Reducing environmental impacts of SRC through evidence-based integrated decision support tools

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ERA-NET Bioenergy, 4th WoodWisdom-Net Research Programme Seminar in collaboration with ERA-NET Bioenergy, Helsinki, 7/2/2012
Presentation outline

• Project and partners description, background

• Effects on biodiversity

• Effects on soil

• Effects on water

• Conclusions and recommendations for SRC cultivation
General project description

• Title: RATING-SRC (“Reducing environmental impacts of SRC through evidence-based integrated decision support tools”)

• ERA-NET Bioenergy Joint Call SRC focus area 3: Environmental aspects of SRC


• 5 partners from 2 ERA-NET Bioenergy countries (Sweden and Germany)
Project consortium

CHALMERS

Project partner

Partner of the vTI group, coordinated by vTI
Rating-SRC general objective

• to produce **scientific evidence** in order to **create** appropriate **decision-making tools** to **optimise impacts** of SRC on the environment
Why?

• A shift on agricultural land-use to SRC in areas adjacent to “wood-fuel” power stations (small or large) is anticipated...

• Implications (positive and negative) to environmental parameters (soil, water, biodiversity, landscape) in micro- (near the field) and macro- (regional) scale need to be evaluated (further use by decision-makers)

• Environmental advantages of SRC a means for balance to elevated grain prices

• SRC as sustainable energy generation system: recycling of wood-ash and sewage sludge should be considered
How?

• **Identification** → **Quantification** → **Evaluation** of potential environmental impacts (positive or negative)

⇒

• **Recommendations** to optimise SRC impact
• **Filter mapping** of appropriate SRC locations
WP 1 - Identifying the baseline: current knowledge of SRC impacts

1.1. Identification of decision-making and policy context for SRC in the ERA-Net countries
1.2. Analysis of perceptions related to SRC impact on landscape
1.3. Identification of potential effects of SRC cultivation on biodiversity (including effects of wood-ash recycling)
1.4. Identification of potential effects of SRC concerning soil aspects (including effects of wood-ash recycling)
1.5. Identification of potential effects of SRC concerning water issues

WP 2 - Assessment of SRC impact on biodiversity

2.1. Synthesis of research results from biodiversity projects performed by consortium members
2.2. Impact of SRC on soil microbial diversity
2.3. Impact of wood-ash/sludge recycling on plant diversity in SRC

WP 3 - Assessment of SRC impact on soil issues

3.1. Impact of SRC on soil physical characteristics and composition of SOM
3.2. Impact of SRC on soil quality in terms of heavy metals

WP 4 - Assessment of SRC impact on water issues

4.1. Impact of SRC on water budgets
4.2. Assessment of SRC impact on water quality

WP 5 - Evaluation of SRC impact on the environment and development of support tools for decision-making

5.1. Development of a sustainability framework appropriate for SRC establishment
5.2. Evaluation of SRC impact on the environment
5.3. Recommendations to increase the positive and mitigate the negative impacts of SRC on the environment
5.4. Filter mapping of appropriate SRC locations in case study areas
5.5. Dissemination of project results
WP 1 - Identifying the baseline: current knowledge of SRC impacts

Why?

• Current status of knowledge and research
• Gaps in knowledge

How?

• Detailed reviews on all environmental issues
• Analyses of reviews to identify gaps
WP1 – Special Issue in LBF
Special Issue in LBF – Published articles

Ioannis Dimitriou, Christel Baum, Sarah Baum, Gerald Busch, Ulrich Schulz, Jörg Köhn, Norbert Lamersdorf, Peter Leinweber, Pär Aronsson, Martin Weih, Göran Berndes und Andreas Bolte The impact of Short Rotation Coppice (SRC) cultivation on the environment

Sarah Baum, Martin Weih, Gerald Busch, Franz Kroiherr und Andreas Bolte The impact of Short Rotation Coppice plantations on phytodiversity

Ulrich Schulz, Oliver Brauner und Holger Gruß Animal diversity on short-rotation coppices – a review

