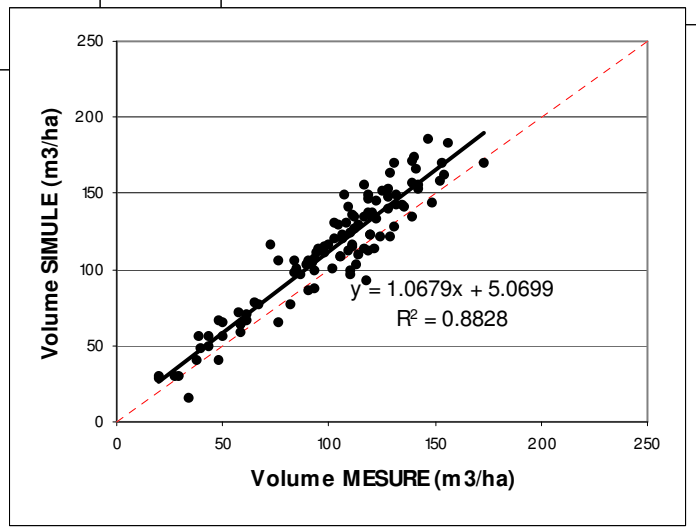
Validation on the whole forest area

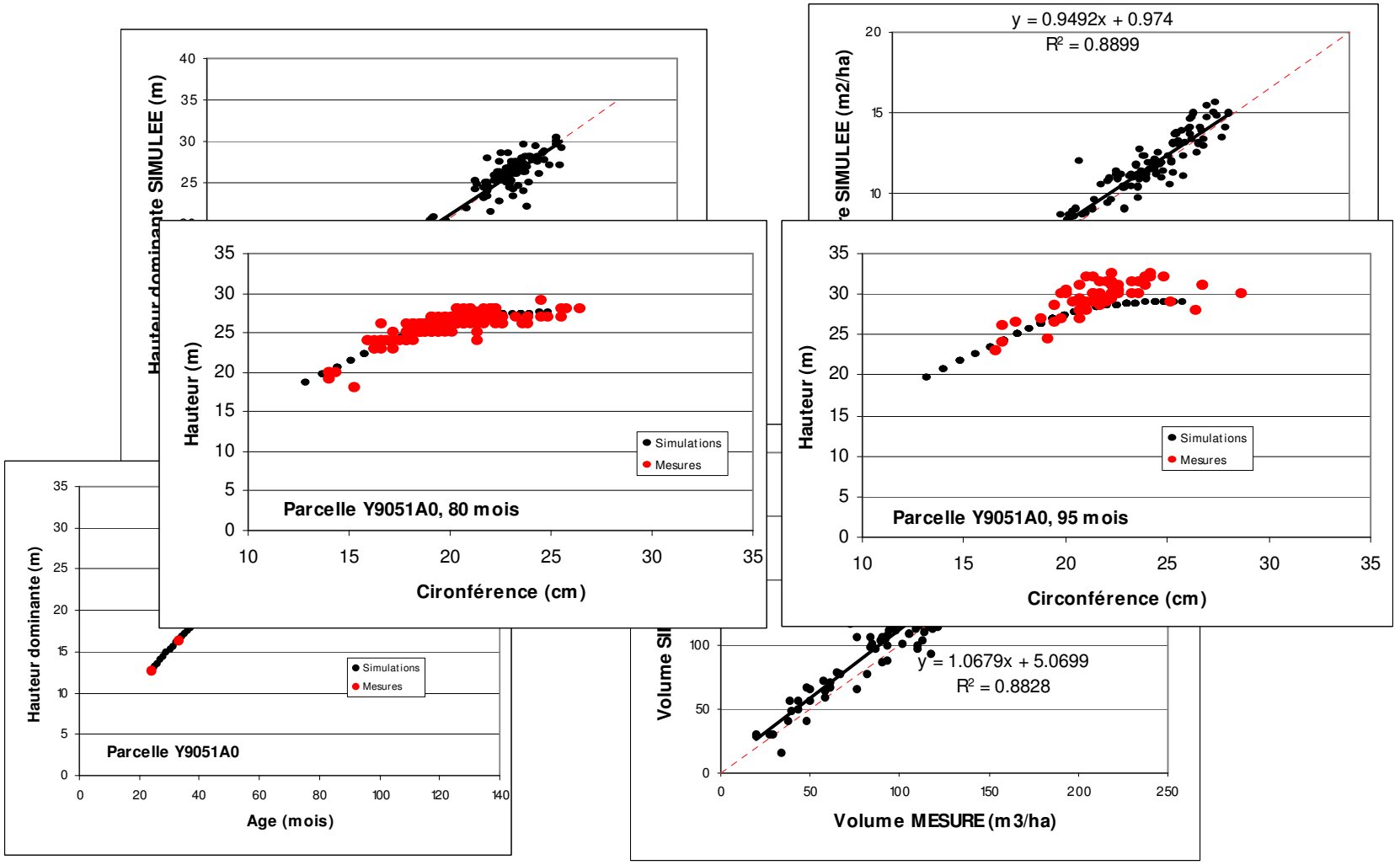




