Climate change induced carbon competition: bioenergy versus soil organic matter reproduction - an indicator based assessment

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Problem

Climate change driven by fossil fuel burning
➔ mitigation: renewable energies

Climate change will alter the soil carbon cycling
➔ soil organic matter (SOM): globally important pool

Production of bioenergy has an impact on both:
Replacement of fossil energy
Changing the soil carbon cycle
Objective

On a regional scale:

- Estimation of **SOM turnover conditions** driven by global warming

- Assessment of **bioenergy impact on SOM** (carbon re-production cycle)

- Provide an **combined assessment scheme** to identify “hot spots” of carbon competition
Study region: Central Germany

Data base:

Climate (821 cells):
Future (2001 – 2100):
IPCC scenarios A1B, A2 and B1
Past (1961-2000): C20 data
Regionalized using REMO & WETTREG

Soil:
German soil map BUEK1000
(scale 1:1,000,000; Hartwich et al., 1998)

• problem:
  – Identification of sub regions with potential biomass competition between bioenergy and SOM

• scaling approach:
  – Identification of Bioenergy Producing Units (BPU)

• required:
  Indicator to assess bioenergy impact on carbon re-production cycle
  Indicator to assess SOM turnover driven by global warming
Assessment of biogas production

Knowledge base about biogas plants:

Location
Data from Das et al. (2012)

Carbon catchment area
Subplots from Voronoi interpolations
available agricultural area → AA
CORINE data (CLC2006; Keil et al., 2010)

Carbon consumption
Installed capacity → IC
Data from Das et al. (2012)

Definition of BPU’s
Indicator for carbon consumption → CAP=IC/AA
Classification approach

Capacity Index

\[ \text{CAP} = \frac{\text{IC}}{\text{AA}} \]

1\text{st} and 3\text{rd} quartile of a lognorm dist.

- low: \( \text{CAP} \leq 0.042 \)
- Medium: \( 0.042 < \text{CAP} \leq 0.131 \)
- high: \( \text{CAP} > 0.131 \)
Results: CAP

Capacity Index  \( \Rightarrow \) \( \text{CAP} = \frac{\text{IC}}{\text{AA}} \)  

*(Carbon transformed to biogas)*
Conditions for SOM turnover (soil organic matter)

CCB model: Franko et al. (2011), Geoderma (166) 119-134
Assessment of soil management

SOM supply = \frac{c_{amount} \times Quality}{time}
Biologic Active Time (BAT)

- BAT is an indicator for environment conditions of microbes
- BAT is a function of soil temperature, soil moisture and soil aeration
- annual BAT is calculated from air temp., rainfall and soil texture

**equal input**

65 dt Crep /a

**different result:**

<table>
<thead>
<tr>
<th>SAND</th>
<th>LOAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1500</td>
</tr>
</tbody>
</table>

**BAT_y=44 d**

**BAT_y=29 d**
Assessment of soil management

SOM supply = \( \frac{C_{\text{amount}} \times Quality}{\text{biologic active time}} \)

Final SOM level according to Management (SOM supply)

- High SOM supply
- Low SOM supply
Climate change: BAT

predicted change: ca. +2.5 K ; -20 mm
Sustainable SOM supply

\[ \text{past climate} \]
\[ \text{SOM} = \frac{C_{\text{input past}}}{B\text{AT}_{\text{past}}} \]

\[ \text{future climate} \]
\[ \text{SOM} = \frac{C_{\text{input future}}}{B\text{AT}_{\text{future}}} \]

\[ \text{carbon demand will increase} \]
\[ CDI = \frac{C_{\text{future}}}{C_{\text{past}}} = \frac{B\text{AT}_{\text{past}}}{B\text{AT}_{\text{future}}} \]
Results: carbon demand index

CDI: carbon demand for soil

Increase of SOM supply to sustain SOM level

soil texture
Combined Assessment

carbon demand for biogas

carbon demand for soil org. matter

CAP level
- high
- medium
- low

CDI level
- high
- med
- low
### Results: BPU assessment

<table>
<thead>
<tr>
<th>CAP</th>
<th>CDI</th>
<th>BPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>No alert</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>No alert</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Warning</td>
</tr>
<tr>
<td>Medium</td>
<td>Low</td>
<td>No alert</td>
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<tr>
<td></td>
<td>Medium</td>
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<td>High</td>
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</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Warning</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Hot spot</td>
</tr>
</tbody>
</table>

- **hot spots:** adaptation strategies may be developed on *local scale*

*paper accepted in JPNSS*
Conclusions / Summary

Methodology:

Definition of **BPU as spatial system**

**CDI and CAP: indicators** for large scale assessment of potential carbon competition

Advantages: **low data requirements** and transferable

Results for Central Germany:

general increasing carbon demand to sustain SOM

„hot spot“ areas ≈ 5% ; „warning“ level ≈ 30%

⇒ further CAP increase should take into account CDI values

Search for adaptation strategies requires more detailed database
Thank you for attention!

..... any questions

Acknowledgements

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Basic principle of CCB Candy Carbon Balance

SOM dynamics in dependence of

- **site conditions**
- **Initial conditions**
- **soil management**
  - reproduction flux $C_{rep}$

- turnover conditions
  - BAT

$C_{org}$-Dynamics in annual time steps

Graph (1996-2010)