How to include soil C changes in life cycle assessments (LCA)?

Some agricultural systems contribute more to soil carbon sequestration than others...

Approaches used to model soil C in LCA

- IPCC guidelines on soil carbon changes
  - Advantages: Simple
  - Disadvantages: Not accurate, only four categories of carbon input

- Use soil carbon models like Roth C or C-TOOL directly
  - Advantages: More accurate than IPCC
  - Disadvantages: Does not take the time-dynamics of the emissions and climate impact into account

Challenges in modelling soil C in LCA

- A typical LCA of food would estimate emissions from one year
- However, added carbon to the soil is released over a longer period, which should be taken into account
- Important to take the soil C dynamics into account
- Different well-accepted soil carbon models, such as RothC or C-TOOL, can be used
- Point of departure in C-TOOL
Build up of soil carbon towards a new steady state
- based on decay curves of single C additions

Decay of biomass carbon added to the soil

The Bern Carbon Cycle Model

Atmospheric load from biomass carbon
- stored in soil vs. burned
Idea of the approach

Based on one year’s addition of carbon to the soil
- the soil C dynamics of this carbon is modelled using either C-TOOL, RothC or another soil model
- in combination with the Bern Carbon Cycle model to take the time dependent emissions into account

Estimation of the ‘sequestration factor’

1. Emissions from soil decay of added C – combined with Bern Carbon Cycle Model – to estimate the area below the summed curve, $S_T$.

2. Calculate the emission reduction or sequestration factor:

$$R_T = \frac{A_T - S_T}{A_T}$$

<table>
<thead>
<tr>
<th>DK</th>
<th>Time perspective (years)</th>
<th>20</th>
<th>100</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_T$ (%)</td>
<td>21</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

The approach is published in J of Clean Prod (2013): C sequestration of selected feed crops

<table>
<thead>
<tr>
<th>Fodder crop</th>
<th>C input to the soil (kg C ha^{-1} year^{-1})</th>
<th>$x 0.10$</th>
<th>-397</th>
<th>$x 44/12$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley, 100% straw removal</td>
<td>1773</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley, 0% straw removal</td>
<td>2651</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat, 100% straw removal</td>
<td>3456</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat, 0% straw removal</td>
<td>4682</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass-dower, silage</td>
<td>5956</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass-dower, grazed</td>
<td>6741</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize silage</td>
<td>1370</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Practical example: organic dairy farm

Emissions to air (N$_2$O, NH$_3$ etc.)

INPUTS
HERD
61 cows
25 youngstock

FIELD
1.5 ha barley
3.2 ha oat
25 ha pea/barley
63 ha grass-clover

OUTPUTS
61 x 8500 kg ECM

Emissions to soil and water (NO$_3^-$ etc.)

Simplified values for carbon sequestration

<table>
<thead>
<tr>
<th>Input Description</th>
<th>Carbon sequestration (kg CO$_2$/ha year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals (straw incorporated)</td>
<td>100</td>
</tr>
<tr>
<td>Cereals (straw removed)</td>
<td>-500</td>
</tr>
<tr>
<td>Grass-clover</td>
<td>850</td>
</tr>
</tbody>
</table>
Practical example: organic dairy farm
Calculation of carbon sequestration

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>kg CO$_2$/ha</th>
<th>Carbon sequestration (kg CO$_2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 ha arable crops</td>
<td>x 100 kg CO$_2$/ha = 2900 kg CO$_2$</td>
<td></td>
</tr>
<tr>
<td>63 ha grassland</td>
<td>x 850 kg CO$_2$/ha = 53550 kg CO$_2$</td>
<td></td>
</tr>
</tbody>
</table>

**Imported feed**
- 15 t grass clover silage (8.3 t/ha) = 2 ha x 850 kg CO$_2$/ha = 1700 kg CO$_2$
- 30 t cereals (4.5 t/ha) = 7 ha x 100 kg CO$_2$/ha = 700 kg CO$_2$

**TOTAL**
= 58850 kg CO$_2$

$\approx$ 582 kg CO$_2$/ha

**$\approx$ 0.10 kg CO$_2$/kg ECM**

Carbon footprint of milk from 23 organic dairy farms

- 0.20
- 0.30
- 0.80
- 1.30
- 1.80

UK1 UK2 UK3 UK4 UK5 UK6 UK7 UK8 DK1 DK2 DK3 DK4 DK5 DK6 DK7 DK8 F1 F2 F3 F4 F5 F6 F7 DK, conv.

Carbon footprint (kg CO2 eq./kg ECM)

Characteristics of the suggested approach

- Based on actual data on C inputs from e.g. crop residues, manure etc.

  (All farm activities, which is changing the C inputs to the soil, is included)

- The C input to the soil is multiplied with an ‘sequestration factor’

- If used for crops, the C input is scaled to the C input from a reference crop

- The time perspective is 100 years (but could also be 20 years or other)
Thanks for your attention!