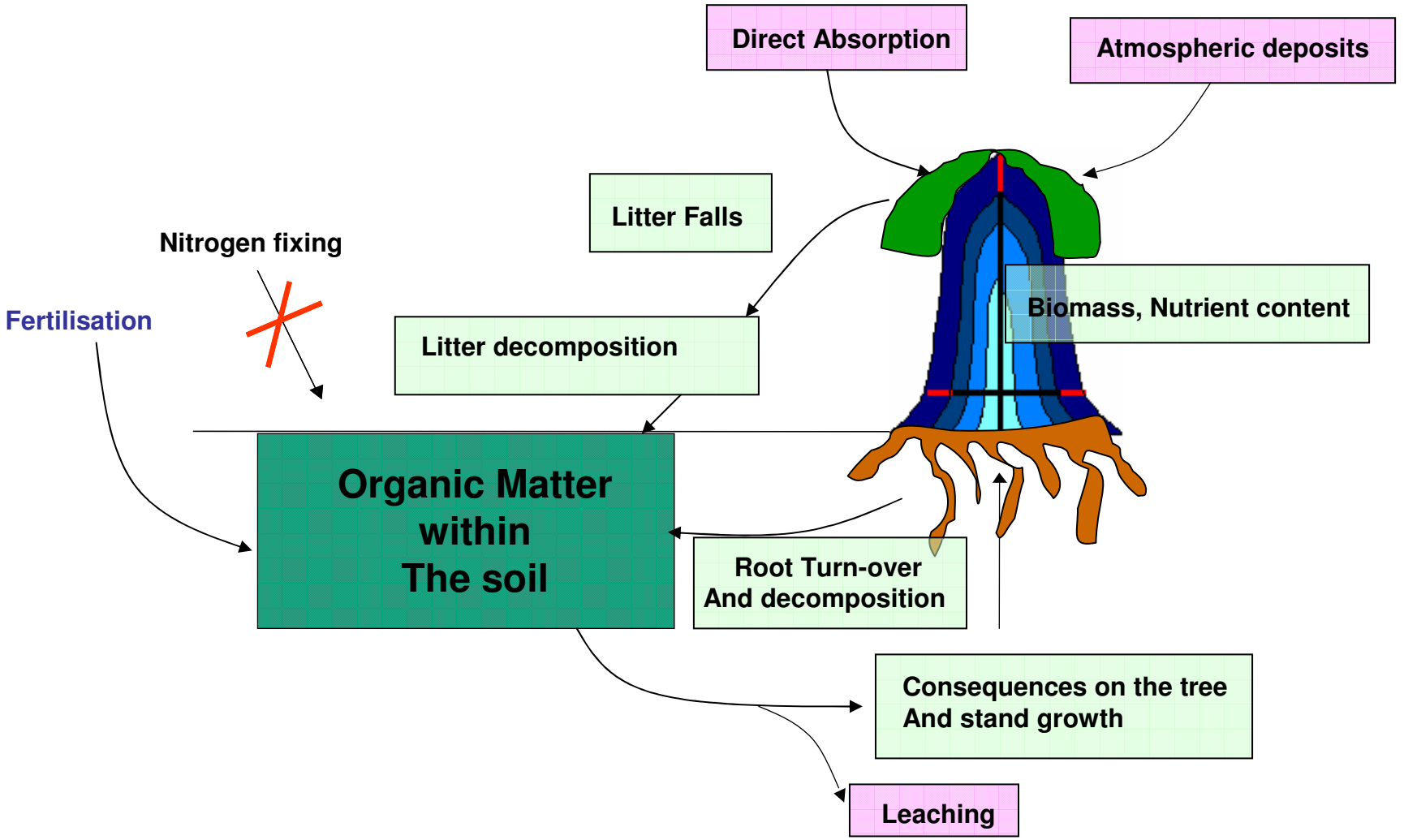




Validation on the whole forest area