Christel Baum, Peter Leinweber, Martin Weih, Norbert Lamersdorf und Ioannis Dimitriou Effects of short rotation coppice with willows and poplar on soil ecology

Ioannis Dimitriou, Gerald Busch, Silvia Jacobs, Paul Schmidt-Walter und Norbert Lamersdorf A review of the impacts of Short Rotation Coppice cultivation on water issues

Gerald Busch The impact of Short Rotation Coppice cultivation on groundwater recharge – a spatial (planning) perspective

Jörg Köhn Socio-economics in SRC – a review on concepts and the need for transdisciplinary research

4th WoodWisdom-Net Research Programme Seminar in collaboration with ERA-NET Bioenergy, Helsinki, Finland, 7/2/2012
Assessment of SRC impact on biodiversity

• Considered components of biodiversity
  – *Phytodiversity*: plant species diversity (vascular plants)
  – *Zoodiversity*: species diversity of ground beetles and breeding birds (indicator species approach)
  – *Soil biodiversity*: soil microbial population, ectomycorrhizal (EM) fungi
Assessment of SRC impact on biodiversity

• Field studies
  – *Phytodiversity*: 15 sites (poplar and willow) in Germany and Sweden (SRC, adjacent land-uses, landscape: 225 km² area)
  – *Zoodiversity*: 2 sites (poplar and willow) in Germany (SRC, adjacent arable sites)
  – *Soil biodiversity*: 2 sites (poplar/willow) in Germany (SRC, adjacent arable sites)
Biodiversity: location of study sites

- Soil diversity (UoR: Rostock University)
- Phytodiversity (vTI)
- Zoodiversity (HNEE: Univ. Appl. Science Eberswalde)
- Zoodiversity, Phytodiversity, Soil diversity

4th WoodWisdom-Net Research Programme Seminar in collaboration with ERA-NET Bioenergy, Helsinki, Finland, 7/2/2012
Biodiversity: Phytodiversity recordings

- Vegetation mapping and sample design:
  - Estimation of percentage cover of the layers
  - Species lists with percentage cover
- SRC: 5 plots (3.3m x 6.7m): 111m² total area
- Other land uses: 5 plots (4m x 5m): 100m² total area
- In addition: soil seed bank sampling, radiation measurements

Source: Baum, Bolte and Weih, GCB Bioenergy (in press)
Biodiversity: Results phytodiversity

- High plant species number in SRC (> A: arable land, >Fm_D: mixed forest Germany, ≈ G: grassland)
- Species-rich SRC with more evenly distributed abundance of plant species
Biodiversity: Results phytodiversity

• SRC has the most balanced species distribution regarding habitat preferences
• Temporal variation of stand structures provides habitats for both light-demanding ruderal species and woodland species adapted to low light conditions

Proportions of species habitat preference. a: arable fields, g: grassland, r: ruderal sites, w: woodlands, x: indifferent, ns: not stated. A: arable land, Fm_D: mixed forest Germany, G: grassland

Source: Baum, Bolte and Weih, GCB Bioenergy (in press), modified
Biodiversity: Results phytodiversity

- SRCs’ α diversity includes 4% to 9% of landscape γ diversity
- SRC diversity effect on landscape level increases with decreasing species richness of landscapes (→ most positive diversity effects in species-poor landscapes)

Multiple regression
(Overall model: $R^2=0.71$, $p=0.0459$)

| Variable                  | Estimate | Standard Error | Pr > |t| |
|---------------------------|----------|----------------|-------|---|
| Intercept                 | 16.347   | 2.846          | 0.0022|   |
| Number habitat types      | -0.646   | 0.213          | 0.0291|   |
| SRC shoot age             | -0.513   | 0.375          | 0.2296|   |

Source: Baum, Bolte and Weih, Bioenergy Research (in review)
Biodiversity: Results phytodiversity

- In landscape context SRC are important habitats for plant species of (anthropogenic) disturbed sites.
- Red list species are seldom found.

