Combining Ecosystem Modelling and Remote-Sensing to Understand the Spatial and Temporal Dynamics of the Carbon Budget of Fast-Growing Eucalyptus Plantations

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Carbon and water budgets of Eucalyptus plantations at the landscape scale

ca. 350000 new hectares of Eucalyptus plantations established per year in Brazil (ABRAF, 2009)

- These land-use changes are likely to impact strongly on regional carbon budgets and the spatial and temporal distribution of CO_2 sinks and sources
- Principal carbon sink in fast-growing Eucalyptus forests : exportation of wood: up to 100 t C ha^{-1} at the end of a six-year rotation
- Stand productivity is highly variable both temporally and spatially.
- How can long-term intensive management or climate change scenarios affect plantations' current and future net ecosystem productivity?

Our approach:

Ecophysiological modelling of interrelated water, carbon and nitrogen fluxes

G'DAY Model (Generic Decomposition And Yield (Comins & McMurtrie, 1993; Corbeels et al., 2005))

Use of remotely-sensed information in the aim of conducting spatial simulations on a sub-regional scale

Why use an ecophysiological modelling approach?

- To identify main limiting and driving factors
- To predict probable medium and long-term evolutions of all terms of the carbon balance
- To evaluate the possible effect of the change of different ecophysiological parameters

Why spatial application?

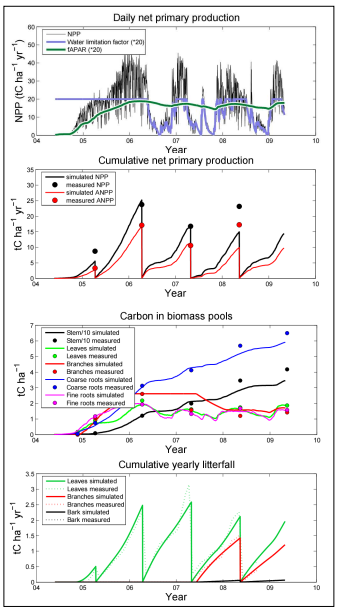
- To address all these questions on a scale that is relevant for forest managers, clean development mechanism planners, public and non governmental environmental protection agencies

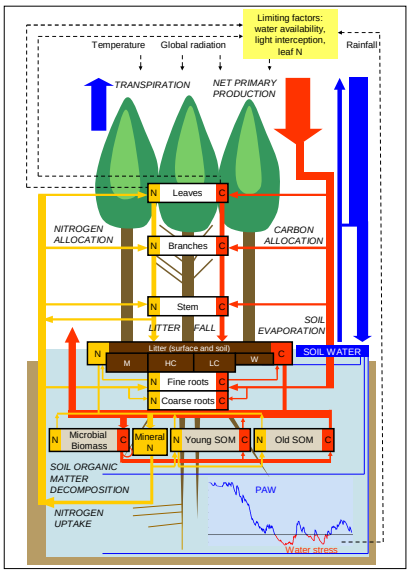
So far:

- Model adapted for application on a daily time-step to Eucalyptus plantations of São Paulo state, south-eastern Brazil
- Model tested on an experimental stand, first conclusions drawn
- Application of the model on a network of 16 stands of different productivity using satellite data-inferred fraction of Absorbed Photosynthetically Active Radiation (fAPAR)

G'Day ecosystem model

This model is based on a simple but comprehensive description of principal plant and soil mechanisms and simulates the coupled evolution of carbon, nitrogen and water content of plant, litter and soil pools, as well as the fluxes between them. We have developed a version of the model that is driven by a remotely-sensed estimation of fAPAR.





The model was tested on a fertilized experimental stand of the Estação Experimental de Itatinga, São Paulo.

Simulated daily NPP is limited by intercepted radiation at the start of growth. After 2 years of growth, water limitation affects simulated production very strongly.

