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# Optimizing lignocellulosic cropping systems to achieve multiple benefits

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How Attractive Systems for Bioenergy Feedstock Production in Sustainably Managed Landscapes are for Rural Development / Koliko su atraktivni sustavi proizvodnje biomase za obnovljivu energiju u održivom upravljanju okolišem za ruralni razvoj.
IEA Bioenergy Task 43 Workshop, 27/03/2018
Sveučilište J.J. Strossmayera, Aula Magna, Kralja Petra Svačića 1d, Osijek

# Short Rotation Coppice in Sweden


Mechanised planting with approx. 12 000 cuttings/ha

# Short Rotation Coppice in Sweden

- Ca. 10 000 ha are currently cultivated in Sweden for energy (with willow – Salix sp.)
- Predictions for rapid increase (e.g. Ministry of Agriculture, 2006; Federation of Swedish Farmers, 2006)
- Grown on agricultural land (weed control, planting, fertilisation – similar to an agricultural crop)
- Harvested every 3-4 years, life span app. 25 years, average production: 6-10 t DM/ha/yr

# Short Rotation Coppice in Sweden

- SRC cultivated area remained almost stable between 1995-2010 but decreased during the last 7-8 years from ca 14 t to ca 10 t ha, predictions have not become true...
- …farmers do not usually fertilise and biomass production is therefore lower than the potentially achieved…
- …increases of grain prices and cheaper biomass material give negative sings for area increase…

# SRC ‘value’ must improve!

# Gross margins of SRC cultivation

| Price (€/GJ) | Yield level (t DM per hectare) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 2 | -291 | -306 | -322 | -337 | -352 | -368 | -383 | -398 |
| 3 | -226 | -228 | -230 | -233 | -235 | -237 | -239 | -242 |
| 4 | -161 | -150 | -139 | -128 | -117 | -107 | -96 | -85 |
| 5 | -96 | -72 | -48 | -24 | 0 | 24 | 48 | 72 |
| 6 | -30 | 7 | 44 | 81 | 118 | 154 | 191 | 228 |
| 7 | 35 | 85 | 135 | 185 | 235 | 285 | 335 | 385 |

Gross margin of SRC (EUR/ha) for a range of yields and wood chip prices (for Swedish conditions in 2009; 1 MWh = 3.6 GJ, 1 t DM = 15.8 GJ). In: Dimitriou and Rosenqvist (Biomass and Bioenergy, 2011)

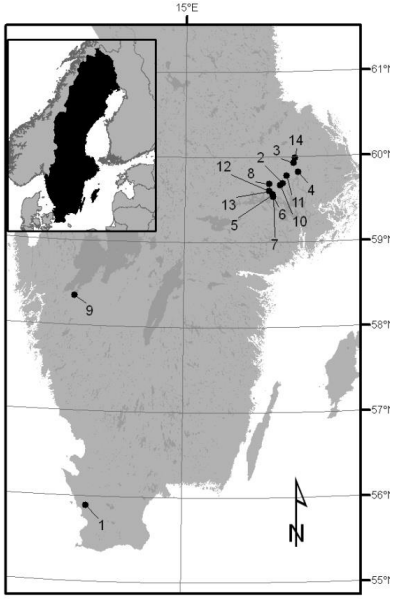
*On top of these numbers, you need to add the farm subsidy and possible renewable energy subsidies!*

