Competition for light and light use efficiency for *Acacia mangium* and *Eucalyptus grandis* trees in mono-specific and mixed-species plantations in Brazil

G. le Maire [1], Y. Nouvellon [1, 2], J.L.M. Gonçalves [3], JP. Bouillet [1, 3], JP. Laclau[1, 4]

[1] CIRAD, UMR Eco&Sols, Montpellier, France. guerric.le_maire@cirad.fr; [2] IAG, University of São Paulo, São Paulo, Brazil; [3] ESALQ, University of São Paulo, Piracicaba, Brazil; [4] Ecology Department, University of São Paulo, São Paulo, Brazil

Context

300,000 new hectares of Eucalyptus plantations are established per year in Brazil, on a total of 4,200,000 hectares (ABRAF, 2009).
These plantations are highly productive, about 50 m^3/ha/y, and the exportation of wood is up to 100 t C ha-1 at the end of a six-year rotation.
Nitrogen fertilizer inputs are applied to meet tree requirements, and to compensate for the large nitrogen outputs associated with wood exportation .
The use of fertilizers comes with economic and potential environmental costs.

→ **Mixed plantations with N-fixing species might be an attractive option for limiting the use of fertilizer in highly productive Eucalyptus plantations**.

In mixed plantations, it is however difficult to disentangle the effects of N fixation from the effects of light competition within and between the species and the density of species.

Approach

In this study, **the 3D model of forest canopy radiation absorption MAESTRA** (Wang and Jarvis 1990; Medlyn 2004) was applied on a randomized block design experiment in southern Brazil of Acacia Mangium and Eucalyptus grandis mixed-plantations.

Mixed species experiment

- **Randomized block design** set up in southern Brazil, including a replacement series and an additive series design, as well as a nitrogen fertilization treatment, and conducted during a full 6 years rotation (Figure 1) (Laclau et al. 2008).
- The **gradient of competition** between Eucalyptus and Acacia in this design resulted in very different conditions of growth of Acacia, from totally dominated up to dominant canopies. In this study we focus on the pure and 50/50 stands
- **Complete inventory** (equivalent diameters DBH, height) twice a year
- **Destructive sampling** of 10 trees per treatment in block 4 once a year for the establishment of allometric relationships for crown height and diameters, leaf area, trunk biomass; Allometries are generally very precise

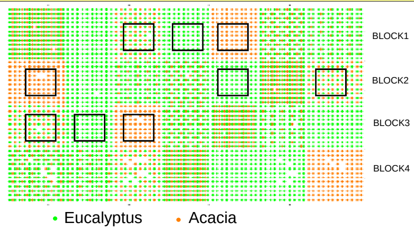

Figure 1: The randomized block experiment mixing Eucalyptus and Acacia with different densities. Black squares encompass the 100% Eucalyptus, 100% Acacia and 50/50 treatments used in this study (36 tree in each square)

MAESTRA parameterisation

- Each tree **position and sizes** was described dynamically through the entire rotation (Figure 2). They were all linearly interpolated between inventory dates, except leaf area. All trees are represented by a half-ellipsoidal crown.
- **Leaf area of each tree** was obtained from destructive sampling and allometric relationships at the dates of destructive inventory, and interpolated using a classical seasonal variation pattern (obtained from another experiment) (le Maire et al. 2010).
- **Leaf reflectance and transmittance** in PAR and soil reflectance were obtained from leaf-scale measurements on a large database obtained on this site, and representative of within and inter-tree variability. They were considered constant with time.
- **Leaf angle distribution function**, adjusted with a beta distribution, was obtained from measurements during destructive sampling. Two other beta distributions were adjusted for the **leaf area distribution** within the crown. All these distributions were considered to be constant with time.
- The simulations were performed for the **2 last years of the rotation**, with half-hourly meteorological data. The 100 closest surrounding trees were considered when calculating the shading of the target tree.
- Daily **absorbed photosynthetically active radiation (APAR) is calculated for each trees**, and compared with tree biomass increment measurements.