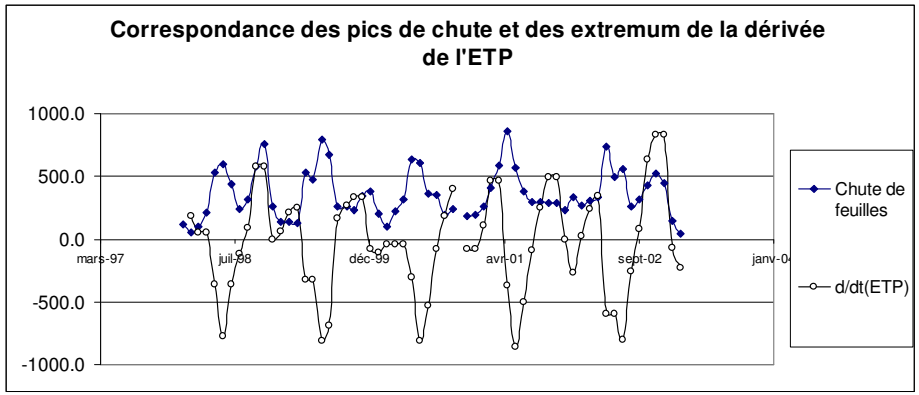
Integrating nutrient cycling and soil organic matter