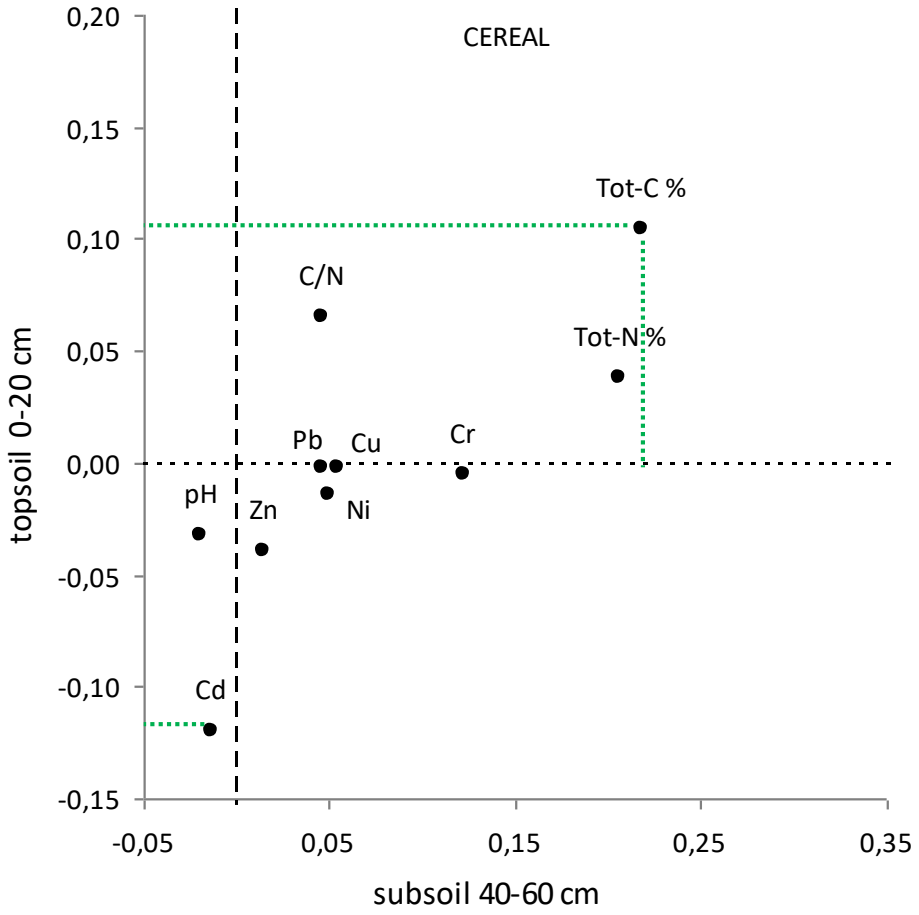
# Additional values?

