Best practices for soil organic carbon management in agricultural systems

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Workshop: Best practices addressing environmental and climate needs
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The importance of soil carbon

• Soil organic carbon (SOC), a component of organic matter, is vital to *essential soil functions* and to the ecosystem services.

• Farming practices causing *declining* returns and inputs of carbon (C) to soils and pose threats to soil functions, but

• A number of farming practices have shown potential for increasing SOC content and can contribute to improving **long-term crop productivity**, improve the **physical and biological properties** and **C sequestration**.
SmartSOIL aims:

• To identify agronomic practices that result in an optimized balance between crop productivity, restoration and maintenance of vital soil functions esp. soil carbon sequestration.

• To develop and deliver a decision support toolbox to support farmers, advisers and policy makers.

Modelling impact of different farming practices on SOC with LTE data, and an extensive stakeholder consultation process, in six case study regions: Denmark, Scotland, Spain, Poland, Italy and Hungary
Best practices for soil organic carbon

SOC stocks can be increased in three main ways:

• by **enhancing** plant residues and root inputs to soils

• **increasing** the quantity of organic matter inputs such as manure and compost to the soil (from on/off farm)

• by **reducing** decomposition losses through minimising disturbance of soil
Best practices for soil organic carbon

Practices that promote good soil carbon management:

- Crop rotation
- Residue management
- Adding manure or compost
- Cover & catch crops
- Conservation agriculture (reduced tillage, residue management & rotation)
Best practices for SOC: benefits

- Enhances soil quality - soil productivity, structure, workability
- Potential to improve yields
- Reduces erosion
- Weed, pest and disease management – rotation, manure
- Closes mineral cycles at farm (or regional) level - manure
- Reduces inputs (mineral fertilisers) cc, manures
- Improved water infiltration and plant establishment - residue management, cc
- Saves time, labour and fuel - conservation agriculture
Best practices for SOC: long term benefits

**Impact on SOC**

**Denmark:**
- Cover crops
- Organic manure
- Residue management
- Conservation Agriculture

**Italy:**
- Cover crops
- Organic manure
- Residue management
- Conservation Agriculture

**Relative Increase in SOC [t/ha] after 30 years**

- **SOC topsoil**
- **SOC subsoil**
Best practices for SOC: Cost-effectiveness (€/t CO₂e/ha) cost=impact on gross margin

Scottland

cc + oats

cc + barley

Aragon

cc + maize

cc + olives/vines

Marginal Abatement Cost Curves
Best practices for SOC: Cover crops

Cover crops added to arable rotations or provide vegetative cover between rows of main crops in orchards and vineyards

- Provide cover - reduce soil erosion
- Deep roots – improve structure
- Capture N – reduce leaching
- Add N if legumes - reduce inputs
- Potentially increase crop yields
## Cover crops: co-benefits

<table>
<thead>
<tr>
<th>Type of benefit</th>
<th>Size of effect</th>
<th>Type of effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion protection</td>
<td><img src="green" alt="+" /></td>
<td>Reduced soil erosion and run-off to water bodies (positively impacting water quality)</td>
</tr>
<tr>
<td>Prevent nutrient leaching (N, P)</td>
<td><img src="yellow" alt="%" /></td>
<td>Crop scavenges N from the soil and makes it available for the following crop, contributing to reduced nitrate leaching</td>
</tr>
<tr>
<td>Promote soil biodiversity</td>
<td><img src="green" alt="+" /></td>
<td>Increase in soil organisms and activity</td>
</tr>
<tr>
<td>Promote above ground biodiversity</td>
<td><img src="green" alt="+" /></td>
<td>Provides habitats and potentially enhances biological control of pests and diseases</td>
</tr>
<tr>
<td>Reduce soil emissions</td>
<td><img src="yellow" alt="%" /></td>
<td>Potential reduction in ammonia emissions if managed effectively, although incorporation of the cover crop may also result in nitrous oxide emissions</td>
</tr>
</tbody>
</table>

**Legend:** ++ maximum positive effect, + positive effect, 0 no effect, - negative effect, -- maximum negative effect  
**LB:** Legume-based cover/catch crop; **NLB:** Non-legume-based cover/catch crop
Cover crops: expected changes compared to business as usual (regional)

<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
<th>Italy</th>
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<tbody>
<tr>
<td>SOC (0-100 cm) [t C/ha]</td>
<td>1.4 (1.6%)</td>
<td>0.8 (1.2%)</td>
</tr>
<tr>
<td>Productivity [t/ha]</td>
<td>0.03 (0.3%)</td>
<td>0.01 (0.2%)</td>
</tr>
<tr>
<td>Optimal N-rate [Kg N/ha]</td>
<td>-1 (0.8%)</td>
<td>-1 (1.1%)</td>
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<tr>
<td>Need for N-input [Kg N/ha]</td>
<td>-1.0</td>
<td>-1.4</td>
</tr>
</tbody>
</table>