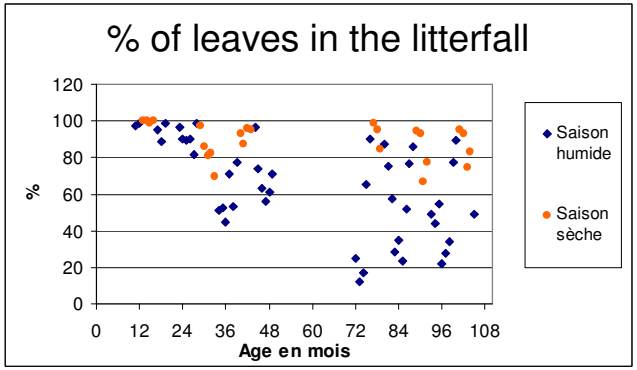


Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM

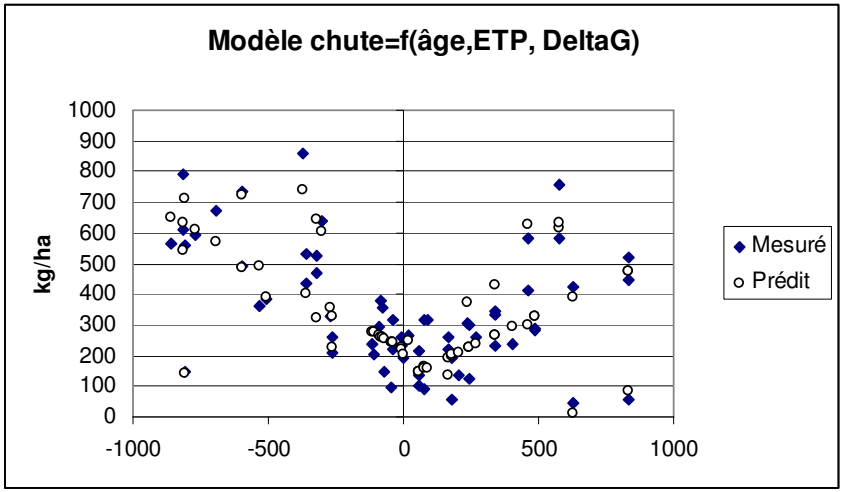
Litterfall model

(DEA Biologie forestière 2003-2004, Rémi D'annunzio)





Segmented linear regression between litter fall intensity and the derivative of PET. The slope varies with stand age and production. The litter composition varies with the season

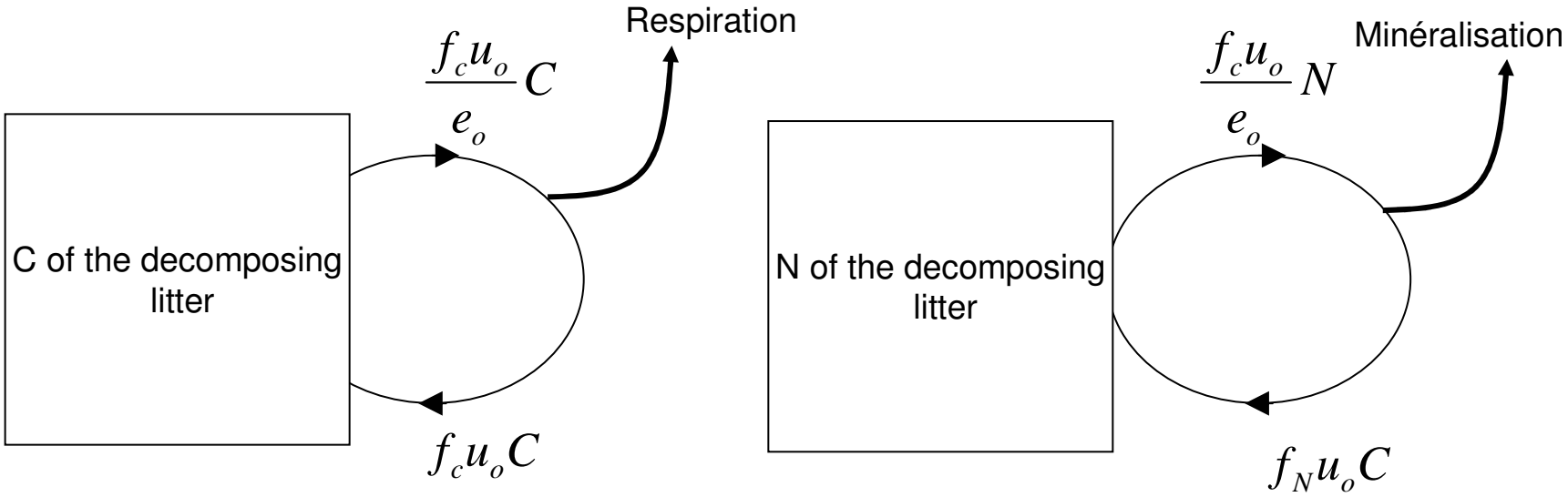


R^2=0.82 for the monthly litterfall

LitterDecomposition model

(Agren and Bosatta, 1998, D'annunzio et al. 2008)

The same parameters drives C and N dynamics



f_C, f_N : C and N concentration of the decomposers
u_o : growth rate of the decomposers by C unit
e_o : efficiency of the decomposers

(Ågren et Bosatta, 1998)

LitterDecomposition model

(Agren and Bosatta, 1998, D'annunzio et al. 2008)