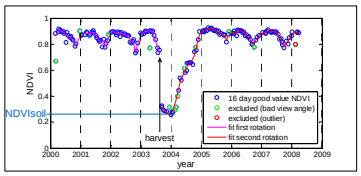
Net primary production, biomass components and litter fall are well simulated until the third year of growth. But higher water use efficiency during the 4th and 5th years of growth are not simulated by the model, leading to strong underestimation of growth towards the end of the rotation.

Remotely-sensed temporal series of fAPAR on 16 stands

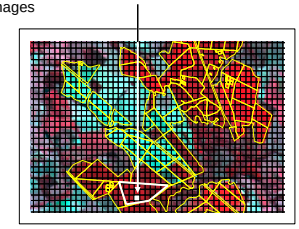
Sixteen stands were chosen within the same climatic zone, to form a network of company-managed clonal plantation stands of 5 ages and contrasted productivity levels. The stands were aged 1 to 5 years and displayed productivity levels of 30 to 55 t ha^{-1} of dry wood exported per year.

On each stand the fraction of absorbed photosynthetically active radiation was measured by hemispherical photography at 2 dates in 2008 (height of the wet season and end of dry season).

MODIS 16-day good-value Normalized Difference Vegetation Index (NDVI) time series were obtained for each stand for the period 2000-2008.



Each stand was represented by one MODIS pixel chosen with an automatic and objective technique involving the use of CBERS and MODIS same-date images



In the model, fAPAR drives net primary production.

Carbon allocation :

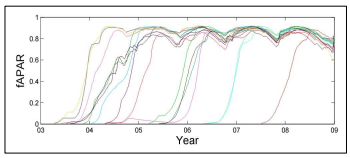
A target leaf area index value is inferred from fAPAR using a field calibrated radiation extinction coefficient.

The leaf allocation coefficient is modulated so that simulated LAI approaches target LAI.

Target fine root and branch biomasses are linearly related to LAI ; coarse root biomass is related to stem mass.

Specific leaf area declines with mean stand height.

Litterfall is modelled as a fixed rate of leaf area turnover.

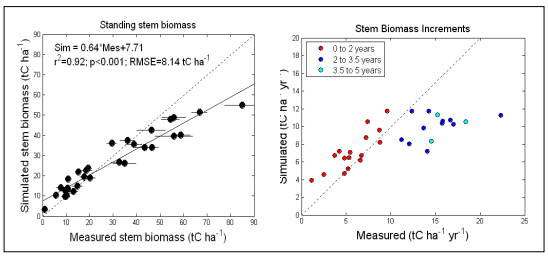


Daily values of fAPAR of each stand from planting date to 2008 were inferred from the NDVI time series, using an empirical field-calibrated procedure (Marsden et al. 2009).

Model application on 16 stands with fAPAR derived from NDVI time series

Simulations were conducted using MODIS-derived fAPAR of each stand.

Soil characteristics were used to estimate stand-specific maximum plant available water (Tomasella et al. 2000). As production is limited by water, soil water holding capacity is a critical model parameter. It is particularly difficult to estimate in these very deep weathered soils where Eucalyptus roots can extend to large but unknown depths.

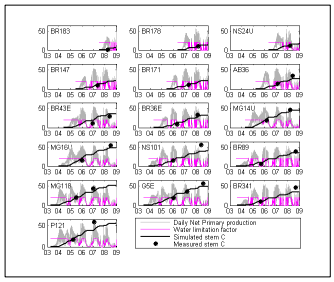


Conclusions and perspectives

The relationship between measured and simulated biomass is biased : in its current form the model fails to simulate the full range of observed biomasses. Production of stands older than 3 years is too strongly limited.

Dispersion of the simulated values around the regression line suggests that the different levels of light interception observed on the 16 stands, and surface soil textural characteristics, are not sufficient to explain different productivity levels.

Improvement of the transpiration and water balance sub model is required to attain better simulation of growth after age 3 years.



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