Source: Baum, Bolte and Weih, Bioenergy Research (in review)
Biodiversity: Results zoodiversity

Spring occurrence of ground beetles, recorded with pitfall traps

- High number of ground beetles in crops (arable fields).
- Forest species are only found in older SRC.
**Biodiversity: Results zoodiversity**

- Breeding bird diversity are promoted by variable SRC stand structures.
- Rare species are seldom found in SRC.

Source: Gruß and Schulz (2011)
Biodiversity: Results soil biodiversity

- Changes of soil microbial population under SRC: increased ratio of fungal/bacterial and Gram-/Gram+ bacteria.
- Decreased colonisation density of all tested groups of microorganisms in SRC compared to wheat crop; → lower decomposition of SOM

Source: Baum et al. (in review)
Biodiversity: Results soil biodiversity

- Ectomycorrhizal fungi are introduced by willow SRC into arable soils.
- Increased accumulation of assimilates and SOM in the soils (latter also due to lower microbial decomposition).

Diversity and relative abundance of ectomycorrhizal fungal taxa (%)

3- and 6-year rotation (rot 3 and 6) in spring (S) and autumn (A)

Source: Baum et al. (in review)
Assessment of SRC impact on biodiversity

• **Main conclusions**
  
  – *Phytodiversity*: SRC are an important source for phytodiversity in the landscape. The diversity effect of SRC is highest in homogenous, species-poor landscapes. The temporal variation of SRC structure is an important reason for the positive phytodiversity effects.
  
  – *Zoodiversity*: SRCs are not habitats for rare species (ground beetles, breeding birds) and are often less populated than open landscapes. However, structural diversity in SRC can promote breeding bird diversity.
  
  – *Soil biodiversity*: Lower soil microbial population and the introduction of ectomycorrhizal (EM) fungi into soils seems to be the main reason for the accumulation of soil organic carbon in SRC sites compared to arable land.
Assessment of SRC impact on soil issues

• SRC vs arable fields for tot. C and trace elements

• Soil organic matter quality under SRC
<table>
<thead>
<tr>
<th>Site</th>
<th>Year planted</th>
<th>Variety</th>
<th>Reference field crop</th>
<th>Sludge/Ash</th>
<th>Last harvest</th>
<th>Mineral fertilization</th>
<th>Soil texture (0-20 cm)</th>
<th>Biomass 2009</th>
<th>Previous use before SRC</th>
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<td>Jorr</td>
<td>Pea/Cereals</td>
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<td>Tora</td>
<td>Cereals</td>
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<td>Y (2)</td>
<td>silty clay</td>
<td>4.2</td>
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</table>
Relative differences between willow SRC plantations versus the reference. The values are the averages for all the locations of the different soil quality parameters investigated in topsoil (0-20 cm) and in subsoil (40-60 cm). Positive values represent higher observations of the studied parameter in the willow SRC plantations, in percentage (Dimitriou et al, unpublished).

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Impact of SRC vs ref on soil

- C storage in soil organic matter is higher under SRC than under conventional agricultural crops.

- Cd concentrations in the soil under SRC are lower than under conventional agricultural crops (ca. 12% lower in topsoil).

- Sludge applications did not affect the above differences of Cd in topsoil.
Effects of SRC on the organic matter of arable soils:

- potentials of SRC to increase the concentrations of organic matter in arable soils with initial low are moderate $C_{\text{org}}$ concentrations were described by many authors

- the composition and stability control the decomposability of soil organic matter (SOM)

- changes in the SOM quality under SRC can be assumed by: changed litter composition combined with changes in the soil microbial community structure (introduction of ectomycorrhizal fungi by the host plants willows and poplar)

The quality of SOM indicates the sustainability of changes in the $C_{\text{org}}$ concentrations in arable soils.
Correlation between the concentrations of aliphatic lipids and organic C in the soil (W - willow, P - poplar, Ref. - annual arable crops)

\[ y = 9.0 x - 28.3 \]
\[ R = 0.89^{***}, n = 11 \]

\[ y = 5.7 x - 23.7 \]
\[ R = 0.98^{*}, n = 4 \]
Increased concentrations (µg g⁻¹) of fatty acid methyl ester (FAME) in the soil under willows compared to annual arable crops at the test site Ultuna (S) - indication of increased organic matter stability.