Small increases

Less N inputs

FOR EU GROSS MARGIN IMPACTS (AVERAGE VALUES) OF ADDING COVER MAY [INCREASE] BY 16.60 €/HA OR [DECREASE] GROSS MARGIN BY 270 €/HA
Key messages

• No one size fits all - heterogeneity in soils management, practices, farming systems, people, skills

• SOC management requires a long-term effort – and knowledge/skills

• Good SOC soils, measures should target maintaining these levels of soil carbon + avoiding losses e.g. crop rotations, cover crops & residues.

• Low SOC soils, measures should target securing carbon already in soil + enhancing SOC inputs, e.g. crop rotations, manure & residues

• SOC management also involves management of nitrogen and phosphorus
Stakeholder consultation: diverse contexts

Cover crops hard to establish
Some may reduce mineral N available

Cover crops reduce soil moisture & create nutrient competition between crops

Min-till looks “messy”, reduces initial yield

High cost of cover crop establishment

Straw has high economic value

Traditional farmers resist change
High manure handling costs
Stakeholder consultation: key messages

• Perception of **scientific uncertainty** about practices
• Lack of real or **‘best practice’** examples
• Lack of support/good quality **advice**
• Difficulty of demonstrating impact on **productivity and profitability in the long term**
• Practices perceived as **uneconomic, impractical or needing investment**
• Soil **carbon** is not part of farmers’ everyday language
• Invest time in **learning**, talk to other farmers
• **Limited knowledge** about/familiarity with practices
• Difficulty in **integrating practices** into farm system
Incentives to overcome barriers

- Financial incentives
- Use simple language and quantify impact
- Evidence of benefits – impact on productivity and profitability
- Integrating advice into existing advice channels, policies and regulations
- Improve the quality of advice
- Real life case study examples
- Facilitate learning among farmer networks
SmartSOIL Toolbox: FactSheets

SmartSOIL FACTSHEET
BOOSTING ON-FARM SOIL ORGANIC MATTER WITH COVER/CATCH CROPS

WHAT IS IT?
Adding cover/catch crops to crop rotations helps improve soil quality, reduce soil erosion, enhance nutrient cycling and water holding capacity, and as a result, potentially increase crop yields. Cover crops are grown to provide vegetative cover between rows of main crops in orchards and vineyards, or between periods of regular production to prevent erosion. They also function as an additional carbon sink when used as a cover crop. Cover crops can be left on the field to be used as straw mulch, as animal feed, or as a source of energy and may or may not be returned to the land later (e.g., with manure). Crop residues remaining on the land supply additional SOM (organic matter) to the soil, improving soil structure, root system development, and plant growth. Additionally, residues left at the surface will be less disturbed by using reduced tillage and they can help to reduce erosion and surface soil evaporation (the residues act as mulch).

WHAT ARE THE BENEFITS?
- Enhanced soil organic matter content
- Reduced soil erosion and leaching of nutrients
- Improved water infiltration and plant establishment
- Potential yield improvements

Soil Quality
Time planning of cover/catch crops, such as clover, ryegrass, or leghanes, to otherwise bare soil helps to increase carbon and/or nitrogen levels within the soil, critical to soil quality. Planning cover crops increases soil organic matter (SOM) and thus soil organic carbon (SOC) (see box below). SOM promotes nutrient cycling, which may result in more nitrogen available to plants and less lost through leaching. Overall, soil structure is improved, increasing water retention and infiltration, workability, and reducing soil erosion and fertilizer run-off.

Reduction of Inputs
With effective management, cover/catch crops capture nitrogen within the soil, for use by the following main crop and increase water holding capacity. Moreover, nitrogen-fixing crops (e.g., legumes) transfer atmospheric nitrogen into the soil. Fewer inputs of both fertilizer and water may thus be necessary. Cover/catch crops can also provide effective weed and pest control. If tailored to the farming system, where type of cover crop and timing are carefully considered, fewer herbicide and pesticide inputs will be needed. Reduced fertilizer and herbicide/pesticide use prevents several on-farm and off-farm benefits, including potential cost-savings, reduced run-off, less impact on biodiversity, and lower risk of soil compaction from field operations.