- via environmental impact/services?
- multifunctional uses of SRC

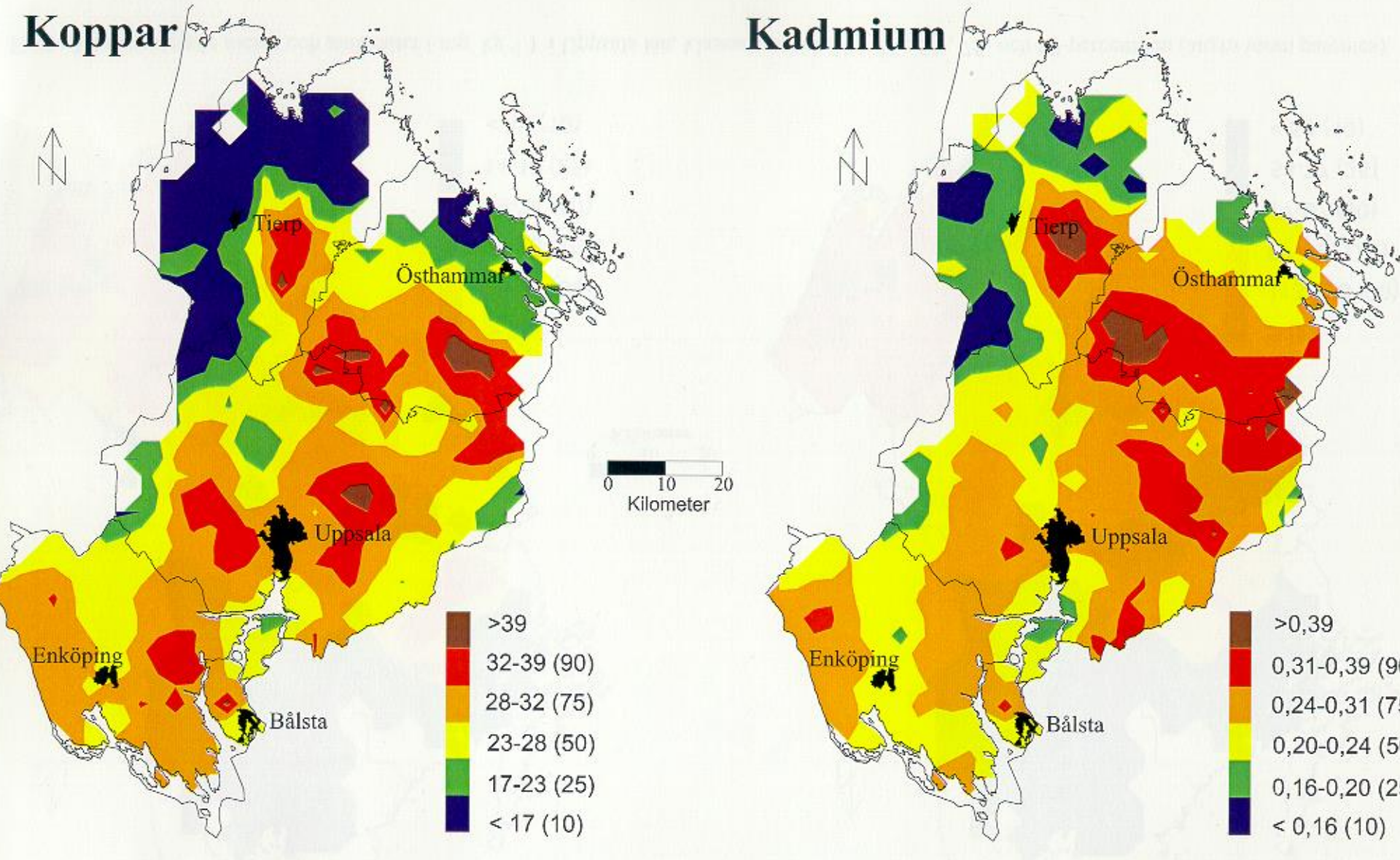
| | Name | Year planted | Clone | Reference field | Sludge /Ash | Harvested | Inorganic fertilisation | Soil type (0-20 cm) | Biomass 2009-10 | Previous use /before SRC |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Billeberga I | 2002 | Sven | Cereals | Y/N (1) | 2008 | N | sandy loam | 8.5** | Sugarbeet |
| 2 | Billeberga II | 1994 | Torhild | Cereals/rapeseed | Y/N (3) | Annually | N | loam | 2** | Cereals |
| 3 | Djurby Gård | 1990 | 78021 | Cereals | Y/N (3) | 2007/2011 | N | silty clay | 5.3 | Cereals |
| 4 | Forkarby | 1995 | 78112 | Cereals | N/N | 2008 | Y (1) | silty clay | 11 | Cereals |
| 5 | French Trial | 1994 | 78021 | Cereals (eco) | N/N | 2007/2010 | Y (8) | clay loam | 9.3 | |
| 6 | Hacksta | 1994 | Jorr, Rapp | Peas/cereal | Y/Y (4) | 2008 | Y (1) | clay loam | 4.2 | Cereals |
| 7 | Hjulsta II | 1995 | Jorr | No ref | N/N | 2008 | N | clay | 9.6 | Oil crops/cereals |
| 8 | Kurths trial | 1992 | Ulv/Rapp | Cereals (eco) | N/N | 2007/2010 | N | clay loam | 12.4 | Cereals |
| 9 | Lundby Gård I | *2000 | Tora | Cereals | Y/Y (1) | 2005 | Y (1) | clay | 4.9 | Cereals |
| 10 | Lundby Gård II | 1995 | 78021 | Cereals | N/N | 2005 | N | clay | 2.5 | Cereals |
| 11 | Puckgården | 1992 | 78112 | Cereals | N/N | 2008 | Y (4) | silty clay | 10** | Cereals |
| 12 | Skolsta | 1993 | 78021, Orm | Cereals | Y/Y (1) | 2004 | Y (2) | silty clay | 4 | Cereals |
| 13 | Säva | 1993 | Rapp, Orm | Grass | Y/N (2) | 2007 | N | silty clay | 7.4 | Cereals |
| 14 | Teda I | 2000 | Tora | Grass | Y/Y (2) | 2009 | Y (2) | silty clay loam | 8 | Cereals |
| 15 | Teda II | 1993 | 78112 | Grass | Y/Y (2) | 2007 | Y (2) | clay | 1.7 | Cereals/Set-aside |
| 16 | Åsby | 1996 | Tora | Cereals | Y/Y (1) | 2008 | Y (2) | silty clay | 4.2 | Cereals |

Tab. 1. Description of the different locations where groundwater pipes were established. *



