Silviculture for Plantations and Restoration in Brazil

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Topics

- Eucalyptus forests in Brazil
- From Empirical to Process-Based Forest Research
- Atlantic Forest Restoration: Using Plantation’s Concepts
Brazil = 8,511,965 km², Almost 50% Forest

Climate
Mean Annual Temp
= 15 to 29°C
60 to 84°F

Rain
= 700 to 2500 mm/yr
28 to 98 in/yr

Elevation 90% < 800 m
< 2600 ft

So, why plantations?
**Brazilian Population**

Population (Millions)

- 10 % Urban
- 30 % Urban
- 80 % Urban

**European Immigration**

- Year: 1500, 1550, 1600, 1650, 1700, 1750, 1800, 1850, 1900, 1950, 2000

**Impact on the Biomes**

- Atlantic Forest (7%)
- Savanna (50%)
- Amazon (86%)

- Year: 1500, 1550, 1600, 1650, 1700, 1750, 1800, 1850, 1900, 1950, 2000

- Pristine Areas (%)

- Y-axis: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

- X-axis: 1500, 1550, 1600, 1650, 1700, 1750, 1800, 1850, 1900, 1950, 2000
São Paulo State Deforestation

Dr. Navarro and friends in a 1925
BRAZIL CONTEXT

- 6 Mha Eucalyptus, Pinus, Acacia, Tectona
- 4-fold Increase in Productivity (40 yrs)
- Short-Rotation, Wood Plot-Level Studies
- Yield Models: Site-Species-Specific (SI, BA)

Seeds sources: Sao Paulo State Forests, USP Forests, Australia, USA, Central America Countries
Typical Imported Seeds Plantation - 1970

The Same Area Today *E. grandis* Clone
Slash Management (No Burn)

Subsoilers
**Eucalyptus grandis x urophylla 1.5 year-old**

35 kg P/ha (31 lb P/ac)
No Fertilization

**The Same Area Today E. grandis Clone**

30 to 40% Genetics
60 to 70% Silviculture
Extreme (Low) Values

- *Inadequate Climates*
- *Inadequate Soils*
- *Not Tested Clones*

- WNPP < 500 g m$^2$yr$^{-1}$

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- *Adequate Climates*
- *Adequate Soils*
- *Local Selected Clones*
- *Fertilization*

*Weeds and Pests Control*

WNPP up to 4000 g m$^2$yr$^{-1}$

*4 years-old*
Environment + Genetics + Management = 1 year 6 to 8 years
Empirical Approach Restricts Extrapolations Across Spatial and Temporal Scales:

- Environmental and Management Changes
- Sustainability and Resource Use
- Global Cycles: C, Water, Nutrients

C sequestration: 345 million ha tropics

- Process-Based Models
- Production Ecology
- Plot-Level Studies Trials
To Characterize the Production Ecology of Clonal *Eucalyptus* Plantations:

Transect 14 stands of *E. grandis* x *urophylla* along a geographic gradient
Sampling:

- Biomass regression for above- and belowground
- Specific edaphic attributes

Results:

MAI:
- No edaphic effect (Fertilized Forests)
- Rainfall Dominant Growth Factor
  + 2.2 Mg ha\(^{-1}\) y\(^{-1}\) per 100 mm y\(^{-1}\)

Root: Above Partitioning:
- Ratio Decreased With Productivity

\[
\text{MAI} = - 7.1 + 0.022 \text{ Rainfall} \\
\text{R}^2 = 0.80, P < 0.0001
\]

\[
\text{R:A} = 0.495 - 0.012 \text{ SI} \\
\text{R}^2 = 0.55, P = 0.002
\]
Resource-Use-Efficiency:

Water Use Efficiency = \( f(1/\text{VPD}) \)

Light- and N-use-efficiency increased with Rainfall (Productivity):
Higher stomatal conductance and aboveground allocation

BEPP Experimental Network
Brasil Eucalyptus Produtividade Potential

www.ipef.br/bepp/
BEPP – Main Objectives

- To estimate the potential productivity and efficiency use of resources of *Eucalyptus* genotypes in Brazil
- To determine the C fixation, allocation and storage of *Eucalyptus* plantations under water, nutrient and dominance manipulations
- To test how stand structure and dominance influence production
- To develop information for management applications to increase wood production and sustain the environment