SmartSOIL FACTSHEET
RESIDUE MANAGEMENT: IMPROVING SOIL ORGANIC MATTER AND REDUCING SOIL EROSION

WHAT IS IT?
Crop residues are materials usually not taken away but rather left in a field or orchard after the crop has been harvested. They include stalks, trash, leaves, roots and seed pods. Some crop residues are removed from the land to be used as straw in stables, as animal feed or as a source of energy and may or may not be returned to the land later (e.g., with manure). Crop residues remaining on the land supply additional SOM (organic matter) to the soil, improving soil structure, root system development, and plant growth. Additionally, residues left at the surface will be less disturbed by using reduced tillage and they can help to reduce erosion and surface soil evaporation (the residues act as mulch).

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Soil Quality
Soil quality refers to soil attributes, soil functions and to the associated services delivered by soils. The soil quality may be described in terms of chemical, physical and biological properties. These characteristics determine the soils’ abilities to retain water and nutrients needed by plants as well as providing the physical and biological environment to reduce crop stress and losses from disease and pests. Soil quality therefore is a range of ecosystem services that include soil sustainability, buffering water, receiving nutrients, reducing emissions of greenhouse gases and pollutants.

Soil Quality Enhancement
Timely planning of cover/catch crops, such as clover, ryegrass, or leghanes, to otherwise bare soil helps to increase carbon and/or nitrogen levels within the soil, critical to soil quality. Planning cover crops increases soil organic matter (SOM) and thus soil organic carbon (SOC) (see box below). SOM promotes nutrient cycling, which may result in more nitrogen available to plants and less lost through leaching. Overall, soil structure is improved, increasing water retention and infiltration, workability, and reducing soil erosion and fertilizer run-off.

Reduced soil erosion and capping/slaking
Leaving crop residue on the field also offers a layer of protection over the soil, which might otherwise be bare. The residue reduces the impact of wind and water causing soil erosion as well as soil capping or crusting, which may occur on other soils.

Improved water infiltration and plant establishment
Residues help to retain water on the soil, and by improving soil structure, they can improve water infiltration and storage in the soil. This is particularly important for cropping systems in drier climates. They also improve soil tilth, which aids root systems’ development and therefore plant growth. This is
Common messages:
Invest time in learning
Talk to other farmers
Consult an adviser
Smartsoil.eu Tool and Toolbox

Welcome to the SmartSOIL Toolbox
optimising yield and soil carbon on your farm.

The SmartSOIL toolbox has been developed to help advisers and farmers identify cost-effective management options to optimise crop yields and soil carbon for their particular farming systems, soils and climates. Click on the boxes below with blue link text to access the toolbox contents: Decision Support Tool, Real Life Case Studies, Publications and Videos.

The SmartSOIL project (2011-2015) used modelling to identify cost-effective farming practices which can optimise crop productivity and SOC storage. Click on the boxes below with red link text to access the scientific outputs: Deliverables, publications, the policy options and maps.
SmartSOIL partners

smartsoil.eu
## Project deliverables www.smartsoil.eu

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<tr>
<th>Project Deliverable</th>
<th>Description</th>
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<tr>
<td>D2.4</td>
<td>Report on critical low soil organic matter contents, which jeopardise good functioning of farming systems</td>
</tr>
<tr>
<td>D5.2</td>
<td>Overview of socio-economic influences on crop and soil management systems</td>
</tr>
<tr>
<td>D4.1</td>
<td>Overview and assessment report of decision support tools and knowledge platforms, SmartSOIL Report</td>
</tr>
<tr>
<td>D2.1</td>
<td>Report describing the practices and measures in European farming systems to manage soil organic matter</td>
</tr>
<tr>
<td>D3.2</td>
<td>Cost-effectiveness of SOC measures</td>
</tr>
<tr>
<td>D2.3</td>
<td>Changes in soil organic matter content in time as impacted by different farming systems</td>
</tr>
<tr>
<td>D1.3</td>
<td>Simplified model of management on SOC flows and stocks and crop yield</td>
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<tr>
<td>D1.2</td>
<td>Model comparisons and identification of model linking soil carbon to soil properties and crop productivity</td>
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<tr>
<td>D1.1b</td>
<td>Meta-analyses and new experiments of crop yield to soil functions</td>
</tr>
<tr>
<td>D2.2</td>
<td>Typical farming systems and trends in crop and soil management in Europe</td>
</tr>
<tr>
<td>D3.1</td>
<td>Soil and Soil Organic Carbon within an Ecosystem Service Approach Linking Biophysical and Economic Data</td>
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<tr>
<td>D5.1</td>
<td>Uptake of soil management practices and experiences with decisions support tools: Analysis of the consultation with the farming community</td>
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Selected project publications www.smartsoil.eu