The substrate is characterized by a synthetic variable : **the quality**

Quality is a decreasing function of **time**, with parameters that characterize the decomposers activity and the edaphic conditions.

$$q(t) = \frac{q_o}{\left[1 + \beta \cdot \eta_1 \cdot f_c \cdot u_o \cdot q_o{}^{\beta} \cdot t\right]^{\frac{1}{\beta}}}$$

$$C(q) = C_o \left(\frac{q}{q_o}\right)^{\frac{1-e_o}{\eta_1 \cdot e_o}}$$

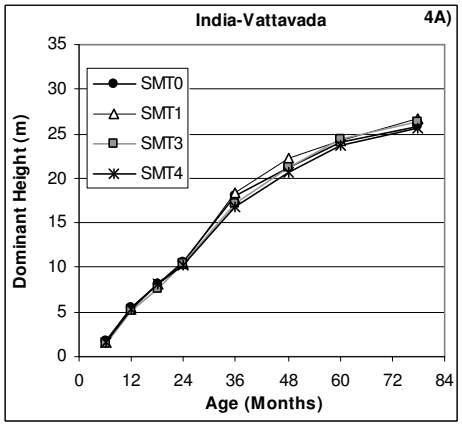
$$N(q) = C_o \left(\frac{q}{q_o}\right)^{\frac{1-e_o}{\eta_1 \cdot e_o}} \cdot \left[\frac{f_N}{f_C} - \left(\frac{f_N}{f_C} - r_o\right) \cdot \left(\frac{q}{q_o}\right)^{\frac{1}{\eta_1}}\right]$$

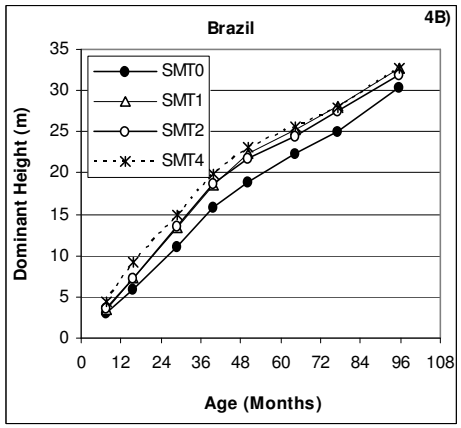
The organic matter is not divided into pools but the substrate, humus and SOM are a continuum : **the model is said "continuous"**

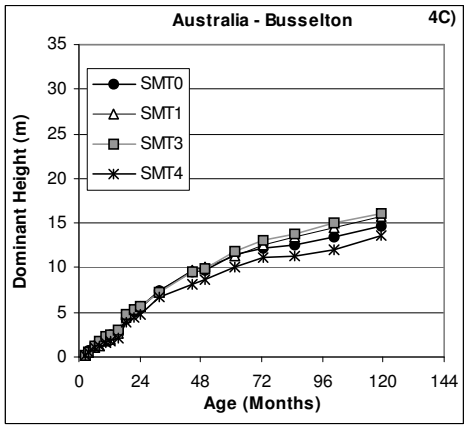
(Ågren et Bosatta, 1998)

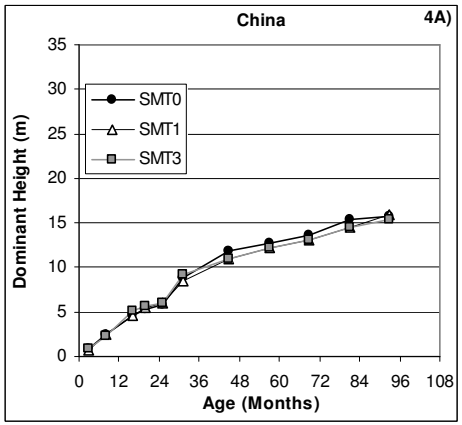
Response Curves on the growth module

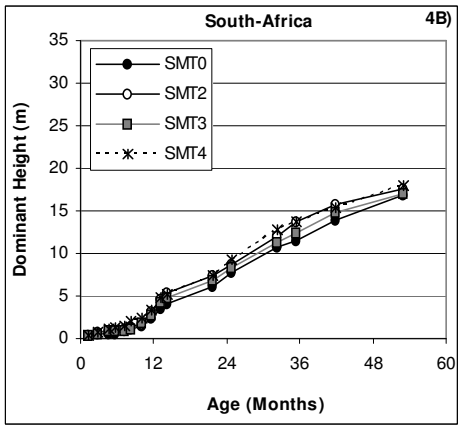
(Saint-André et al. 2008)

