Organic soils and their CO$_2$-emissions

Steen Gyldenkærne and Mogens Greve, Aarhus University
Ongoing projects

› New estimation methodology for perennial wooden areas not qualifying as forest – hedges (not horticulture)

› LiDAR flown in 2006 and 2014/15

- Estimation of volume, m³/m²
- Change in volume between 2006 and 2014/15
- 2006 resolution 1.6 m * 1.6 m
- 2014/15 resolution 0.4 m * 0.4 m
- Chip volume - measured in chipped hedges - ≈ 0.01 m³/m³
Ongoing projects

› Wetland restoration
  - Partly financed by Pillar 2 – EU subsides
  - Currently app. 120 project applications

Current land use

Current water table

Future water table
Organic soils and their CO$_2$-emissions

Steen Gyldenkærne and Mogens Greve, Aarhus University
Organic soils
Something about measurements
Danish data
CAP, Common Agricultural Policy
  ▪ Good Agricultural and Environmental Conditions (GAECs)
  ▪ Statutory Management Requirements (SMRs)
We are looking for a PhD student
  ▪ Interested in RS
  ▪ Organic soils
## Setting the scene: Emissions from organic soils (CO₂ and N₂O)

<table>
<thead>
<tr>
<th>Submissions</th>
<th>2017, total kt CO₂-eq, ex. LULUC</th>
<th>Organic soil, kt CO₂</th>
<th>Organic soil, N₂O, kt CO₂-eq</th>
<th>Pct</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>2380839</td>
<td>101080</td>
<td>13457</td>
<td>4.8%</td>
</tr>
<tr>
<td>ISL 2019 v1</td>
<td>4755</td>
<td>6977</td>
<td>25</td>
<td>147.3%</td>
</tr>
<tr>
<td>LVA 2019 v2</td>
<td>11306</td>
<td>4758</td>
<td>809</td>
<td>49.2%</td>
</tr>
<tr>
<td>LTU 2019 v1</td>
<td>20417</td>
<td>6087</td>
<td>520</td>
<td>32.4%</td>
</tr>
<tr>
<td>FIN 2019 v4</td>
<td>55334</td>
<td>11379</td>
<td>1500</td>
<td>23.3%</td>
</tr>
<tr>
<td>SWE 2019 v1</td>
<td>52660</td>
<td>8391</td>
<td>832</td>
<td>17.5%</td>
</tr>
<tr>
<td>IRL 2019 v2</td>
<td>60744</td>
<td>8984</td>
<td>672</td>
<td>15.9%</td>
</tr>
<tr>
<td>DNK 2019 v1</td>
<td>49226</td>
<td>3601</td>
<td>477</td>
<td>8.3%</td>
</tr>
<tr>
<td>NOR 2019 v1</td>
<td>52713</td>
<td>2480</td>
<td>375</td>
<td>5.4%</td>
</tr>
<tr>
<td>EST 2019 v1</td>
<td>20880</td>
<td>911</td>
<td>130</td>
<td>5.0%</td>
</tr>
<tr>
<td>DEU 2019 v1</td>
<td>906611</td>
<td>35908</td>
<td>2838</td>
<td>4.3%</td>
</tr>
<tr>
<td>LIE 2019 v1</td>
<td>194</td>
<td>6</td>
<td>1</td>
<td>3.3%</td>
</tr>
<tr>
<td>NLD 2019 v1</td>
<td>193260</td>
<td>4829</td>
<td>702</td>
<td>2.9%</td>
</tr>
<tr>
<td>CHE 2019 v2</td>
<td>47159</td>
<td>556</td>
<td>65</td>
<td>1.3%</td>
</tr>
<tr>
<td>POL 2019 v2</td>
<td>413781</td>
<td>2740</td>
<td>2540</td>
<td>1.3%</td>
</tr>
<tr>
<td>SVN 2019 v3</td>
<td>17453</td>
<td>92</td>
<td>9</td>
<td>0.6%</td>
</tr>
<tr>
<td>GBR 2019 v1</td>
<td>474346</td>
<td>1120</td>
<td>1070</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Submissions</th>
<th>2017, total kt CO₂-eq, ex. LULUC</th>
<th>Organic soil, kt CO₂</th>
<th>N₂O, kt CO₂-eq</th>
<th>Pct</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUT 2019 v2</td>
<td>82261</td>
<td>304</td>
<td>50</td>
<td>0.4%</td>
</tr>
<tr>
<td>HRV 2019 v2</td>
<td>25020</td>
<td>92</td>
<td>10</td>
<td>0.4%</td>
</tr>
<tr>
<td>ROU 2019 v3</td>
<td>113796</td>
<td>350</td>
<td>24</td>
<td>0.3%</td>
</tr>
<tr>
<td>GRC 2019 v1</td>
<td>95421</td>
<td>244</td>
<td>25</td>
<td>0.3%</td>
</tr>
<tr>
<td>BGR 2019 v1</td>
<td>61367</td>
<td>0</td>
<td>155</td>
<td>0.3%</td>
</tr>
<tr>
<td>ITA 2019 v1</td>
<td>427708</td>
<td>913</td>
<td>95</td>
<td>0.2%</td>
</tr>
<tr>
<td>FRA 2019 v1</td>
<td>471028</td>
<td>220</td>
<td>522</td>
<td>0.2%</td>
</tr>
<tr>
<td>HUN 2019 v2</td>
<td>63788</td>
<td>62</td>
<td>0</td>
<td>0.1%</td>
</tr>
<tr>
<td>BEL 2019 v1</td>
<td>114540</td>
<td>75</td>
<td>9</td>
<td>0.1%</td>
</tr>
<tr>
<td>CYP 2019 v6</td>
<td>8945</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>CZE 2019 v1</td>
<td>128675</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>ESP 2019 v1</td>
<td>340231</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>LUX 2019 v1</td>
<td>10236</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>MCO 2019 v2</td>
<td>87</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>MLT 2019 v4</td>
<td>2152</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>PRT 2019 v2</td>
<td>70546</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>SVK 2019 v4</td>
<td>43316</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
Defintion of organic soils

