Effect of the model choice for simulating soil carbon stocks and stock changes: comparison of four soil models

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European forests at the moment → C sink/source

Sink/source role dependent on:

- Natural / Anthropogenic disturbances
- Forest management
- Climate change
Soil C flux assessments:

- Measurements: time consuming and expensive
- Soil C models: assumptions, simplification of the reality, various time and space scales, specific

BUT different models → different results
Objective

Evaluation of model effects on the assessment of C stocks and stock changes in forest soils
Research questions

- What is the effect of the initialization of C stocks on the simulation of the soil C fluxes?
- How does the choice of the model affect the stock change assessment?
Material and methods

- Comparison of 4 soil C models
  - FORESEE - 4C
  - ROMUL
  - Rothamsted Carbon Model – RothC
  - Yasso
Material and methods

- Comparison of 4 soil C models

  - FORESEE - 4C: ✔ Process-based
    ✔ Simulations down to rooting depth
    ✔ Daily soil C dynamic
Material and methods

- Comparison of 4 soil C models
  - ROMUL: ✓ Process-based
    ✓ Simulations down to 1 m
    ✓ Monthly soil C dynamic
Material and methods

- Comparison of 4 soil C models

  - Rothamsted Carbon Model – RothC:
    - Process-based
    - Simulations down to 40 cm
    - Monthly soil C dynamic
Material and methods

- Comparison of 4 soil C models
  - Yasso: ✓ Dynamic soil C model
    ✓ Simulations down to 1 m
    ✓ Yearly soil C dynamic
Study sites

FIN-VT-pine
FIN-MT-pine
FIN-MT-spruce
FIN-OMT-spruce

DE-Cho-pine
DE-Aug-spruce
## Study sites

|-------------|-------------|-------------|---------------|---------------|---------------|-------------|

### Stand and soil data

<table>
<thead>
<tr>
<th>Moisture/ nutrient</th>
<th>Subxeric</th>
<th>Mesic</th>
<th>Mesic</th>
<th>Rich</th>
<th>Wet/ moderate</th>
<th>Dry/ moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand age</td>
<td>36</td>
<td>75</td>
<td>55</td>
<td>65</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>Basal area m(^{-2}) ha(^{-1})</td>
<td>22</td>
<td>31</td>
<td>28</td>
<td>25</td>
<td>43</td>
<td>38</td>
</tr>
</tbody>
</table>
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  Initial C stocks
  Litter time series of 4C and EFIMOD
  C in the organic, mineral and total soils
Conclusion
### Initial C stocks [kg C m⁻²]

|----------------|--------------|--------------|----------------|------------------|----------------|--------------|

| 4C / ROMUL      | 3.4          | 4.1          | 4.4            | 11.2             | 9.5            | 10.7         |

- Measured total soil C

| Depth (cm)      | 40           | 95           | 200            |

| RothC           | 1.9          | 2.4          | 3.2            | 9.7              | 1.9            | 6.4          |

- Measured C in mineral soil down to 40 cm
## Initial C stocks [kg C m\(^{-2}\)] - Yasso

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Average 4C</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Litter</td>
<td>5.6</td>
<td>3.6</td>
<td>4.6</td>
<td>5.4</td>
<td>7.7</td>
<td>12.0</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>EFIMOD Litter</td>
<td>4.3</td>
<td>7.6</td>
<td>4.0</td>
<td>10.2</td>
<td>11.4</td>
<td>7.6</td>
</tr>
<tr>
<td><strong>Stand age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young stand</td>
<td>2.7</td>
<td>3.7</td>
<td>4.9</td>
<td>7.2</td>
<td>12.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Rich soil</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old stand</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Measured C</td>
<td>3.4</td>
<td>4.1</td>
<td>4.4</td>
<td>11.2</td>
<td>9.5</td>
<td>10.7</td>
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<td>75</td>
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<td>65</td>
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</tr>
</tbody>
</table>
Litter time series – 4C and EFIMOD

4C litter \rightarrow \text{stem mortality}
Litter time series – 4C and EFIMOD

Young stands (VT → 36y, Cho → 50y) + high density (BA Cho=38 m⁻²ha⁻¹)
C in the organic layer

ROMUL peak increases wood litter input to the organic layer.
C in total soil and mineral layer: 4C litter

FIN-VT-pine

FIN-OMT-spruce

DE-Cho-pine

RothC: high C

Initial C in mineral layer (9.7) similar to total C (11.2)

Yasso lower

ROMUL: effects remaining from 4C litter peaks

SOC in total and mineral soils [kg C m$^{-2}$]
C stock changes in 20 years

RothC/Yasso < 4C/ROMUL → Equilibrium vs none

Stock changes in 20 years [kg C m⁻²]

+ : C sink  - : C source
### Annual C stock changes [g C m\(^{-2}\) a\(^{-1}\)]

<table>
<thead>
<tr>
<th>Median values</th>
<th>Total soil C</th>
<th>C mineral layer</th>
<th>Minimum total C</th>
<th>Maximum total C</th>
</tr>
</thead>
<tbody>
<tr>
<td>All combinations (sites/model/litter)</td>
<td>18.1</td>
<td>7.8</td>
<td>-44.4</td>
<td>120.5</td>
</tr>
<tr>
<td>4C</td>
<td>145%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROMUL</td>
<td>-49%</td>
<td></td>
<td></td>
<td>High sensitivity of the model choice</td>
</tr>
<tr>
<td>RothC</td>
<td>87%</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Yasso</td>
<td>-49%</td>
<td></td>
<td></td>
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Conclusion

What is the effect of the initialization of C stocks on the simulation of the soil C fluxes?

- Initialization with measured soil C if available
  
  → 4C and ROMUL similar trends for total soil C

- Initialization with litter input: easily available
  
  → Yasso: forest soils often not in equilibrium with the actual stand
Conclusion

How does the **choice of the model** affect the stock change assessment?

- High sensitivity

- Annual stock changes different from $-49\%$ to $145\%$

- **Simulations on small vs. large scales**

  - On small scales, high accuracy with detailed data
  - On large scales, detailed data are often not available

  ➥ Data availability strongly influences the model choice
Further research

- Comparison with long-term soil C measurements
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Thank you for your attention!

Kiitos seurasta!