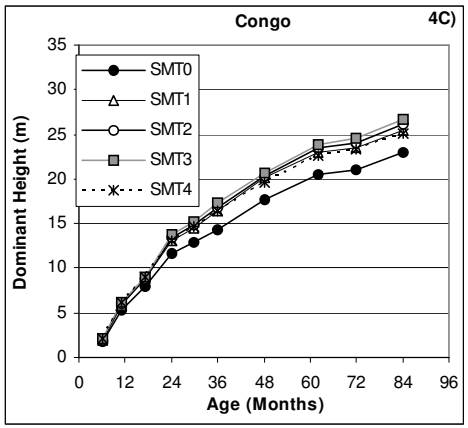












Dominant height as a function of age

⇩

Site Index

-Slash management (CIFOR Network)

- Unchanged

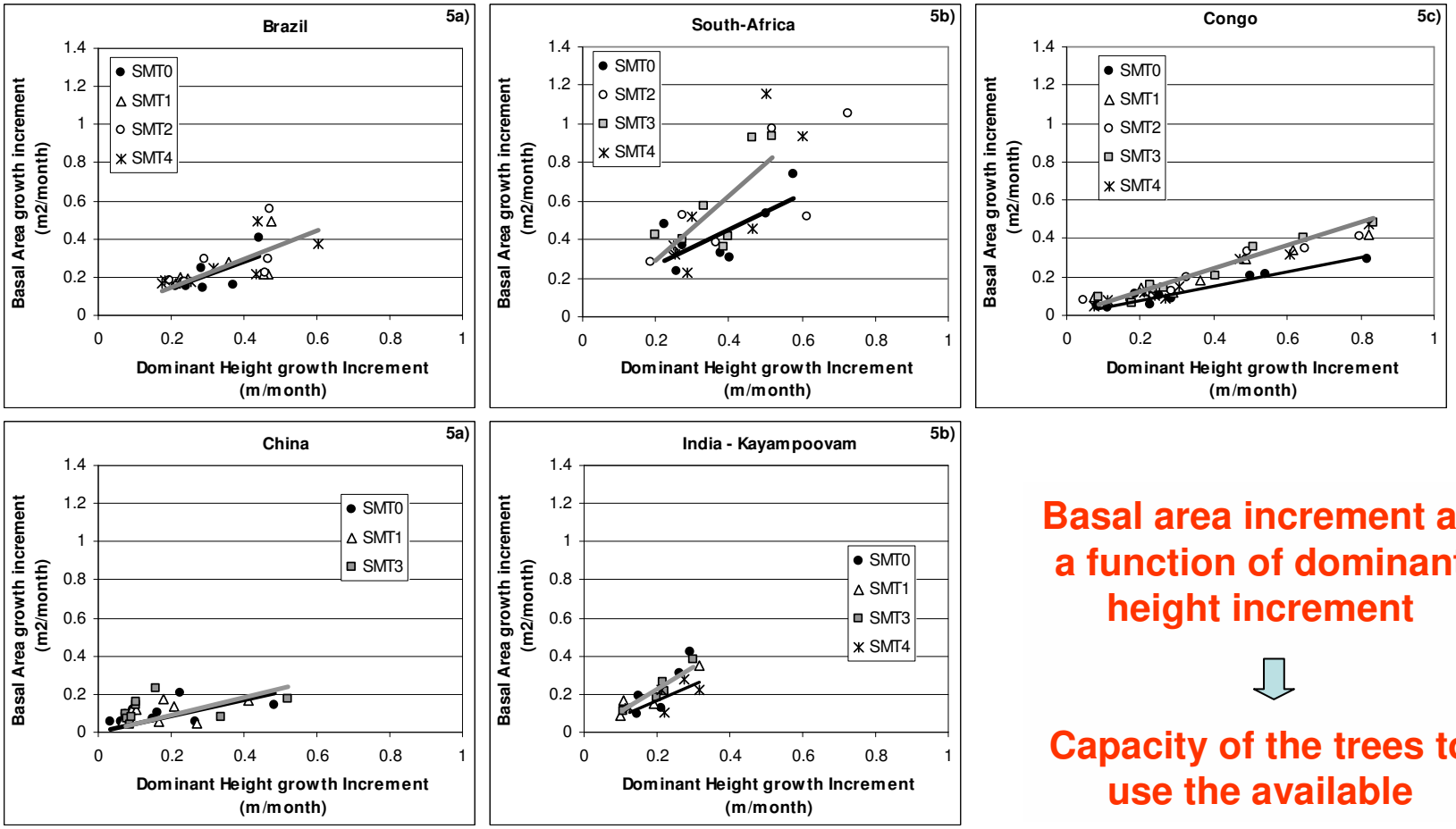
- Changed but the system was resilient during the rotation