Organic soils are identified on the basis of criteria 1 and 2, or 1 and 3 listed below (FAO 1998) (from the 2013 Wetland Supplement):

1. Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm.

2. Soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter).

3. Soils are subject to water saturation episodes and has either:
   a. At least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has no clay; or
   b. At least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has 60% or more clay; or
   c. An intermediate proportional amount of organic carbon for intermediate amounts of clay.
## EF from 2013 IPCC Wetland Supplement

<table>
<thead>
<tr>
<th>Land use category</th>
<th>Climate/vegetation zone</th>
<th>EF, ton C/ha/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland, drained</td>
<td>Boreal/temperate</td>
<td>7.9</td>
</tr>
<tr>
<td>Grassland, drained</td>
<td>Boreal</td>
<td>5.7</td>
</tr>
<tr>
<td>Grassland, drained, nutrient-poor</td>
<td>Temperate</td>
<td>5.3</td>
</tr>
<tr>
<td>Grassland, deep-drained, nutrient-rich</td>
<td>Temperate</td>
<td>6.1</td>
</tr>
<tr>
<td>Grassland, shallow-drained, nutrient-rich</td>
<td>Temperate</td>
<td>3.6</td>
</tr>
</tbody>
</table>

- Grassland EF is lower than Cropland
- Deep-drained has higher EF than shallow-drained
Measuring C content in soil samples

› Take a soil sample with a stick
   ▪ Dry it
   ▪ Remove stones
   ▪ Grind it
   ▪ Sieve it
   ▪ Take a subsample of xx gram
   ▪ Add acid if necessary to remove \( \text{CaCO}_3 \)
   ▪ Burn it, where you are measuring the emitted \( \text{CO}_2 \)
   ▪ Estimate the Carbon content in %

› Result: % Carbon, gram/gram
An organic soil

Imagine this is an organic soil, >12 % OC

Top layer: 20 cm thick
OC: 24 %

What is the carbon content if it is ploghed to 40 cm?

- Above 12 %
- 12 % (organic)
- Below 12 % (not organic)
We have to rethink the way we estimate CO₂ emissions from organic soils

- In Wetlands we assume that there is no CO₂ if the average water table is 10 cm below the surface

  - C build-up is equal to the degradation in the unsaturated zone

\[
\Delta C = C_{\text{input}} - C_{\text{degradation}}
\]

- This concept is used when modelling C turnover in land
- We should think using this concept to drained organic soils too
\[ \Delta C = C_{\text{input}} - C_{\text{deg}} \]

\[ C_{\text{input}} = \text{dead organic matter} + \text{roots} + \text{root exudates} \]

\[ C_{\text{deg, ha}} = \% \text{ OC} \times \text{bulk density (t/m}^3\text{)} \times \text{distance to water table (m)} \times \text{EF}_{\text{deg}} \text{ (ton/ton)} \times 10000 \text{ m}^2 \]
Degradation depends on the total amount of OC in the aerobic soil compartment.
Total degradation depends on the total amount of OC in the aerobic soil compartment.

Input is fairly constant between years, you don't have to measure NEE.

Equilibrium state (mineral soils)

Degradation

Input

% OC

Equilibrium state (mineral soils)
Degradation depends on the total amount of OC in the aerobic soil compartment.

Input is fairly constant between years, you don't have to measure NEE.

