Carbon accounting of forest bioenergy: from model calibrations to policy options

The Transatlantic Trade in Wood for Energy: A Dialogue on Sustainability Standards and GHG Emissions
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Patrick Lamers
Outline

• Carbon debt
  – Concept
  – Modeling options
  – Example: South-Eastern US studies

• Options to deal with carbon debt
  – Policy options
  – Industry options
  – Conclusions
Carbon debt

Concept
Modeling options
The question

- **Time lag** and volume of (pulse) emissions from biogenic C release and thus the overall climate mitigation potential of bioenergy

- **Not** whether biogenic C released during combustion is taken up again via forest growth
  - sustainable forestry is a prerequisite!
Modeling options

Framework choices
1. Reference point
2. Spatial boundary: stand vs. landscape (LS)
3. Empirical vs. theoretical forest inventory data: dynamic vs. fixed LS
4. Forest C vs. whole LCA
5. Displacement effects
6. C accumulation vs. climate dynamics
7. Albedo effect

Scenario assumptions and parameterization
Framework choices

1. Reference point
   - Defines a timelag
   - Definition important
   - Terminology varies
   - Currently most common:
     - **Payback**: the time until the site reaches its pre-harvest carbon level
     - **Parity**: the time until the site reaches the same carbon volume as the reference scenario (e.g. protection)

2. Stand vs. Landscape
   - Single plot
     - Only one scenario at any given time
     - The baseline remains static
   - Multi plot
     - Bundle of possible harvest plots (fixed or dynamic)
     - Scenario applied to one patch; other plots continue growing or releasing carbon (decay)
Stand level: single plot

Source: Eliasson et al. 2013
Landscape level

Multiple similar plots of varying (here) or same age

Average over all single plots

Source: Eliasson et al. 2013
Typical stand level C balance

Carbon density (Mg C ha$^{-1}$)

1. Harvest
2. Harvest

Carbon break-even points
Carbon parity point

Carbon payback time: $t_{be1} + t_{be2} - x$
Typical landscape C balance

Compare e.g. to: Mitchell et al. 2012
Modeling options

**Framework choices**
1. Reference point
2. Spatial boundary: stand vs. landscape (LS)
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5. Displacement effects
6. C accumulation vs. climate dynamics
7. Albedo effect

**Scenario assumptions and parameterization**
5. Displacement effects

- Market mediated effect (demand-supply interrelation)
- Regional, supra-regional, global
- Competition for fiber may result in competition for land (and thus land use change)

Graph: Pöyry in Dehue 2013
6. C accumulation vs. climate dyn.

- Typically: Cumulative CO$_2$ emissions → C fluxes without climate responses

- Impulse response functions (IRF)
  - Describe the atmospheric decay of a pulse emission
  - Important to understand the climate response to pulse emissions
  - Can be used to describe temperature responses

- Additional measures / indicators:
  - GWP$_{bio}$: Global Warming Potential (biomass)
  - (I)GTP: (Integrated) Global Temperature Change Potential

6. C accumulation vs. climate dyn.

- Typically: Cumulative CO$_2$ emissions $\rightarrow$ C fluxes without climate responses

  Climate responses have been shown to differ between fossil fuel CO$_2$ emissions and those generated by biomass combustion and subsequent tree (re-)growth

- Additional measures / indicators:
  - GWP$_{\text{bio}}$: Global Warming Potential (biomass)
  - (I)GTP: (Integrated) Global Temperature Change Potential

7. Albedo effect

- Surface albedo: reflection coefficient describing the diffuse reflectivity of a surface

Source: Cherubini et al. 2013
Modeling options

Framework choices
1. Reference point
2. Spatial boundary: stand vs. landscape (LS)
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Scenario assumptions and parameterization
1. Energy counterfactual
2. Forest baseline
3. Forest assortment
4. Forest biome
Parameterization I

1. Energy counterfactual
   • GHG counterfactual!
   • Direct replacement vs. grid mix?
   • (Supra-) National vs. Regional?

2. Forest baseline
   • No harvest?
   • Protection?
   • In-/excluding wildfire?
   • Pulp and paper harvest?
   • Other?
     → Depends on (regional) economics at harvest
     → Varies over time!
     → Not static!
3. Forest assortment
   • Large variety of sourcing areas and feedstock
   • US SE: pine thinnings, residues (e.g. tops)
   • BC: residues, MPB
   • Russia: commercial forestry residues, e.g. aspen
   • ...

