Productivity and carbon allocation in monospecific and mixed-species plantations of *Eucalyptus grandis* and *Acacia mangium* in Brazil

Yann Nouvellon\textsuperscript{1,2}, Jean-Paul Laclau\textsuperscript{1,2}, Daniel Epron\textsuperscript{1,2,3}, Guerric Le Maire\textsuperscript{1}, Leonardo de Moraes Gonçalves\textsuperscript{2}, Jean-Pierre Bouillet\textsuperscript{1,2}

\textsuperscript{1}CIRAD, Montpellier, France
\textsuperscript{2}University of Sao Paulo, Brazil
\textsuperscript{3}University of Nancy, France
### Overall Context

- Increase in world demand for wood products

<table>
<thead>
<tr>
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<th>1980</th>
<th>2005</th>
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</thead>
<tbody>
<tr>
<td>Wood production for industry (M m³ yr⁻¹)</td>
<td>1450</td>
<td>1710</td>
</tr>
<tr>
<td>Wood production for Energy (M m³ yr⁻¹)</td>
<td>1530</td>
<td>1840</td>
</tr>
<tr>
<td>Production of cellulose (M t yr⁻¹)</td>
<td>125</td>
<td>175</td>
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</tbody>
</table>

- In 2000, forest plantations represented 5% of total forest area, but provided 33% of collected wood (Millenium Ecosystem Assessment, 2005)
Eucalyptus plantations in Brazil:
plantation rate: + 300,000 ha/yr in Brazil

- Planted mostly for cellulose, and charcoal (steel industry, etc)
Main reasons for their success:

- High yields despite highly weathered tropical soils (30 to 70 m³ ha⁻¹ yr⁻¹ in Brazil (SP))
- Ability to grow as coppice
High productivity

High wood exportations at the end of the 6 yrs rotation

High exportations of nutrients

- Increase fertilizations?
- Plurispecific plantations with nitrogen fixing trees?
Acacia mangium

Eucalyptus grandis

Nutrient cycles
Nutrient inputs and outputs, Nitrogen fixation, nutrients fluxes between ecosystem compartments,…

Water cycle
Evapotranspiration, stomatal regulation, competition for water resources, water-use efficiency,…

Research

Monospecific stands

plurispecific (mixed-species) stands

Carbon cycle
GPP, respiration, C allocation, ANPP, NEP, …

Canopy Carbon Balance

Net Ecosystem Carbon Exchange

Gross Photosynthesis

Dark and Photo Respiration

bole respiration

root respiration

microbial respiration

litter respiration
- 100% Acacia
- 100% Eucalyptus
- 50% Euc. 50% Acacia
- 100% Acacia

- 7 treatments => only 3 considered in this study
- 4 blocks (repetitions)
- Planted in 2003, clear-cut in 2009
- This study: the 2 last years: 2007-2009
Main goals and hypotheses

Goals

=> compare the wood production, and C allocations of monospecific stands of Acacia and Eucalypt, and plurispecific stands Acacia/Eucalypt

Hypotheses

⇒ a large part of the differences in wood production between monospecific stands is explained by differences in C allocation

⇒ The C allocation patterns of each species is modified in mixed- species plantations compared to mono-specific plantations due to inter-specific interactions and shifts in soil N status

Litton et al., 2007
Methodology

Monitoring of litterfall + $\Delta$ foliage biomass

Inventories (Tree height, diameter) + allometry

\[ TBCA = F_s - L_a + \frac{\Delta C_L + \Delta C_s + \Delta C_R}{\Delta t} \]

Cumulated soil CO2 effluxes

Litter fall

Changes in C stocks in the soil, forest floor, roots

Giardina et al., 2004; Ryan et al. 2004, 2010
Soil CO₂ effluxes measurements

- **Eucalyptus grandis**
- **Acacia mangium**

- 54 soil collars in mixed-species stands (27 by species = 9 * 3 blocks)
- 27 soil collars in each monospecific stand
- Measurements every two weeks
Results: Tree Growth

In plurispecific stands, Acacia were clearly dominated by Eucalyptus.

Despite low differences in tree height, Acacias in mixed stands were much lighter than in 100%A stands, and Eucalyptus trees in mixed were much heavier than in 100%E stands.

Despite lower biomass in 100%A than in 100%E at year 6, production during the two last years was higher in Acacia stands.

Total aboveground biomass at the end of the 6 yr-rotation:
- 68.2 tC/ha in 100%E
- 66.0 tC/ha in 100%A
- 62.0 tC/ha in 50%E50%A

Total production is lower in mixed stand compared to monospecific stand.
Results: Soil CO$_2$ effluxes

Soil CO$_2$ effluxes in mixed stands were higher than in 100%E and 100%A.
Results: Soil CO₂ effluxes

**Acacia 100%**
- Litterfall: 736 gC m⁻²
- Δ root: 246 gC m⁻²
- Δ Lit: -94 gC m⁻²
- TBCA: 1915 gC m⁻²

**Eucalyptus 100%**
- Litterfall: 1163 gC m⁻²
- Δ root: 569 gC m⁻²
- Δ Lit: 330 gC m⁻²
- TBCA: 2509 gC m⁻²

**Mixed stand E50%A50%**
- Litterfall: 1062 gC m⁻²
- Δ root: 510 gC m⁻²
- Δ Lit: 265 gC m⁻²
- TBCA: 2651 gC m⁻²

**Fs** is the highest in mixed stand, lowest in Acacia 100%, and intermediate in Eucalyptus 100%.
In the stands with the highest wood production, the fraction of ANPP allocated to litter production was the lowest.

Stands with highest wood production, also allocate proportionally less to the belowground system.

Allocation patterns explain a large part of the differences in wood production.
Simulation of APAR with MAESTRA showed that both at the individual tree scale and the stand scale, light-use efficiency (LUE) is higher for Acacia 100% stands, lowest for mixed stands, and intermediate for Eucalyptus 100% stands.

Differences in C allocations shown in this presentation explain a large part of these differences in LUE.
Perspectives

1) Quantify carbon allocations to aboveground respiration (=> differences in carbon use efficiencies?)

2) In mixed-species stands, to estimate TBCA for each species => do inter-specific competitions change the fraction of GPP allocated belowground?

3) Describe the allocations patterns over a whole rotation => are age-related changes in carbon allocation pattern species-specific?
Thanks....