COMBINING ECOSYSTEM MODELLING AND REMOTE-SENSING TO ESTABLISH THE SPATIAL AND TEMPORAL DYNAMICS OF THE CARBON BUDGET OF FAST-GROWING TROPICAL EUCALYPTUS PLANTATIONS

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ABSTRACT

In the aim of estimating regional-scale carbon budgets of Eucalyptus plantations, the G'Day ecosystem model was combined with remotely-sensed estimates of the daily fraction of absorbed photosynthetically active radiation (fAPAR).

CONTEXT

Regional carbon budgets and the spatial and temporal distribution of CO_2 sinks and sources are likely to be strongly impacted by land-use changes. In many tropical regions the rapid expansion of highly productive Eucalyptus plantations, conducted on short rotations, is a significant example of these changes (ca. 350000 new ha planted per year in Brazil for example). The principal carbon sink in these fast-growing forests is the exportation of wood, representing up to 100 t C ha^{-1} at the end of a six-year rotation, but stand productivity is highly variable both temporally and spatially. For the establishment of sub-regional carbon budgets it is important to gain insight into carbon fluxes in the principal ecosystems, and in the case of Eucalyptus plantations to understand how long-term intensive management or climate change scenarios can affect current and future net ecosystem productivity.

COMBINING REMOTE SENSING AND ECOSYSTEM MODELLING

We adopted a modelling approach to study the interrelated water, carbon and nitrogen fluxes of a plantation stand, with the objective of using remotely-sensed information to conduct spatial simulations on a sub-regional scale. The G'DAY (Generic Decomposition And Yield (Comins & McMurtrie, 1993; Corbeels et al., 2005)) model was adapted for application on a daily time-step to the case of Eucalyptus plantations of São Paulo state in south-eastern Brazil. 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 daily fAPAR. We obtained fAPAR from a temporal series of MODIS Terra Vegetation Index 16-Day 250m resolution V005 series (MOD13Q1) images, after the calibration of a relationship between MODIS NDVI and fAPAR measured on the field by hemispherical photography. Daily fAPAR was fed into the model and determined light-dependent photosynthetic assimilation. A corresponding daily target value of leaf area index (LAI) was computed and carbon allocation between plant components was adjusted in order to match the target LAI. In this way the coherence between input fAPAR, and internal carbon allocation and litter fall values was ensured.

Model adaptation and calibration

Sub models were tested, modified and calibrated on an experimental site in Itatinga, São Paulo, representative of typical regional cultivation practices. Experimental measurements carried out from plantation to four years of age included soil water content, evolution of nitrogen and carbon pools in different biomass components, leaf area index, soil respiration flux, soil carbon and nitrogen pools, and litter fall. The adjusted model accurately estimated Net Primary Production (NPP), biomass components and litter fall during the first 3 years of growth. An observed very strong drop (-40%) in production during the third year of growth (Fig. 1) was correctly simulated by the model as a result of the limitation of carbon assimilation by soil water deficit. However, the model was unable to simulate the subsequent very high production rate that was measured during the fourth year, unless critical model parameters were changed (water holding capacity, water use efficiency, litter fall rate).