**BASIC TREATMENTS**

<table>
<thead>
<tr>
<th>Fertilization</th>
<th>Irrigation</th>
<th>Planting</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential</td>
<td>Irrigated</td>
<td>Uniform</td>
<td>FIU</td>
</tr>
<tr>
<td>Potential</td>
<td>Irrigated</td>
<td>Heterog.</td>
<td>FIH</td>
</tr>
<tr>
<td>Potential</td>
<td>No</td>
<td>Uniform</td>
<td>FNU</td>
</tr>
<tr>
<td>Traditional</td>
<td>Irrigated</td>
<td>Uniform</td>
<td>TIU</td>
</tr>
<tr>
<td>Traditional</td>
<td>No</td>
<td>Uniform</td>
<td>TNU</td>
</tr>
</tbody>
</table>
gs – per Clone

Jan 2007

gs (mmol/m²/s)

DPV (kPa)

ARA
BSC
COP
VER
IPB
CEN
VCP

gs = per Clone
Fine root distribution
Partial Results...

- Irrigated trees have 20% higher transpiration.
- They grow 20 to 30% more wood.
- WUE of Irrigated Plots equal or higher than Rainfed Plots.
Forest - Center
MAI = m³/ha/yr

Also Centered in Water
Liters/ctch/yr
Trad + F + I + FI
IMA (m³/ha/ano)

[Diagram showing IMA values for different treatments: Trad, + F, + I, + FI, with values 532, 560, 700, 728 ft³ ac⁻¹ y⁻¹]

Genetics + Bad Silviculture
Genetics + Good Silviculture

Forest Plantations

● = 100,000 ha
## WOOD PRODUCTS INDUSTRY (2002)

<table>
<thead>
<tr>
<th>Product</th>
<th>UN 1000</th>
<th>Production</th>
<th>Domestic Consumption</th>
<th>Source</th>
<th>Planted(1)</th>
<th>Native(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp</td>
<td>t</td>
<td>8.020</td>
<td>5.020</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Paper</td>
<td>t</td>
<td>7.800</td>
<td>6.879</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Charcoal</td>
<td>mdc</td>
<td>26.200</td>
<td>26.200</td>
<td>68%</td>
<td>32%</td>
<td>-</td>
</tr>
<tr>
<td>Sawnwood</td>
<td>m³</td>
<td>22.300</td>
<td>20.000</td>
<td>35%</td>
<td>65%</td>
<td>-</td>
</tr>
<tr>
<td>Plywood</td>
<td>m³</td>
<td>2.600</td>
<td>900</td>
<td>60%</td>
<td>40%</td>
<td>-</td>
</tr>
<tr>
<td>MDF</td>
<td>m³</td>
<td>845</td>
<td>716</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Particleboard</td>
<td>m³</td>
<td>1.800</td>
<td>1.800</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OSB</td>
<td>m³</td>
<td>90</td>
<td>80</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fiberboard</td>
<td>m³</td>
<td>507</td>
<td>295</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EGP</td>
<td>m³</td>
<td>285</td>
<td>220</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mouldings</td>
<td>m³</td>
<td>490</td>
<td>50</td>
<td>40%</td>
<td>60%</td>
<td>-</td>
</tr>
<tr>
<td>Doors</td>
<td>um</td>
<td>6.300</td>
<td>4.700</td>
<td>70%</td>
<td>30%</td>
<td>-</td>
</tr>
<tr>
<td>Floors</td>
<td>M²</td>
<td>22,50</td>
<td>15,20</td>
<td>50%</td>
<td>50%</td>
<td>-</td>
</tr>
<tr>
<td>Blocks / Blanks</td>
<td>m³</td>
<td>430</td>
<td>360</td>
<td>100%</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

(1) Industrial roundwood: 110 millions m³
(2) Industrial roundwood: 66 millions m³

### Brazil's Plantation Projections

<table>
<thead>
<tr>
<th>Year</th>
<th>Projected Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>790,000 ac</td>
</tr>
<tr>
<td>2004</td>
<td>1,148,000 ac</td>
</tr>
<tr>
<td>2005</td>
<td>1,366,000 ac</td>
</tr>
<tr>
<td>2006</td>
<td>1,548,000 ac</td>
</tr>
</tbody>
</table>

Legend:
- **Green**: Pinus
- **Orange**: Eucalyptus
Plantation - Conclusion

- Brazil has a high potential to produce multipurpose wood from different species with high productivity and using less land.
- Plantations must be continuously studied to be correctly managed for the long-term sustainability.