**FAME - fatty acid methyl ester**

**ges. FAME Salix viminalis (0 - 10 cm) Ultuna,**

**ges. FAME Ref. (0 - 10 cm) Ultuna**
Summary and conclusions soil organic matter quality

-increased concentrations of long-chain fatty acids in the organic matter caused by the changed litter quality indicate a higher stability of SOM (lower decomposability) under SRC than under annual arable crops

-higher thermal stability of the alkyl aromatics confirmed this tendency

Sustainable increased organic matter concentrations in the soil under SRC can be assumed.
<table>
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<tr>
<th>CODE</th>
<th>Name</th>
<th>Year Planted</th>
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<td>Cereals</td>
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</table>
Averages of NO$_3$-N and PO$_4$-P concentrations in the groundwater of SRC and reference in each of the different locations throughout the whole experimental period. Numbers correspond to the locations as described in Tab. 1 (Dimitriou et al., unpublished).
Averages of NO$_3$-N and PO$_4$-P concentrations in the groundwater of all fields pooled together for willow SRC and reference fields for the whole experimental period (Dimitriou et al., unpublished).
Treatment and N-dynamic
(“Fuhrberger Feld”)

- Soil treatment -

Control
Site P/2009
Site preparation for P/2009
Site P/2009 (Poplar, planted 2009)
Treatment and N-dynamic

(“Fuhrberger Feld”)

- Species / Age / Stand density -

Site P/1994 (Poplar, planted 1994, harvested once in 2006)

Site W/2005 (Willow, planted 2005, partly harvested 2010)

Site W/1994 (Willow, planted 1994, first harvested 2010)
Treatment and N-dynamic ("Fuhrberger Feld")

Nitrate in the soil solution, 100 cm soil depth

SRC and water quality - conclusions

- NO$_3$-N leaching from SRC was significantly lower than from reference fields.

- NO$_3$-N leaching from SRC was not elevated during autumn or spring when most leaching from commercial fields occur.

- Site preparation for SRC establishment and management (no harvest) can result in extensive N mineralisation.

- PO$_4$-P concentrations in the groundwater of SRC were higher compared to reference.

- Sewage sludge applications not responsible for the higher PO$_4$-P concentrations in SRC vs reference fields.
Water budgets – Study aims

1. Comparison of water budgets of two different land use types (Willow-SRC, fallow grassland) on sandy soils.
2. Evaluation of the influence of harvest operations on SRC‘s water budget partitioning.

Basic approach:
- Water budget simulations of study sites using a hydrological process model (CoupModel: „coupled heat and water transport model“)
- Model parameterized, run and validated with measured field observations
  - Driving variables: climatic data
  - Input parameters:
    - Soil hydraulic properties → water storage capacity
    - stand characteristics (leaf area index [LAI], canopy height, root distribution) → pot. evapotranspiration and water uptake
  - Validation variables: Soil matric potential, stand precipitation
Results 1: fallow grassland vs. Willow-SRC

Higher transpiration and interception losses of willow stands result in reduced groundwater recharge.

<table>
<thead>
<tr>
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<td>179</td>
</tr>
<tr>
<td></td>
<td>262</td>
<td>170</td>
</tr>
</tbody>
</table>
Results 2: harvesting effects 2010 & 2011

- Less interception and transpiration from the regrowing willow stand
- 2010: regrowth of W05b is slow because of a dry period in June/July
- 2011: regrowth of W05a is fast, water budgets merely differ