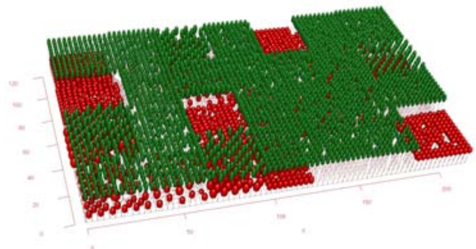

Figure 2: Graphical representation of the scene used in MAESTRA to compute absorbed photosynthetically active radiation for each individual tree (with Maeswrap R code by R. Duursma). Values are in meters. Scene at 54 months

Results

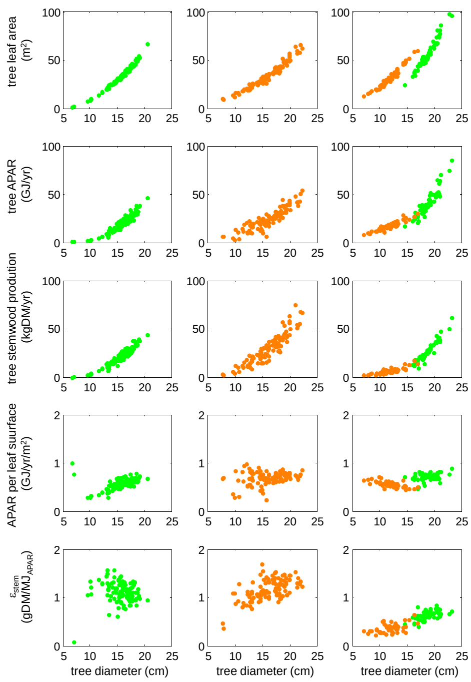

Figure 3: Tree-scale results, pooled for the blocks 1 to 3. Eucalyptus are in green, Acacia in orange. ε_{stem} is the radiation use efficiency for stemwood production

Tree- scale

- Tree APAR and stemwood production are function of tree diameter, i.e. the biggest trees are growing faster, and absorb more light
- Their ratio (ε_{stem}) show almost no correlation with tree diameter
- ε_{stem} is lower for single trees in the 50/50 mixed species stands, i.e. big eucalyptus trees in the 50/50 stand absorb more light but does not grow faster than in the pure stand; this may be explained by a different allocation scheme (toward leaves or belowground allocation) or by water stress increase
- wood production per unit leaf area is lower in the 50/50 treatment

Stand-scale

- Acacia trees are completely dominated by Eucalyptus in the 50/50 stand. Even if the Eucalytus of the 50/50 grow faster than in the pure stand, this does not compensate the large reduction of Acacia growth in the 50/50 treatment.
- The total leaf area of the 50/50 experiment is higher than in pure stands, but stemwood production is lower. The hypothesis is that the allocation pattern changes. Eucalyptus in the 50/50 stand reach a high LAI
- Acacia shows a surprisingly high stemwood production during this period (which was not the case between 0 and 4 years).
- The eventual benefit of the nitrogen-fixing species is not visible in the mixture with 50% of each species

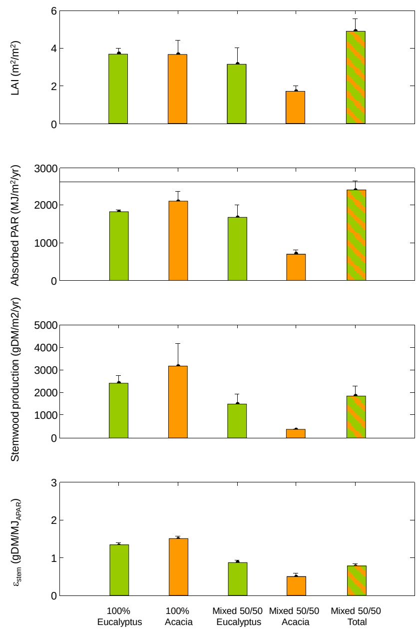

Figure 4: Stand-scale results, averaged for the blocks 1 to 3 (with two standard deviations as error bars). ε_{stem} is the radiation use efficiency for stemwood production

Conclusion

The combination of modelling and measurements have proven interesting for separating the different effects of light on individual tree crown. The results have shown that the 50/50 stand does not benefit in terms of total stemwood growth. This would have to be confirmed by calculations on the entire rotation

More attention has to be paid to introducing acacias in an additive series with the same density of eucalyptus trees as in the monospecific stands.

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