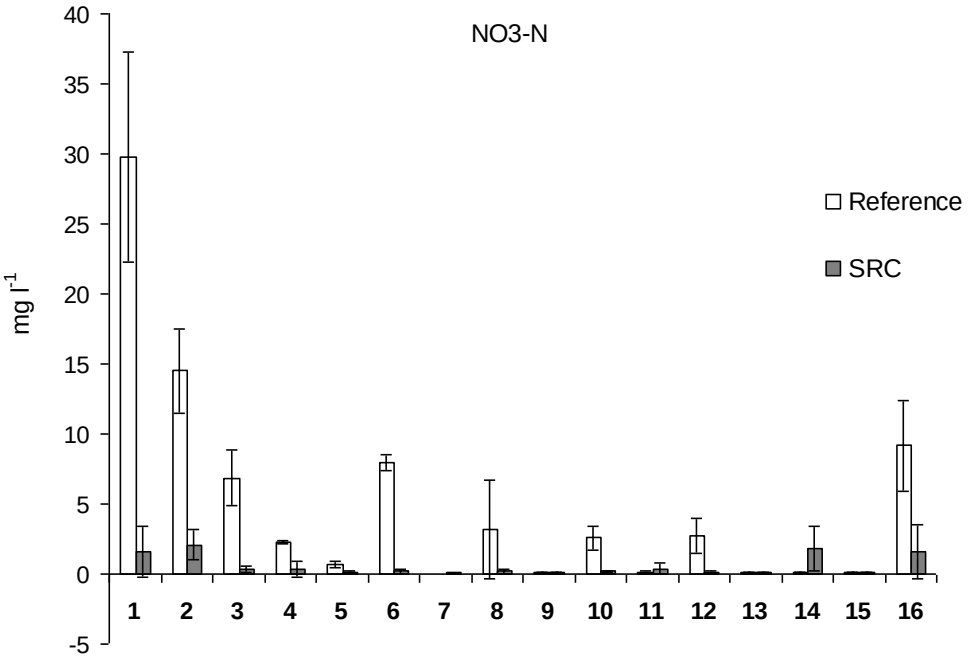


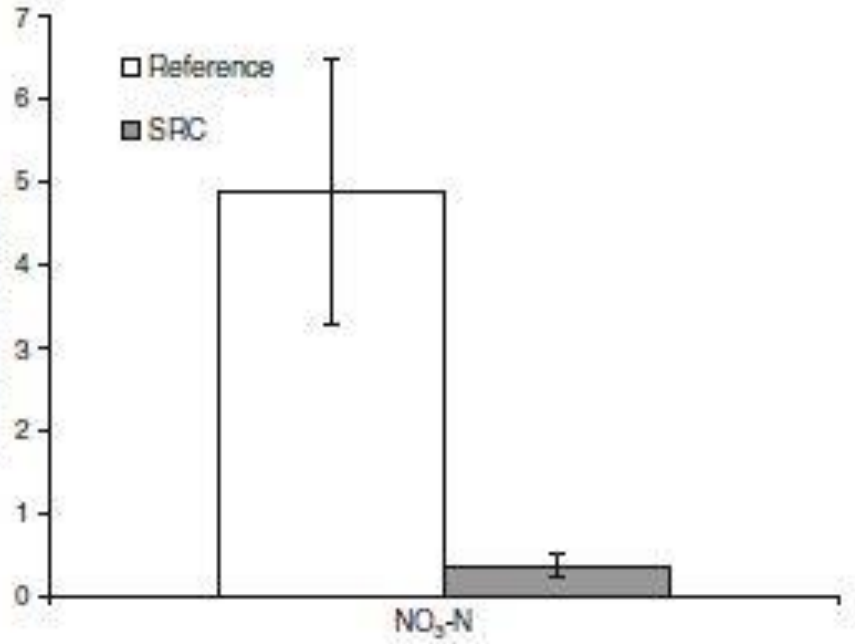

Relative differences between willow SRC plantations versus the reference. The values are the averages for all the locations of the different soil quality parameters investigated in topsoil (0-20 cm) and in subsoil (40-60 cm). Positive values represent higher observations of the studied parameter in the willow SRC plantations, in percentage (Dimitriou et al, 2012).