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>W05a</td>
<td>W05b</td>
</tr>
<tr>
<td>W05a</td>
<td>W05b</td>
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<tr>
<td>Precipitation</td>
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<tr>
<td>Interception</td>
<td>175</td>
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<tr>
<td>Transpiration</td>
<td>229</td>
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<tr>
<td>Soilevaporation</td>
<td>68</td>
</tr>
<tr>
<td>DeepPerc</td>
<td>179</td>
</tr>
</tbody>
</table>
Conclusions water budget

• A shift from fallow grassland to willow-SRC reduces groundwater recharge due to higher evapotranspiration rates, however significant impact on catchment level not expected

• Interception and transpiration of a regrowing willow stand are comparatively small until canopy closure is achieved

• A short harvesting interval might thus reduce the negative effect of a land use shift towards willow SRC
List of main recommendations for “sustainably sound” SRC practice

• Establish SRC in homogenous arable landscapes to achieve highest positive effects on phytodiversity

• Variable SRC structures (shoot age, species/clones, area shape) and habitat diversity (intensive land use mixtures) to increase ecotone area and thus biodiversity (phyto- and zoodiversity)

• Cultivate SRC in fields located close to N sources (animal farms, wastewater treatment plants etc) to decrease N outflow to adjacent water bodies

• Cultivate SRC on fields with initial low C and high Cd soil concentrations to improve soil quality

• Harvest more frequently and cultivate SRC for at least 3 cutting cycles to achieve the above

• Recycle nutrients via municipal waste residues (no effect on groundwater and soil quality)
Study area

- bird sanctuary
- priority area: structural enrichment
- arable land
- pasture
- municipality
- biogas plant
- competition with maize
Fuzzy Multi-criteria analysis to show potential effects of goal-oriented allocation of Poplar SRC

(1) High disposition to erosion

(2) High impact on groundwater recharge

(3) Competition with Maize

(4) High-Yield potential

(5) Deficit in landscape structure
"High impact on groundwater recharge"
"Competition with maize"
"Deficit in landscape structure"
Pathway 2: Production-oriented SRC allocation with environmental goals as side-effects

(a) Average membership value of environmental dimensions (wind-erosion, GWR, landscape structure)

(b) Maximum membership value of environmental dimensions (wind-erosion, GWR, landscape structure)
Impact of SRC on socioeconomic conditions

Labour requirements

Welfare

Energy production

Investments

Years before first harvest

Income

- BAU
- 20% SRC

Decision support
Energy crops and the new CAP

• Positive effects on water quality, soil quality and biodiversity (when compared to other arable crops) Greening of Pillar 1
Special Issue Bioenergy Research (Springer) – SRC and the Environment

Water
BERE-431, Author: Dimitriou Impact of willow Short Rotation Coppice on water quality

BERE-438, Author: Schmidt-Walter Groundwater recharge of different aged willow short rotation coppices in a drinking water catchment

BERE-429, Author: Lamersdorf Nitrate seepage output under short rotation coppices (SRC) with poplar and willow in a drinking water catchment near Hannover, Germany

Soil
BERE-428, Author: Dimitriou Changes in organic carbon and trace elements in the soil of willow short-rotation coppice plantations

BERE-427, Author: C. Baum The impact of poplar growth on the composition of soil organic matter and on microbial communities in arable soils

Biodiversity
BERE-425, Author: S. Baum The contribution of short rotation coppice (SRC) to gamma diversity of vascular plants in agricultural mosaic landscapes

BERE-436, Author: Gruss Biodiversity of Breeding Birds and Ground Beetles (Coleoptera: Carabidae) in Short Rotation Coppices and Surrounding Cropland

Overall environmental impact and sustainability
BERE-441, Author: Busch SRC and its multiple impacts on landscape functions - GIS-based tools for rapid regional assessments

BERE-430, Author: Englund Meeting Sustainability Requirements for SRC-Bioenergy: Usefulness of existing tools, responsibilities of involved stakeholders and recommendations for further developments

BERE-437, Author: Langeveld Assessing biophysical and socio-economic communicate multidimensional effects of SRC expansion: model definition and preliminary results
More information?

http://www.ratingsrc.eu/

4 Rating-SRC posters in the poster room!