4. Forest biome
   • Natural biogenic productivity
   • Management adaptation (e.g. fertilization)
   • Site sensitivity, e.g. regarding slash removal
Example

South-Eastern US analyses
The case study area

- Loblolly pine plantations
- Planted post 1950 to generate fiber for timber, pulp & paper
- Rotation time: 25-35 yrs
- Timber & housing market low since 2008
- Increased thinning to save timber value
- Thinnings for P&P and wood pellet production (~25% of total harvest volume)
### Three studies – three outcomes

<table>
<thead>
<tr>
<th>Study</th>
<th>Region</th>
<th>Model</th>
<th>Biome: tree species</th>
<th>Assumed age at initial harvest point</th>
<th>Rotation [years]</th>
<th>Initial land conversion</th>
<th>Harvest share for bioenergy</th>
<th>Methodology/Framework</th>
<th>Forest data</th>
<th>Applicability/Biomass use</th>
<th>Post-harvest carbon cycling</th>
<th>Full LCA</th>
<th>Forest baseline</th>
<th>Energy counterfactual</th>
<th>Displacement modeling</th>
<th>Carbon payback (reference: pre-harvest C level)</th>
<th>Carbon Parity (reference: counterfactual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galik &amp; Abt 2012</td>
<td>VA, USA</td>
<td>FORCARB</td>
<td>Temperate southern: pure Loblolly pine</td>
<td>22</td>
<td>22</td>
<td>Managed to managed forest</td>
<td>Whole-trees</td>
<td>Dynamic landscape</td>
<td>Geospatially explicit</td>
<td>Real case, local use</td>
<td>Yes</td>
<td>No</td>
<td>Protection: no management / use</td>
<td>-</td>
<td>Yes: e.g. shift in forest area, type, management intensity</td>
<td>Managed forest: 36 years Protection reference: 71 years</td>
<td>-</td>
</tr>
<tr>
<td>BERC 2013</td>
<td>South-East USA</td>
<td>Combination</td>
<td>Temperate southern: 8 different forest type groups</td>
<td>Inventory data (0-~130)</td>
<td>dynamic</td>
<td>Managed to managed forest</td>
<td>Whole-trees</td>
<td>Dynamic landscape</td>
<td>Geospatially explicit</td>
<td>Real case, local use and export</td>
<td>Yes</td>
<td>Yes</td>
<td>BAU (timber only harvest)</td>
<td>Fossil electricity (several)</td>
<td>Yes: dynamics regarding pulpwood use e.g.</td>
<td>-</td>
<td>Protection: no harvest, natural regrowth</td>
</tr>
<tr>
<td>Jonker et al. 2013</td>
<td>GA, USA</td>
<td>GORCAM</td>
<td>Temperate southern: pure Loblolly pine</td>
<td>20</td>
<td>20</td>
<td>Managed to managed forest</td>
<td>Whole-trees</td>
<td>Stand- and fixed landscape</td>
<td>Representative, theoretical plots</td>
<td>Real case, export only</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>Fossil electricity (hard coal)</td>
<td>Indirect: shift in management intensity</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

- **FORCARB**
- **Combination**
- **GORCAM**

**Notes:**
- **Temperate southern:**
  - Pure Loblolly pine
  - 8 different forest type groups

**Methodology/Framework:**
- Dynamic landscape
- Stand- and fixed landscape

**Forest data:**
- Geospatially explicit
- Representative, theoretical plots

**Applicability/Biomass use:**
- Real case, local use
- Real case, local use and export
- Real case, export only

**Post-harvest carbon cycling:**
- Yes
- Yes
- Yes

**Full LCA:**
- No
- Yes
- Yes

**Forest baseline:**
- Protection: no management / use
- BAU (timber only harvest)
- Protection: no harvest, natural regrowth

**Energy counterfactual:**
- Fossil electricity (several)
- Fossil electricity (hard coal)

**Displacement modeling:**
- Yes: e.g. shift in forest area, type, management intensity
- Yes: dynamics regarding pulpwood use e.g.
- Indirect: shift in management intensity

**Carbon payback (reference: pre-harvest C level):**
- Managed forest: 36 years
- Protection reference: 71 years
- -

**Carbon Parity (reference: counterfactual):**
- 4-10 (stand) 10-20 (extended stand), < 2 years (landscape)
- 35-50 years
- 12-46 years
Direct comparison

- Galik & Abt: Managed
- Galik & Abt: Unmanaged
- Jonker et al.: Bioenergy
- Jonker et al.: Bioenergy vs. Protection
- BERG: Bioenergy vs. BAU

Years

C payback
C parity
Options to deal with carbon debt

Policy options
Industry options
Conclusions
Policy options to deal with C debt

- ‘Panic’ option: black list (feedstock, region, etc.)
- ‘Proper’ option: regional indicators (biome & forest assortment specific)

→ **Fundamental**: requirement for sustainable forest management (SFM), i.e. replanting, site monitoring, etc.
More policy and industry options

**Policy level**
- Incentivize the use of marginal and unused land
- Increase forest productivity (output)
- Increase supply chain efficiency (avoid losses)
- Integrate fiber production for energy and material (industrial ecology): cascading, residue utilization

**Industry / project level**
- Establish new plantations on degraded/C-poor land → carbon credit
- Increase forest productivity (e.g. fertilizer, weed control) within SFM limits
- Increase initial number of seedlings, early stand density, and the use of pre-commercial thinnings
Conclusions

