Carbon accounting of forest bioenergy using life cycle assessment

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1. Carbon accounting and life cycle assessment

When I can’t sleep, I count carbon...

Adapted from Xavier Gorce
Life cycle assessment

- Climate Change
- Acidification
- Eutrophication
- Ecotoxicity
- Human Toxicity
- Resource Depletion
- Smog
- Ozone Layer Depletion

LIFE CYCLE STAGES:
- Production
- Distribution
- Use
- End-of-life

Resources

Emissions
Life cycle assessment according to ISO standards

Framework (ISO 14040/14044)

Goal and scope definition

Life cycle inventory

Life cycle impact assessment

Interpretation

Applications

• Design and improvement
• Strategic planning
• Policy making
• Communication
• Others
Life cycle of forest products
Comparing functionally equivalent systems

Production of 1 MJ heat for an institutional building
Accounting for emissions and resource extractions

- Emissions to air
- Emissions to water
- Emissions to soil

Production of X

- Electricity, fuel, etc.
- Materials
- Infrastructure

Product X

Extraction of natural resources
Life cycle inventory
Data sources

Primary (or specific) data:
• Data from the forest industry, plants, energy providers, etc.;
• Usually available for foreground processes;
• Data regarding key parameters, conditions of use, etc.

Secondary (or generic) data:
• Literature;
• Statistics;
• Modeling;
• Life cycle inventory databases.
Life cycle impact assessment

- 1 kg CO₂
- 1 kg CH₄
- 1 kg N₂O

= 36 kg CO₂ eq

= 298 kg CO₂ eq
Potential for GHG emissions reductions

- Lower supply chain GHG emissions?
- GHG emissions from combustion compensated by biological carbon sequestration?
- Would forest conservation be better than harvesting to store carbon?
2. Accounting for biogenic carbon
Biogenic carbon neutrality

Is the amount of carbon released from biomass combustion and decay equivalent to the amount of carbon uptaken from the atmosphere?

Δ Carbon = 0 ???
Forest carbon neutrality

Canada – Steady state after 100 years of harvest

Since 1990, it is estimated that 420 million hectares of forest have been lost through conversion to other land uses, although the rate of deforestation has decreased over the past three decades. (FAO)

Equivalent to fossil carbon emissions

Head et al. (2019) Journal of Cleaner Production
Why is quantification a challenge?

- Depends on local parameters (climate, species, soil, etc.) and on forest management practices;
- Complex modelling;
- Definition of a baseline scenario required:
  - To estimate the « without human intervention » carbon stock and compare it to that of the managed forest to quantify anthropogenic carbon flows to be included in the LCA.
3. Timing
Decades-long processes
What if we increase harvest?

Balsam fir – Boreal forest in Québec

Head et al. (2019) Journal of Cleaner Production
Forest bioenergy carbon debt

Compensated by temporary carbon storage in wood used as material

<table>
<thead>
<tr>
<th>Debt (years)</th>
<th>Type of biomass</th>
<th>Energy produced</th>
<th>Fossil fuel substituted</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Branches</td>
<td>Heat</td>
<td>Natural gas</td>
<td>Repo et al. 2010</td>
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<tr>
<td>6</td>
<td>Forest residues</td>
<td>Heat</td>
<td>Fuel oil</td>
<td>Berner &amp; Paré, 2012</td>
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<td>22</td>
<td>Stumps</td>
<td>Heat</td>
<td>Natural gas</td>
<td>Repo et al. 2010</td>
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<td>70-75</td>
<td>Commercial stems</td>
<td>Heat</td>
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<td>Manuilova &amp; Johnston, 2011</td>
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<td>74</td>
<td>Forest residues</td>
<td>Ethanol</td>
<td>Gasoline</td>
<td>McKechnie et al. 2011</td>
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<tr>
<td>90</td>
<td>Whole trees</td>
<td>Heat</td>
<td>Fuel oil</td>
<td>Bernier &amp; Paré, 2012</td>
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<tr>
<td>&gt; 100</td>
<td>Whole trees</td>
<td>Ethanol</td>
<td>Gasoline</td>
<td>McKechnie et al. 2011</td>
</tr>
</tbody>
</table>

Adapted from Beauregard et al. 2012
Take-home messages

• The forest sector plays an important but complex role in the global climate;
• There is no magic solution to fight climate change, but a package of solutions;
• Life cycle carbon accounting is essential to identify the best strategies and avoid bad ideas.
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