% OC

Ton C/ha/year

Equilibrium state (mineral soils)

Net annual C loss

Input
Measuring CO2 emissions

› My feelings

› Only limited need for measuring NEE

- Average C input from the existing crop is a default value
- Only soil respiration is needed for soils with large OC contents
- Eg. SRS2000
Are the IPCC EFs wrong?

- No, they are not wrong. They represent the conditions on which they are measured.
- But do they include all emissions?
- What about soils having >12 % OC?
- And can the estimates be improved?
The Danish case

- Denmark is a flat country with a lot of shallow organic soils

- Soil Mapping
  - in 1975: 175,000 ha
  - in 2010: 107,000 ha

Organic soils are disappearing
The Danish case  II

Area of peatland with different carbon content, 0-30 cm on agricultural soils, 2010

<table>
<thead>
<tr>
<th>Carbon (%C)</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3</td>
<td>App. 65,000</td>
</tr>
<tr>
<td>3-6</td>
<td>62,960</td>
</tr>
<tr>
<td>6-12</td>
<td>43,789</td>
</tr>
<tr>
<td>&gt;12</td>
<td>70,481</td>
</tr>
</tbody>
</table>
Average carbon content on former peatland above the water table, (ton C/ha) after carbon content in the top soil (0-30 cm).

<table>
<thead>
<tr>
<th>Carbon content (%C)</th>
<th>Observations (n)</th>
<th>Carbon content C/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>121</td>
<td>112</td>
</tr>
<tr>
<td>3-6</td>
<td>259</td>
<td>216</td>
</tr>
<tr>
<td>6-12</td>
<td>385</td>
<td>305</td>
</tr>
<tr>
<td>12-24</td>
<td>494</td>
<td>353</td>
</tr>
<tr>
<td>&gt;24</td>
<td>777</td>
<td>415</td>
</tr>
</tbody>
</table>
After 30-40 years

- More or less all aerobic organic matter is gone
- Unless you have or are able to drain further
- How much have you left?
- What is the story-telling on the fate of organic soils?
The Danish case

- We will probably get funding for investigating this further
- Updated EF and emissions in 2024
- We need data from other countries
- If you have any data sets including:
  - % Carbon
  - Bulk density
  - Distance to water table
  - $CO_2$ emissions
  - Please send them to me
  - Steen Gyldenkærne: e-mail: sgy@envs.au.dk
Results

› The current Danish inventory is probably underestimating the CO₂ emissions from soils not qualifying as organic soils

› Over time the emission will cease naturally

› Focus will be on soils with large carbon stocks
CAP

> Enhanced ‘Conditionality’

Conditionality is an integral part of the future CAP framework and replaces ‘greening’ and cross-compliance of the current CAP

- Climate Change
- GAEC 2 – Preservation of carbon rich soils such as peatlands and wetlands (new).
Conditionality is a system of linkage between area- and animal-based CAP payments (in Pillar I or Pillar II) and a range of obligations.

- When recipients of payments (mainly farmers) do not meet the obligations, the payments may be reduced. These obligations originate either in CAP legislation (in the case of "standards for good agricultural and environmental condition" – GAEC) or in non-CAP directives and regulations (SMRs).

- The new system will effectively merge and streamline two elements in the current CAP – known as "cross-compliance" and "greening".
Conditionality

Requirements

- Minimum spending on the environment and climate in CAP Pillar II will be modified.

- In their CAP plan, Member States will remain obliged to earmark at least 30% of their EU Pillar II funding to be spent on the environment and climate.

- Member States will be able to transfer extra funds from Pillar I to Pillar II for environmental purposes, if they wish: in addition to the basic 15% which can be spent on any type of Pillar II support, a further 15% will be possible - which must be devoted only to environmental and climate objectives.
Conditionality

To address these (and other) CAP objectives, each Member State will draw up a "CAP strategic plan". In its plan, each Member State will analyse the situation on its territory in terms of strengths, weaknesses, opportunities and threats (SWOT) – as well as its related needs – in respect of these objectives. **It will set quantified targets** against the objectives and design "interventions" (types of action) for achieving them, on the basis of an EU-level menu. The Commission will approve the plan when satisfied with its quality. **Year-by-year progress against the targets will be monitored and the plan will be adjusted as necessary.**
Conditionality

What does it mean?

- Very **close corporation** between the Agricultural and Climate ministries **is needed**
- Close monitoring of progress has to be shown in the inventories
- Pillar 1 payment (general area subsidy) to all farmers is moved to pay farmers on organic soils to take them out of rotation
- Farmers on mineral soils are paying the bill
PhD student wanted

- Remotely sensed mapping of water table levels and humidity on Danish organic soils
  - Interested in remote sensing
  - Looking for water logged organic soils

- Contact:
  - Senior Advisor Gregor Levin
  - E-mail: gl@envs.au.dk
  - Phone: +45 871 58664