Effects of silvicultural practices on productivity of Atlantic Forest restoration plantation.
OVERAL CONTEXT

**Atlantic Forest Formation**

- One of the world’s greatest centers of tropical biodiversity

  - 20,000 vascular plants *(6,000 endemic)*
  - 190 reptile species *(60 endemic)*
  - 250 mammals species *(55 endemic)*

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**Atlantic Forest Area**

- Highly threatened by deforestation and degradation

Source: [http://mapas.sosma.org.br/](http://mapas.sosma.org.br/)

On these areas:

- Lives 67% of the population
- 80% GDP is generated
The Atlantic Forest degradation

<table>
<thead>
<tr>
<th>coffee plantations</th>
<th>Pasture</th>
</tr>
</thead>
</table>

| sugar cane plantations |

Actual Situation

- Lands with high levels of degradation

Abandoned marginal lands that cannot be rehabilitated for either agricultural or intensive commercial forestry production (Engel & Parrotta, 2001).
Nowadays...

Restoration activities only focus on species composition and fauna/flora interactions.

Silvicultural activities like fertilization and weed control are restricted and with low investments.

These methods don't allow us to evaluate the potential productivity of Brazilian native trees on restoration areas.

Restoration methods to overcome the environmental stress are needed.

Ecophysiological approach about restoration...

Main focus on canopy variables and processes that control forest growth:

• Leaf Area Index
• Light Use Efficiency
• Nitrogen content on leaves

To better understand what affect native forest plantation growth and...

...be able to recommend the best models for Atlantic forest restoration based on ecophysiological processes.
Experimental Design

- Factorial = 3 factors with 2 levels \((2^3)\)
- 5 hectares
- 4 blocks
- 8 treatments

Measurements

- Diameter and height every 6 months since planting (January of 2004)
- Allometric equations for each specie to calculate biomass
- LAI with hemispherical pictures

1) Species Composition Factor (20 different species):

- 50:50: 50% (pioneers) and 50% (not pioneers)
- 67:33: 67% (pioneers) and 33% (not pioneers)
Experimental design: 3 factors with 2 levels ($2^3$)

2) Spacing Factor:

3x1: 3 x 1 m = 3,333 plants hectare$^{-1}$

3x2: 3 x 2 m = 1,666 plants hectare$^{-1}$

Plots have the same size in the field.

<table>
<thead>
<tr>
<th>Pioneers</th>
<th>Not Pioneers</th>
</tr>
</thead>
</table>

3) Silviculture Factor:

**Usual**: 1 fertilization, weed control only on rows

**Intensive**: 4 fertilizations (0, 6, 12 and 18 months), total weed control, soil pH corrections
Results

Composition Factor

More pioneer species (fast growing trees) does not increased WNPP…

Leaf Area Index

36 months

Light Use Efficiency - 50:50 = 67:33 = 0.24 g MJ⁻¹
**Plant Spacing Factor**

- Greater LAI on 3x1m (0.98) than on 3x2m (0.71) lead to higher wood biomass stock at 42 months.
- Competition after 36 months among planted trees.
- Both levels of spacing factor showed the same LUE:
  - 3x1m: 0.25 g MJ⁻¹
  - 3x2m: 0.23 g MJ⁻¹

**Management Factor**

- Leaf Area Index 36 months
  - Intensive = 1.8
  - Usual = 0.8
  - Increased by 3.6-fold
- 10-fold increase in LUE only by the effect of intensive management (0.04 versus 0.46 g MJ⁻¹)
Plant spacing has distinct responses to environmental stress levels.

**Interaction - Silviculture x Spacing**

- Usual
- Intensive

Reduction of the environmental stress

**3x2m plant spacing depends on intensive silvicultural practices to express its maximum productivity**
Leaf Area Index ($m^2 m^{-2}$) 

WNPP (Mg ha$^{-1}$ semester$^{-1}$)

WNPP = 3.13 * IAF - 0.0044
$R^2 = 0.96$
$P < 0.0001$

Individually LAI and [N] can predict growth

Canopy status

Great tool to evaluate the quality of restoration and to manage the plantation to optimize growth

The nutritional status of the canopy improve the capacity to predict growth

WNPP = 0.51 + 1.91 * LAI + 0.31 * N * LAI
$R^2 = 0.99$
$P < 0.0001$
Conclusions

- A 50:50 proportion of pioneers and non-pioneers is indicated to increasing the biodiversity without decreasing productivity.

- The 3x2m spacing showed the similar productivity of 3x1m after 36 months, but demanding intensive silviculture (C4 grass control).

- The “Plantation Technology” increased growth, LAI and LUE, highlighting the potential of Brazilian species for restoration, and commercial, purposes.

Best model to increase biodiversity, reduce costs and achieve high growth rates: 50:50%, 3x2m and intensive management
- Water Resources
- Biodiversity

Eucalyptus

Intact LR

Water

To be restored
Legal Reserve (20 – 80%)

Permanent Preservation

Water

River

Water Resources

Biodiversity
Thanks