Forest Management Strategies for Atmospheric CO$_2$ Mitigation

Timothy A. Martin
Wendell P. Cropper, Jr.
School of Forest Resources and Conservation
University of Florida
Mauna Loa, Hawaii - C.D. Keeling and T.P. Whorf

Atmospheric CO$_2$ Concentration (parts per million)

Year

Forest Store LOTS of $\text{CO}_2$
just through growth (*in situ*)

U.S. EPA 2007
The diagram illustrates the biological carbon balance in a forest. The key components are:

- **Atmosphere**
  - CO₂ Taken Up by Plant Photosynthesis
  - CO₂ Given Off by Respiration / Decay / Fire
  - Net Uptake or Loss of CO₂ by Forest

The balance is calculated as follows:

\[
\text{CO}_2 \text{ Taken Up by Plant Photosynthesis} + \text{CO}_2 \text{ Given Off by Respiration} = \text{Net Uptake or Loss of CO}_2 \text{ by Forest}
\]
ex situ forest carbon sequestration

- Storage in wood products – paper, lumber, furniture
- Storage in landfills
- Substitution for other, carbon-emitting products like steel or concrete
- Substituting for fossil fuels
In Situ + Ex Situ
Forest Carbon Balance

Atmosphere

Plant Photosynth.

Respiration, decay, fire
Silviculture

FOREST

Harvest

Paper
Solid Wood
Forestry Carbon Emission Mitigation Strategies

- Increase forested land area through reforestation or afforestation
- Increase carbon density of existing forests at both stand and landscape scales
- Expand the use of forest products that sustainably replace fossil fuel CO$_2$ emissions
- Reduce emissions from deforestation and degradation

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Objective

• To quantify how different silvicultural scenarios affect the C density of plantation pine forests in northern FL, a region representative of much of the SE U.S. Coastal Plain
Methods

- Phenomenological model of pine plantation C balance based on eddy covariance data from ~15 site-years of data
- Estimates of C fluxes due to silvicultural activities, harvest, storage in wood products
Pattern of Southern Pine Plantation Carbon Sequestration - Yearly

Slash Pine Plantation

Stand-Level Carbon Balance (metric tons CO$_2$ / acre / year)

Year

“Sink”

“Source”
Pattern of Southern Pine Plantation Carbon Sequestration - Cumulative

Slash Pine Plantation

Stand-Level Cumulative Carbon Balance (metric tons CO₂ / acre)

Year

0 5 10 15 20

“Sink”

“Source”
Silvicultural Regimes

• 20 Year Rotation
  – NP fertilizer at age 6 yrs.
  – 100% pulpwood

• 30 Year Rotation
  – NP fertilizer at age 6 and 20 yrs.
  – 50% pulpwood, 50% chip 'n saw / sawlog

• 45 Year Rotation
  – NP fertilizer at age 6, 20 and 30 yrs.
  – Stands thinned to 70 ft² / ac of basal area
  – Final harvest at 45 yrs.
  – 50% pulpwood, 50% sawtimber at thinning;
  – 80% chip 'n saw / sawlog, 20% pulpwood at final harvest
# Carbon Costs of Silvicultural Operations

<table>
<thead>
<tr>
<th>Plantation Age (years)</th>
<th>Silvicultural Activity</th>
<th>Carbon cost (metric tons / ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Site preparation; raking or spot piling, aerial application of herbicide, Savannah bedding</td>
<td>0.095</td>
</tr>
<tr>
<td>1</td>
<td>Machine planting</td>
<td>0.101</td>
</tr>
<tr>
<td>6 for pulpwood scenarios 6, 20, 30 for 45 yr rotation scenarios</td>
<td>Helicopter fertilization, 125 lb/acre DAP, 385 lb/acre urea</td>
<td>0.268</td>
</tr>
<tr>
<td>Rotation age for pulpwood scenarios Thinning age and rotation age for 45 yr rotation scenarios</td>
<td>Harvest</td>
<td>0.456</td>
</tr>
</tbody>
</table>

Modified from Markewitz 2006
# Product Conversion Efficiency and Decay Rates

<table>
<thead>
<tr>
<th>Product</th>
<th>Conversion efficiency (mass of product per mass of log input)</th>
<th>Half-life (yrs; Markewitz 2006)</th>
<th>Annual Decay Rate (1/ yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulpwood</td>
<td>58% (White et al. 2007)</td>
<td>1</td>
<td>0.6931</td>
</tr>
<tr>
<td>Chip 'n Saw and Sawlog</td>
<td>64.5% (Spelter and Alderman 2005)</td>
<td>50</td>
<td>0.0139</td>
</tr>
</tbody>
</table>
20-year rotation

Carbon Stock (Mg / ha)

Year

2000 2020 2040 2060 2080
30-year rotation

- in situ

- paper and solid

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2050</th>
<th>2100</th>
<th>2150</th>
<th>2200</th>
<th>2250</th>
<th>2300</th>
</tr>
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<tbody>
<tr>
<td>Carbon Stock (Mg / ha)</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>140</td>
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Graphs showing carbon stock over different years for in situ and paper and solid 30-year rotation scenarios.
30-year rotation

20-year rotation - total

Year

Carbon Stock (Mg / ha)

2000 2050 2100 2150 2200 2250 2300

0 50 100 150 200 250 300
45-year rotation with thinning

45-year rotation - in situ

45-year rotation - paper and solid
45-year rotation with thinning
Summary

• Lengthened rotations increased carbon density of slash pine plantation forest
  – Increased *in situ* sequestration
  – Increased *ex situ* sequestration in solid wood
• C cost of silvicultural activities was negligible
  – 2.2 Mg/ha over entire 45-year regime, compared to average *in situ* carbon density of 125 Mg/ha
• Sequestration in paper was negligible
Future Plans

• Incorporating uncertainty into estimates
• Economics
• Role of non-plantation stands and prescribed fire at stand and landscape levels
• Role of landfills
  – Possibly greatly increased half-life for paper products
  – Methane emissions = 30 times more warming potential than CO₂
Acknowledgements

- Florida Forestry Association
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- NICCR
- Forest Biology Research Cooperative