Do crop rotations including temporary grasslands improve soil ecosystem services?

Kevin Hoeffner

In response to global changes

EU land cover overview
(Eurostat, 2015)

Permanent grasslands 21%
Crops 22%
Others 57%

Crop management is changing

Tillage
Pesticide
Crop rotation

World population growth
Climate change
Healthy environment
**Grassland soils**
with adapted management

Physically,
Chemically,
Biologically,

superior to almost other cultural systems

---

**High contribution to ecosystem services**

Climate regulation (Stockmann et al., 2013)
Water cycling regulation (Murray et al., 2012)
Landscape quality (Werling et al., 2014)
Biodiversity conservation (Cluzeau et al., 2012)

...
What is the legacy effect of including 6 years versus 3 years of grassland in the crop rotation on Soil Ecosystem Services?

Higher grassland duration in the crop rotation will enhance SES for the following crop.
MATERIALS & METHODS

Soil Ecosystem Services

<table>
<thead>
<tr>
<th>AC</th>
<th>3G</th>
<th>6G</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>G</td>
</tr>
</tbody>
</table>

Grassland effect

Legacy effect

Crop rotation

≠ 3 vs 6 years of grassland

BLOC 1
BLOC 2
BLOC 3
BLOC 4

Five Soil Ecosystem Services

- Biodiversity conservation
  - Micro-organisms
  - Meso-fauna
  - Macro-fauna
- Soil maintenance
  - Aggregate stability
- Food provision
  - Forage production
- Pest regulation
  - Verticillium wilt
- Water regulation
  - Infiltration

Soil
Ecosystem
Services

Crop rotation

Braunschweig – K. Hoeffner
Biodiversity Conservation

**Microbial biomass**
- Mean crop range
- AC: +19%, 3G: +14%
- OTUs
- AC: a, 3G: b, 6G: c

**Bacterial richness**
- OTUs
- AC: a, 3G: a, 6G: a
- F = 1.99, P = 0.155

**Fungal richness**
- OTUs
- AC: a, 3G: b, 6G: ab
- F = 5.45, P = 0.009

**Potential microbial activity**
- Fructose
- AC: a, 3G: a, 6G: a
- F = 0.26, P = 0.770

**Lysine**
- AC: a, 3G: a, 6G: a
- F = 4.25, P = 0.019

**AMF richness**
- Virtual taxa
- AC: b, 3G: ab, 6G: a
- F = 462.34, P < 0.001

Cluzeau et al., 2012

Braunschweig – K. Hoeffner
RESULTS & DISCUSSION

BIODIVERSITY CONSERVATION

Enchytraeids

F = 4.62, P = 0.021

- Litter dwellers
- Opportunistic species
- Soil dwellers
- Deepness dwellers

Mean crop range

Deepness dwellers

F = 1.25, P = 0.305

Soil dwellers

F = 2.99, P = 0.071

Opportunistic species

F = 12.75, P < 0.001

Litter dwellers

F = 4.62, P = 0.021

Pelosi et al., 2018

Beylich and Graefe, 2009

Litter decomposition?
RESULTS & DISCUSSION

BIODIVERSITY CONSERVATION

Enchytraeid

- Litter dwellers
- Opportunistic dwellers
- Soil dwellers
- Deepness dwellers

Mean crop range

F = 4.62, P = 0.021

Abundance (i/m²)

CONFIDENTIAL

Collembola

- Epi-edaphic
- Hemi-edaphic
- Eury-edaphic

F = 2.05, P = 0.152

Abundance (i/m²)

Mean crop range

No treatment effect

Flickr.com

Eu-edaphic

F = 5.73, P = 0.010

No treatment effect

Grassland effect

Cluzeau et al., 2012
RESULTS & DISCUSSION

BIODIVERSITY CONSERVATION

Enchytraeid

F = 4.62, P = 0.021

Collembola

F = 2.05, P = 0.152

Earthworm

F = 10.19, P < 0.001

**Abundance (i/m²)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>AC</th>
<th>3G</th>
<th>6G</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Epi-anecic</strong></td>
<td>a</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>F = 12.93, P &lt; 0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Strict-anecic</strong></td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>F = 22.51, P &lt; 0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Grassland effect**

- **Confidential**

**Water regulation?**

- Litter decomposition?

- Bastardie et al., 2003
- Hoeffner et al., 2019

Cluzeau et al., 2012

Braunschweig – K. Hoeffner
RESULTS & DISCUSSION

SOIL MAINTENANCE
Aggregate stability (Le Bissonnais 1996)

Slow watering = Smoothy rain event
F = 5.56, P = 0.013

High watering = Heavy rain event
F = 4.54, P = 0.025

FOOD PROVISION
Forage production

Abiven et al., 2007

Braunschweig – K. Hoeffner
CONCLUSION

<table>
<thead>
<tr>
<th>Micro-organisms</th>
<th>Grassland effect</th>
<th>Legacy effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbial biomass</td>
<td>✓ +19%</td>
<td>✓ +14%</td>
</tr>
<tr>
<td>Microbial activity</td>
<td>✓ ≈ -17%</td>
<td></td>
</tr>
<tr>
<td>Fungal diversity</td>
<td>✓ -19%</td>
<td></td>
</tr>
<tr>
<td>Bacterial diversity</td>
<td>❌</td>
<td>❌</td>
</tr>
<tr>
<td>AMF diversity</td>
<td>✓ +29%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meso-fauna</th>
<th>Grassland effect</th>
<th>Legacy effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enchytraeid abundance</td>
<td>✓ +/-?</td>
<td>✓ +40%</td>
</tr>
<tr>
<td>Ench. funct. structure</td>
<td>✓ -91%</td>
<td>✓ +84%</td>
</tr>
<tr>
<td>Collembola abundance</td>
<td>❌</td>
<td>❌</td>
</tr>
<tr>
<td>Collemb. funct. structure</td>
<td>✓ +71%</td>
<td>✓ +82%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Macro-fauna</th>
<th>Grassland effect</th>
<th>Legacy effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthworm abundance</td>
<td>✓ +34%</td>
<td>❌</td>
</tr>
<tr>
<td>Earthworm funct. structure</td>
<td>✓ ≈ +66%</td>
<td>❌</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Maintenance</th>
<th>Grassland effect</th>
<th>Legacy effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate stability</td>
<td>✓ +30%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food provision</th>
<th>Grassland effect</th>
<th>Legacy effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage production</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

SoilMan
This is only part of the results
Different SES
From micro-organisms to macro-fauna
=> Strengthens the diagnosis

- Grassland and legacy effect found for different SES
- Grassland and legacy effect on SES are sometimes combined
- For biodiversity conservation, legacy effect is visible at different level (abundance, biomass, funct. structure or diversity)
- For some aspect there is a real interest to integrate 6 years of grassland in the crop rotation
Acknowledgements

The SoilMan project (grant number 01LC1620) was funded through the 2015-2016 BiodivERsA COFUND call for research proposals with the following funders: