Changes in soil carbon stocks and distribution under perennial and annual bioenergy crops

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Introduction

- Bioenergy crops are expected to provide biomass to replace fossil resources and reduce greenhouse gas emissions
- There is a wide range of candidate crops
- Impact on SOC is a key point in the evaluation of the greenhouse gas and environmental benefits of bioenergy crops

- **Aim of the study:**
  - Quantify the impact of different bioenergy crops under contrasted managements on SOC (stocks and distribution)
Experimental site and treatments

Field experiment established in 2006 in northern France

- Temperature: 10.8 °C
- Precipitation: 677 mm yr\(^{-1}\)
- Soil: Deep loamy soil (Luvisol)

A wide range of bioenergy crops with different management practices

<table>
<thead>
<tr>
<th>Crop</th>
<th>Fertiliser-N rate (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mis</td>
<td>0</td>
</tr>
<tr>
<td>Swi</td>
<td>0</td>
</tr>
<tr>
<td>Fes</td>
<td>83</td>
</tr>
<tr>
<td>Alf</td>
<td>0</td>
</tr>
<tr>
<td>Sor</td>
<td>0</td>
</tr>
<tr>
<td>Maize</td>
<td>34</td>
</tr>
<tr>
<td>Tri</td>
<td>60</td>
</tr>
</tbody>
</table>

Two harvest dates:
- Early: October
- Late: February

Two fertiliser-N rates:
- N-
- N+
SOC stocks measurements

- Three sampling dates: 2006, 2011-2012, 2018

**Soil cores:**
- 6 cores per plot × 3 blocks
- 8 cm diameter
- 0-40 cm in 2006 and then 0-60 cm (5 layers)

**Bulk density:**
- Gamma probe and steel cylinders

- C, N and $\delta^{13}$C analysis
- SOC stocks calculated at equivalent soil mass (ESM) in all layers
- Soil particle-size fractionation for some treatments
SOC concentrations in 2006 and 2018

Perennial crops

- Significant increase in L1 (+ 7.6 g kg\(^{-1}\))
- Lower layers: decreasing trend
- No significant effect of N fertilization

Other crops

- Semi-perennial crops: significant increase in L1 and L2 (+ 1.4 g kg\(^{-1}\))
- Annual crops: decrease in all layers
- No significant effect of N fertilization
SOC fractions in 2018 (Layer 1 ≈ 0-5 cm)

- SOC increase in L1 under perennial crops corresponded to an increase in coarse organic fractions (> 200 µm POM et 50-200 µm POM) but also in the more stabilized 0-50 µm fraction.
Accumulation of new C4-derived SOC under perennial crops

- More than half of the new SOC (58% on average in 2018) accumulated in the surface layer (L1 ≈ 0-5 cm)
- Larger increase of new SOC under late (L) than early (E) harvest
Changes in SOC stocks between 2006 and 2018

- SOC stocks increased under **perennial** and **semi-perennial** crops:
  - +3.2 and +2.2 t C ha\(^{-1}\) respectively
  - +5.2 and +4.0 %\(\text{yr}^{-1}\) respectively
- SOC stocks decreased under **annual crops** (-7.1 t C ha\(^{-1}\) => -12.7 %\(\text{yr}^{-1}\))
Conclusions

- Contrasted impacts of bioenergy crops on SOC stocks:
  - perennial and semi-perennial crops increased SOC stocks
  - annual crops (whole plant harvested) decreased SOC stocks

- No significant effect of N fertilization on SOC stocks and distribution

- Stratification of SOC concentrations under perennial crops, with a large increase in the surface layer (L1 ≈ 0-5 cm):
  - observed for both POM and clay-silt size fractions
  - in relation to new C4-derived SOC accumulation, mainly occurring in L1 (importance of aboveground C inputs?)

- Perennial crops: higher increase of new SOC in late than in early harvest suggests higher C inputs in late harvest