- Changed and the system was not resilient after one rotation

Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM

Response Curves on the growth module

(Saint-André et al. 2008)



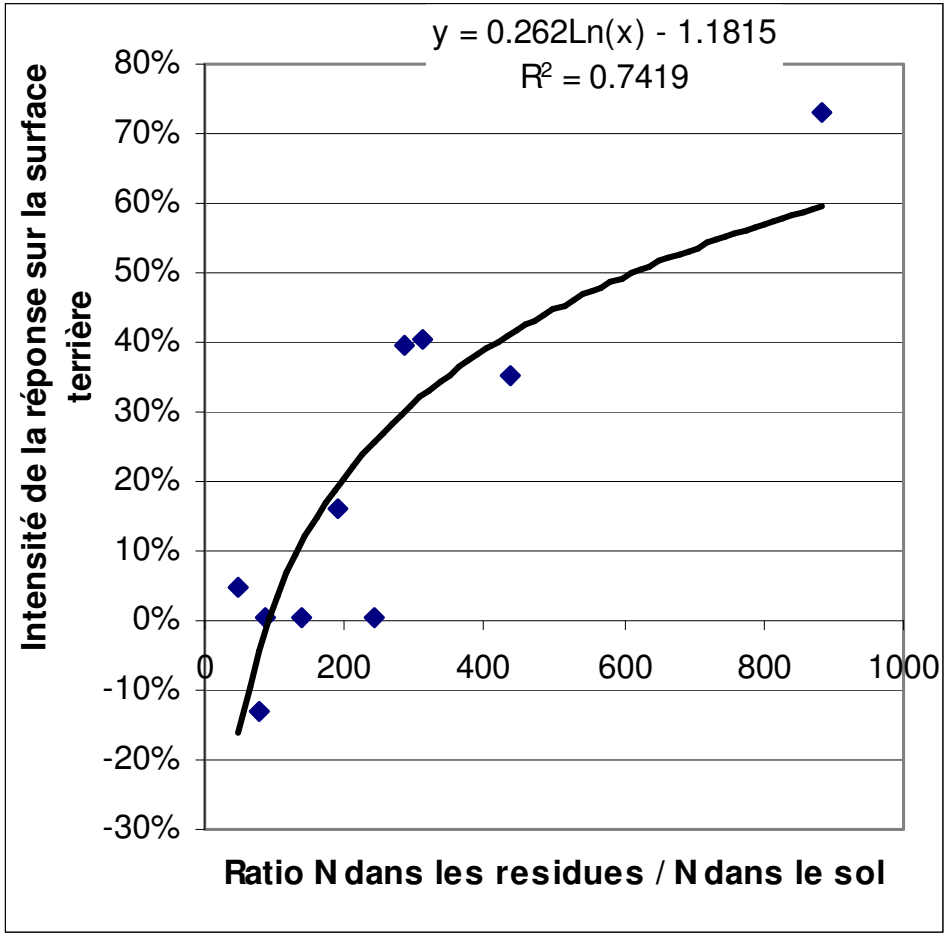
Basal area increment as a function of dominant height increment