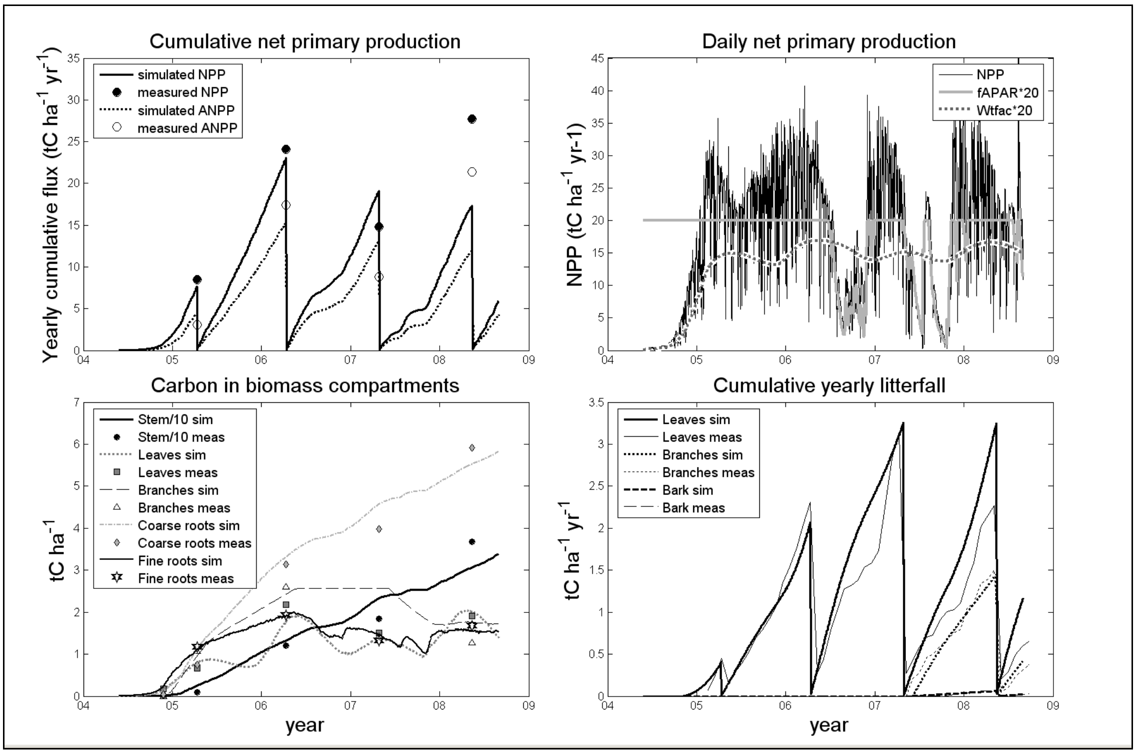

Fig. 1: Simulation results on Itatinga experimental stand.

Application on a network of 16 company-managed stands

A second phase involved the choice of a network of 16 company-managed clonal plantation stands of 5 ages and contrasted productivity levels, located in the same climatic zone and for which temporal series of biomass production data were available. Model simulations carried out on this network of stands aimed at testing whether the model was able to reproduce the strong observed spatial and temporal variations of stand productivity (30 to 55 t ha^{-1} yr^{-1} of dry wood exported). Measured and simulated values of stem biomass at different ages were well correlated (r^2=0.92, Fig 2). However the relationship was biased and the model did not succeed in simulating the full range of productivity levels. This means that the different levels of light interception observed on the 16 stands were not sufficient to explain different productivity levels. In addition, simulations were highly sensitive to the water holding capacity attributed to each stand, which is delicate to determine on these deep soils where roots extend to an unknown depth.

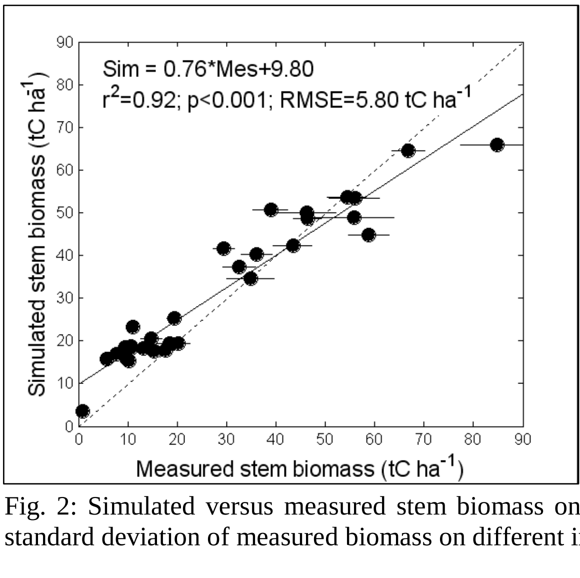

Fig. 2: Simulated versus measured stem biomass on the network of 16 stands. Horizontal lines represent ± 1 standard deviation of measured biomass on different inventory plots of each stand.

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