- Biogenic carbon cycle vs. fossil emissions
- Sustainable forest management (for multiple purposes) is fundamental
- No single correct C debt accounting method
- Current C debate pays little attention to forestry economics & climate dynamics
- Policy options should be carefully weighed and regarded in the wider climate mitigation (policy) context
Results of a model comparison

<table>
<thead>
<tr>
<th>Biomass type Residues/Slash&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Biome: reference case</th>
<th>Min</th>
<th>Max</th>
<th>Studies: forest management regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Sub-) Boreal: BAU + coal based electricity</td>
<td>0</td>
<td>16</td>
<td>23,24,30,33,53; collection instead of slash-burn or decay</td>
<td></td>
</tr>
<tr>
<td>(Sub-) Boreal: BAU + oil based electricity</td>
<td>3</td>
<td>24</td>
<td>23,24,53; collection instead of decay</td>
<td></td>
</tr>
<tr>
<td>(Sub-) Boreal: BAU + natural gas based electricity</td>
<td>4</td>
<td>44</td>
<td>23,24,53; collection instead of decay</td>
<td></td>
</tr>
<tr>
<td>(low-grade) Roundwood&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Temperate southern: Protection&lt;sup&gt;c&lt;/sup&gt; + coal electricity</td>
<td>12</td>
<td>46</td>
<td>28; thinnings and additional fellings on existing plantations (20-25 year rotation)</td>
</tr>
<tr>
<td></td>
<td>Temperate southern: BAU + fossil electricity mix</td>
<td>35</td>
<td>50</td>
<td>61; thinnings and additional fellings on existing plantations (35 year rotation)</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: Protection + coal electricity</td>
<td>0</td>
<td>105</td>
<td>25,30,33; additional fellings in previously unmanaged forest</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: Protection + oil heating</td>
<td>90</td>
<td></td>
<td>18; additional fellings in previously unmanaged forest</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: BAU + coal electricity</td>
<td>53</td>
<td>230</td>
<td>21,30,53; additional fellings in previously un-/managed forest</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: BAU + coal electricity</td>
<td>17</td>
<td>114</td>
<td>53; clear-cut replaced with SRC&lt;sup&gt;d&lt;/sup&gt; (10-20 year rotation)</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: BAU + oil electricity</td>
<td>20</td>
<td>145</td>
<td>53; clear-cut replaced with SRC&lt;sup&gt;d&lt;/sup&gt; (10-20 year rotation)</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: BAU + natural gas electricity</td>
<td>25</td>
<td>197</td>
<td>53; clear-cut replaced with SRC&lt;sup&gt;d&lt;/sup&gt; (10-20 year rotation)</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: BAU + natural gas electricity</td>
<td>300</td>
<td>400</td>
<td>53; additional fellings in managed forests</td>
</tr>
<tr>
<td></td>
<td>(Sub-) Boreal: BAU + fossil electricity</td>
<td>0</td>
<td>0</td>
<td>53; afforestation</td>
</tr>
</tbody>
</table>

Source: Lamers & Junginger 2013
C debt influencing factors

Table 3. Key influencing factors on carbon payback/parity times.

<table>
<thead>
<tr>
<th>Key influencing factor</th>
<th>Increasing carbon payback/parity time (from left to right)</th>
<th>Change involving carbon release (e.g. peatland drainage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land-use/-management</td>
<td>Change involving carbon uptake (e.g. afforestation)</td>
<td></td>
</tr>
<tr>
<td>Silvicultural regime(^{59})</td>
<td>Intensive even-aged forestry (e.g. dedicated replanting with highly productive seeds, fertilization, etc.)</td>
<td>Extensive, close-to-nature forestry (e.g. natural regeneration)</td>
</tr>
<tr>
<td>Plant growth rate</td>
<td>High (e.g. tropical)</td>
<td>Medium (e.g. temperate)</td>
</tr>
<tr>
<td>Carbon content of harvested biomass</td>
<td>Low (e.g. branches)</td>
<td>Medium (e.g. stumps)</td>
</tr>
<tr>
<td>Harvest share of living biomass</td>
<td>Low (e.g. higher deadwood share)</td>
<td>Medium</td>
</tr>
<tr>
<td>Harvesting intensity</td>
<td>Low (e.g. residues only)</td>
<td>Medium</td>
</tr>
<tr>
<td>Fossil fuel conversion efficiency reference</td>
<td>Low (e.g. old coal power plant)</td>
<td>Medium</td>
</tr>
<tr>
<td>Biomass to energy conversion efficiency</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Carbon intensity of substituted fossil fuel</td>
<td>High (e.g. coal)</td>
<td>Medium (e.g. oil)</td>
</tr>
<tr>
<td>Share of otherwise decaying biomass</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Source: Lamers & Junginger 2013
References

References

Thank you!

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