Bioenergy crops and potential for improving soil ecosystem services

Helene Bracht-Jørgensen, Katarina Hedlund and Tina D’Hertefeldt
The potential for soil carbon sequestration under bioenergy crops

Fossil fuel replacement

Reduce Greenhouse Gas emissions by increased carbon sequestration in the soil

Multifunctionality
Soil ecosystem services

- storage of carbon
- chemical water filter
- reduction of soil erosion
- improved water holding capacity
- provides microbial habitats
- sources of longterm nutrients
- improved soil structure and productivity

Soil science society of America https://www.soils.org/about-soils/soil-carbon
Do perennial biofuel crops improve agricultural soils?
Potential benefits

- Significant reduction in CO$_2$–emission when converting arable lands into perennial grasslands

- Perennial biomass crops contribute to sustainability of agricultural land by increased soil carbon and by reduced erosion, leakage and compaction

(Fazio and Monti 2011)
Soil ecosystem services in biomass crops

- Organic Carbon
- Bacterial/Fungal biomass
- \( \text{CO}_2 \) emission
- Potential nitrogen mineralisation
- Water holding capacity
- Particle carbon
Soilservice study sites
Biofuel crops

- Miscanthus
- Salix
- Phalaris
- Poplar
Carbon and microorganisms; Sweden

Loss on ignition

% Organic matter in soil

μg AMF C/g soil

mg Bacterial C/g soil

mg Fungal C/g soil

1-3 year old
5-7 year old
>10 years old
Phalaris
Wheat

1-3 year old
5-7 year old
>10 years old
Phalaris
Wheat

Willow
Young willow gives lower respiration than Biofuel grass
("new" vs. "alternative" P=0.0013)
What is the potential for soil carbon sequestration under bioenergy crop types?

- Soil carbon sequestration rates in willow (short rotation coppice): 0-1.6 tons C ha\(^{-1}\) y\(^{-1}\)

- Crop and site specific effects: Higher benefits on fertile soils

- Model predicts 0.5 tons C ha\(^{-1}\) y\(^{-1}\) in willow

- Life cycle assessments show highest environmental benefits of switchgrass

Management to promote soil carbon

- Straw addition of 3 ton/ha results in a decline of 0.2% carbon per year
- 12 ton straw addition per hectare results in an increase of 0.3% carbon per year
- The bioenergy grass Miscanthus results in 1.5% increase in carbon per year, calculated on root biomass data
Major factors predicting soil carbon sequestration

- net primary production
- decomposition
- rates of the major soil carbon pools and initial soil carbon content
- management practice
- depth of soil being influenced by the bioenergy crop

Carbon sequestration most likely on carbon-depleted soil (e.g., ploughed)

Review MAFF 2001
Soil Carbon in perennial biofuels plantations – soil depth

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<th>Soil Organic Carbon (Mg ha$^{-1}$)</th>
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(Mehdi et al. 1999)
Root production (kg/ha)
Perennial wheat

Annual wheat (on left in each panel) and Perennial wheatgrass

Wes Jackson, www.landinstitute.org
Root biomass under diverse fields

(Hedlund unpublished)
Potential benefits of perennial biofuel crops on agricultural land

- Capacity to improve sustainability of agricultural soil
- Carbon sequestration potential
- Greenhouse gas emission reductions
- Biodiversity in the agricultural landscape
Thanks to

• Jan Frouz
• Petr Hedenec
• Sören Christensen
• Simon Mortimer
• Franciska de Vries
Preliminary conclusions

• Soil carbon did not increase in perennial biofuel crops

• Higher fungal biomass in the 5 and 10-year old willow plantations

• Higher amount of NLFA (mycorrhizal) in *Phalaris arundinacea*, small increase in 10-year-old willow

• Bacterial biomass was not affected by biofuel crops

• Potential nitrogen mineralisation appeared to be higher in all biofuel plantations but was not significant

• Young willow had the lowest CO$_2$ respiration and biofuel grass the highest
Scient Am: New biotech crops solution for sequestration of carbon in soil
<table>
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<th>Woody</th>
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