Capacity of the trees to use the available resources

Response Curves on the growth module

(Saint-André et al. 2008)

Contrasted responses between sites but

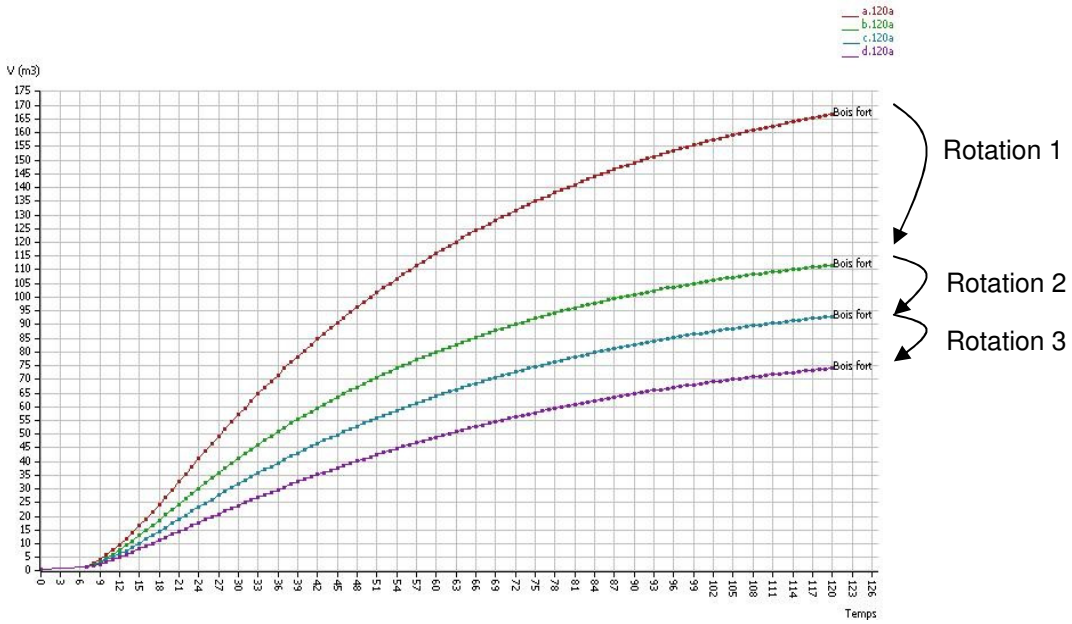


but if we divide the amount of nutrients in the residues (difference between the two opposite treatments) to the nutrient concentration within the soil (a ratio that gives the intensity of loading) we may have a possible way of predicting the intensity of growth response among sites

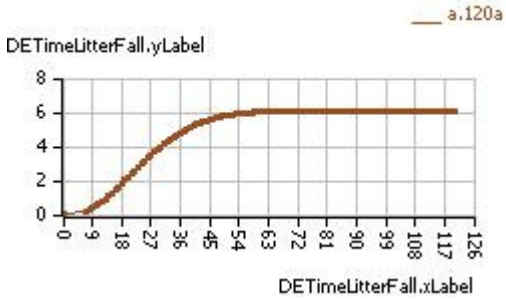
Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM

soil-plant Interaction using the growth and yield approach

Very preliminary results
Obtained recently!



Loss of production when slashes are removed at eachharvesting. Data for the second rotation are currently being collected. Comparison will be done soon !



Literfall model

and

Litter accumulation

Still some model limitations to overcome, but we now have a preliminary tool to simulate both soil and plant interactions with sylviculture practices

Do not yet depend on the treatments