**Figur 4** Interpolerade koppar och kadmiumhalter ( mg $kg^{-1}$ ) i Uppsala län, klassade utifrån10-, 25-, 50-, 75- och 90-percentilen (anges inom paren

# Nutrient leaching



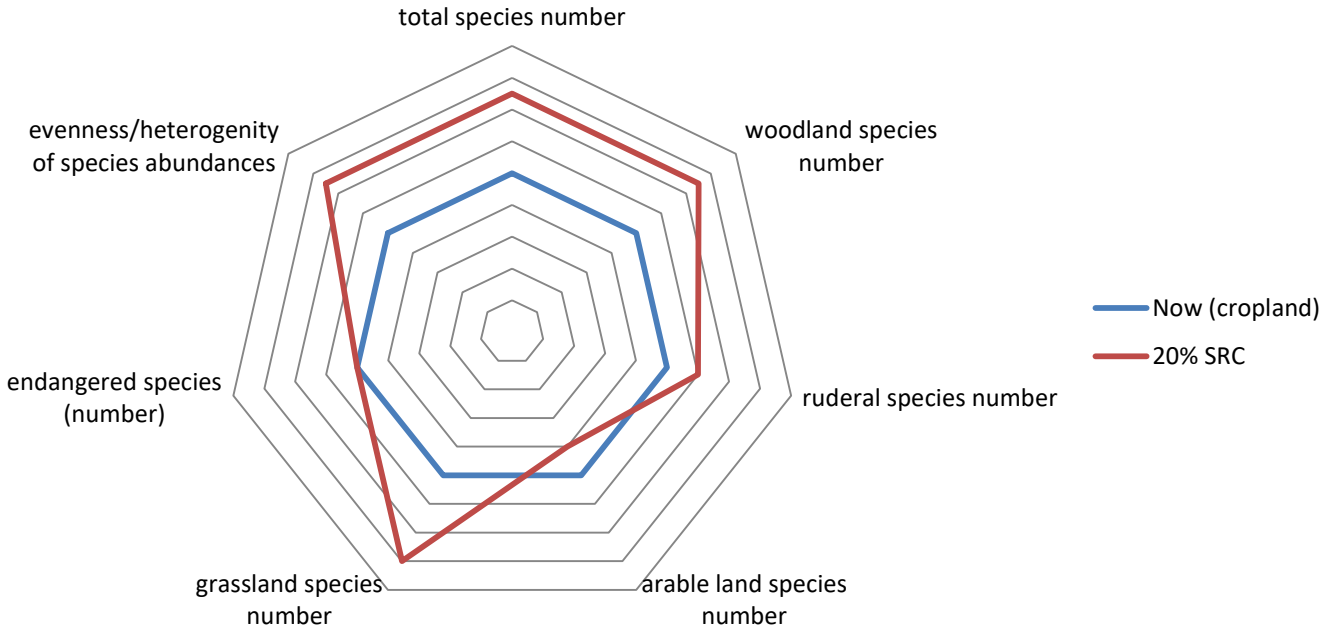




Means, averages and standard errors of NO3–N concentrations in the groundwater of willow short rotation coppice (SRC) plantations and reference fields (Dimitriou et al, 2012 - Bioenergy Research)

# Riparian buffer zones and biomass production

# Biodiversity

# How would phytodiversity be afected by 20% willow in a landscape?




Langeveld et al 2012, Bioenergy Research

# Treatment and utilisation of society's residues and biomass production as a part of the treatment system

# Wastewater treatment in Enköping

# Wastewater treatment in Enköping

Need: 50% N reduction in outflow (Municipality)

Solution : Reduced load of the WWTP through:

1. Septic-tank sludge to rural storage ponds

2. Diversion of wastewater from dewatering of sewage sludge….

# Wastewater treatment in Enköping

…and irrigation of willows with “wet sludge” and treated wastewater


300 km drip irrigation tubes

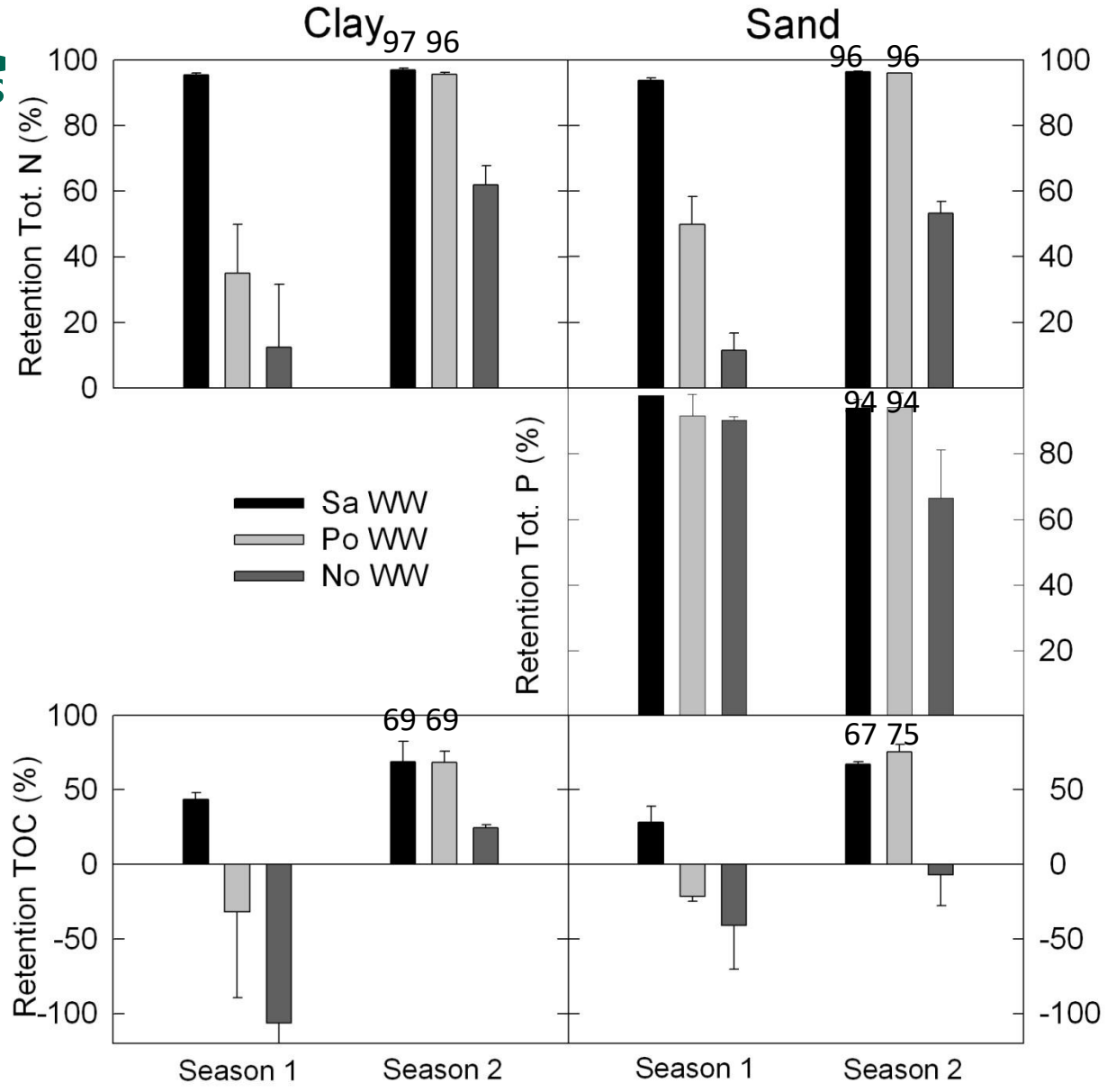

Lined ponds for winter storage

# Wastewater and SRC research issues

N, P, TOC leaching in groundwater

Retention capacity vs maximum amounts applied

Economic calculations and potential




| Element | | Wastewater conc. (mg/L) |
|---|---|---|
| Total N | | 34.7 |
| *Of which* | *$NH_4$-N* | *27.4* |
| | *$NO_3$-N* | *0.2* |
| | *Org. N* | *7.1* |
| Total P | | 4 |
| TOC | | 7.5 |

| | Tot. N load (kg/ha) | Tot. P load (kg/ha) |
|---|---|---|
| Season 1 | 262 | 21.2 |
| Season 2 | 369 | 29.8 |

Relative retention (%) of Tot. N, Tot. P and TOC after wastewater application during two experimental seasons (Dimitriou and Aronsson, Biomass and Bioenergy, 2011).

# Gross margins of SRC cultivation when wastewater is applied

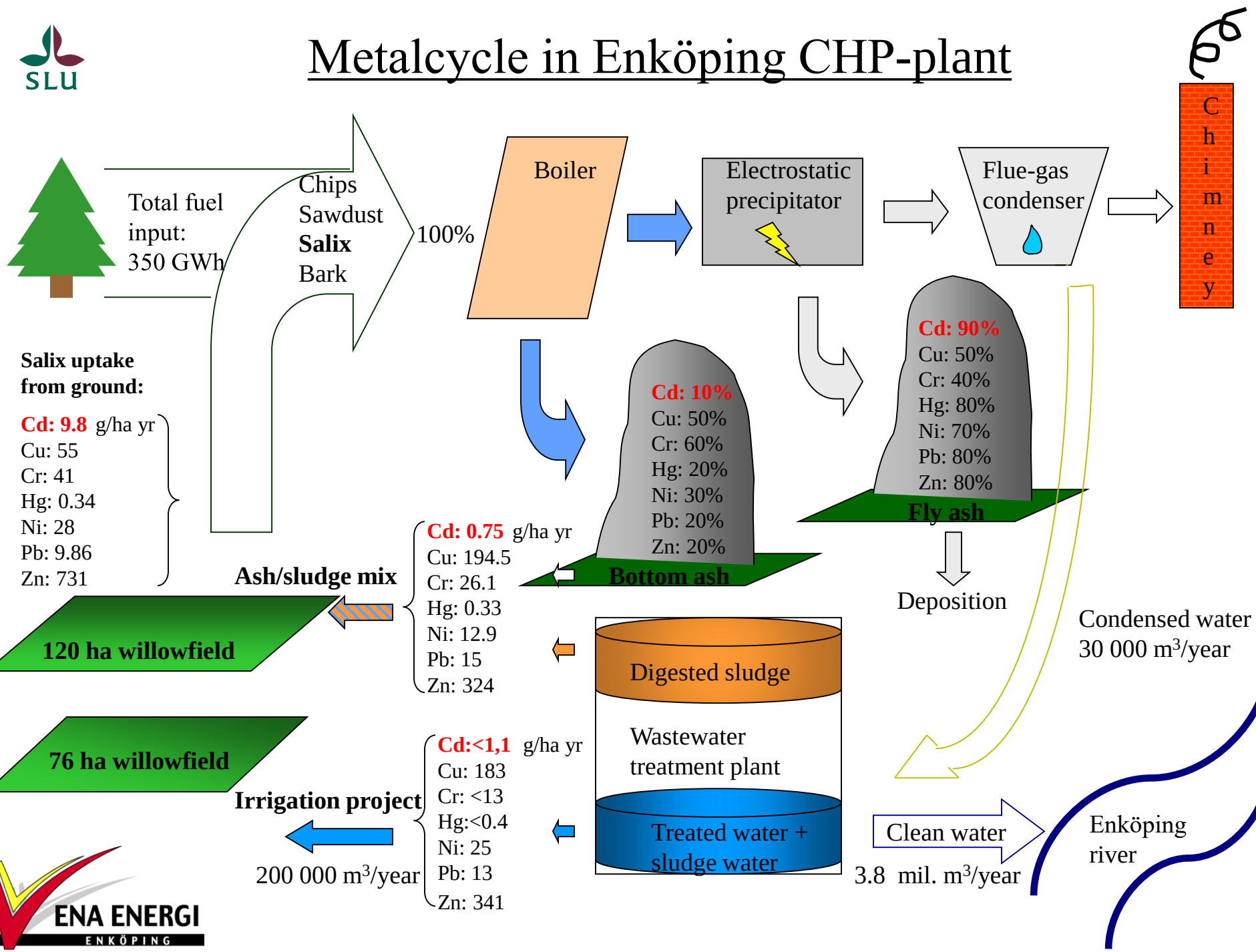
| Price (€/GJ) | Yield level (t DM/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 2 | -242 | -249 | -256 | -264 | -271 | -278 | -286 | -293 |
| 3 | -137 | -131 | -126 | -120 | -114 | -109 | -103 | -97 |
| 4 | -33 | -14 | 5 | 23 | 42 | 61 | 80 | 98 |
| 5 | 72 | 103 | 135 | 167 | 199 | 231 | 262 | 294 |
| 6 | 176 | 221 | 266 | 311 | 355 | 400 | 445 | 490 |
| 7 | 280 | 338 | 396 | 454 | 512 | 570 | 628 | 686 |

Gross margin of SRC (EUR/ha) for a range of yields and wood chip prices (for Swedish conditions in 2009; 1 MWh = 3.6 GJ, 1 t DM = 15.8 GJ) when wastewater is irrigated. In: Dimitriou and Rosenqvist (Biomass and Bioenergy, 2011)

*On top of these numbers, you need to add the farm subsidy, possible renewable energy subsidies!, compensation of the municipality to the farmer for treating the wastewater!*

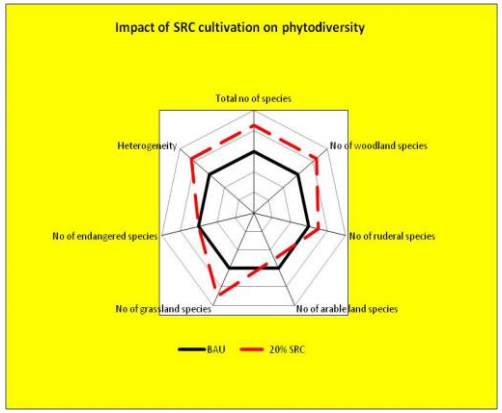

Spreading of sewage sludge and wood-ash (when available) in SRC is very common in Sweden

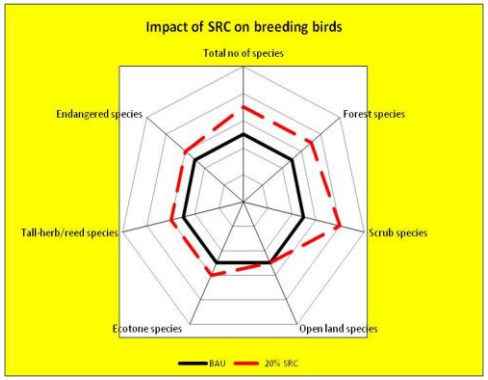
# Metalcycle in Enköping CHP-plant

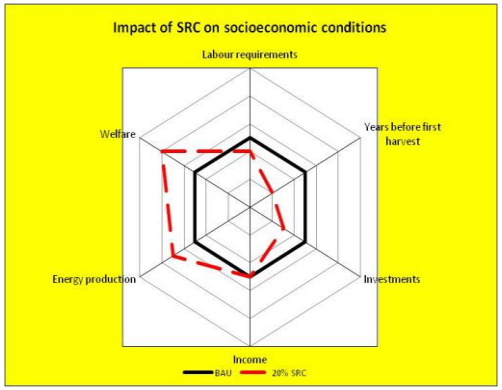


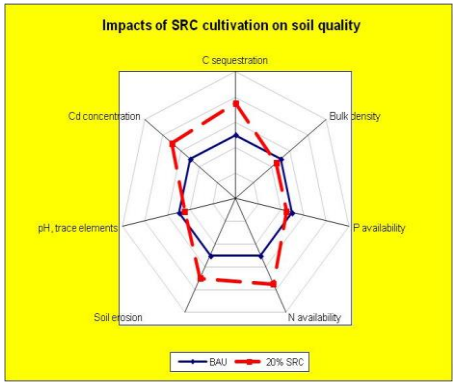
**Consider bioenergy systems as an opportunity to design landscapes that add value…**

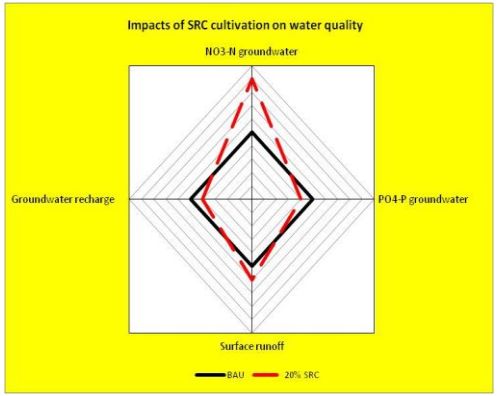
**… and use/develop participatory approaches to include stakeholders/decision makers!**




In Langeveld et al., 2012 (Bioenergy Research)