

SALCA: A comprehensive framework to assess biodiversity & ecosystem services

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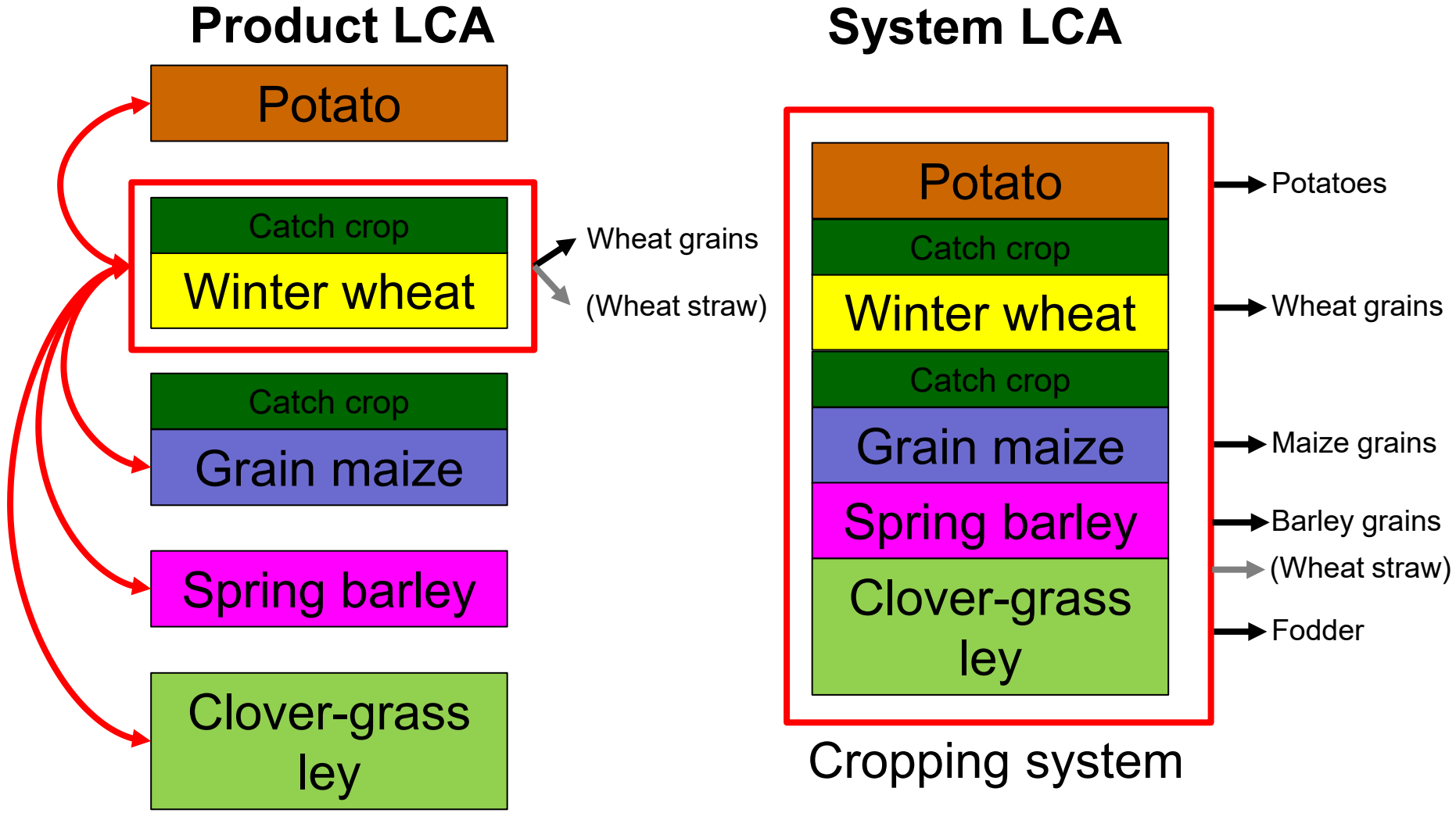
12 October 2026

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Today's Menu

- System boundaries: crop LCA vs. cropping system LCA
- Definition of adequate functional unit
- Swiss Agricultural Life Cycle Assessment (SALCA)
- Productivity – intensity – efficiency
- Optimisation of eco-efficiency
- Ecosystem service assessment
- Some take-aways

LCA of product vs. LCA of system



Defining the functional unit for a cropping system analysis (heterogeneous outputs)

- Mass of products
- Dry mass of products
- Gross energy yield
- Cereal unit
- Raw protein yield
- Digestible energy for human nutrition (considering the coversion of feed to animal food products)
- Nutritional functional unit:
  - Nutrient profile based: Nutrient-rich food index
  - Food pyramid based: contributions to the recommended portions of food groups

  → output can be converted to nutrition years (1 adult person with adequate nutrition during 1 year on average)

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Swiss Agricultural Life Cycle Assessment (SALCA)

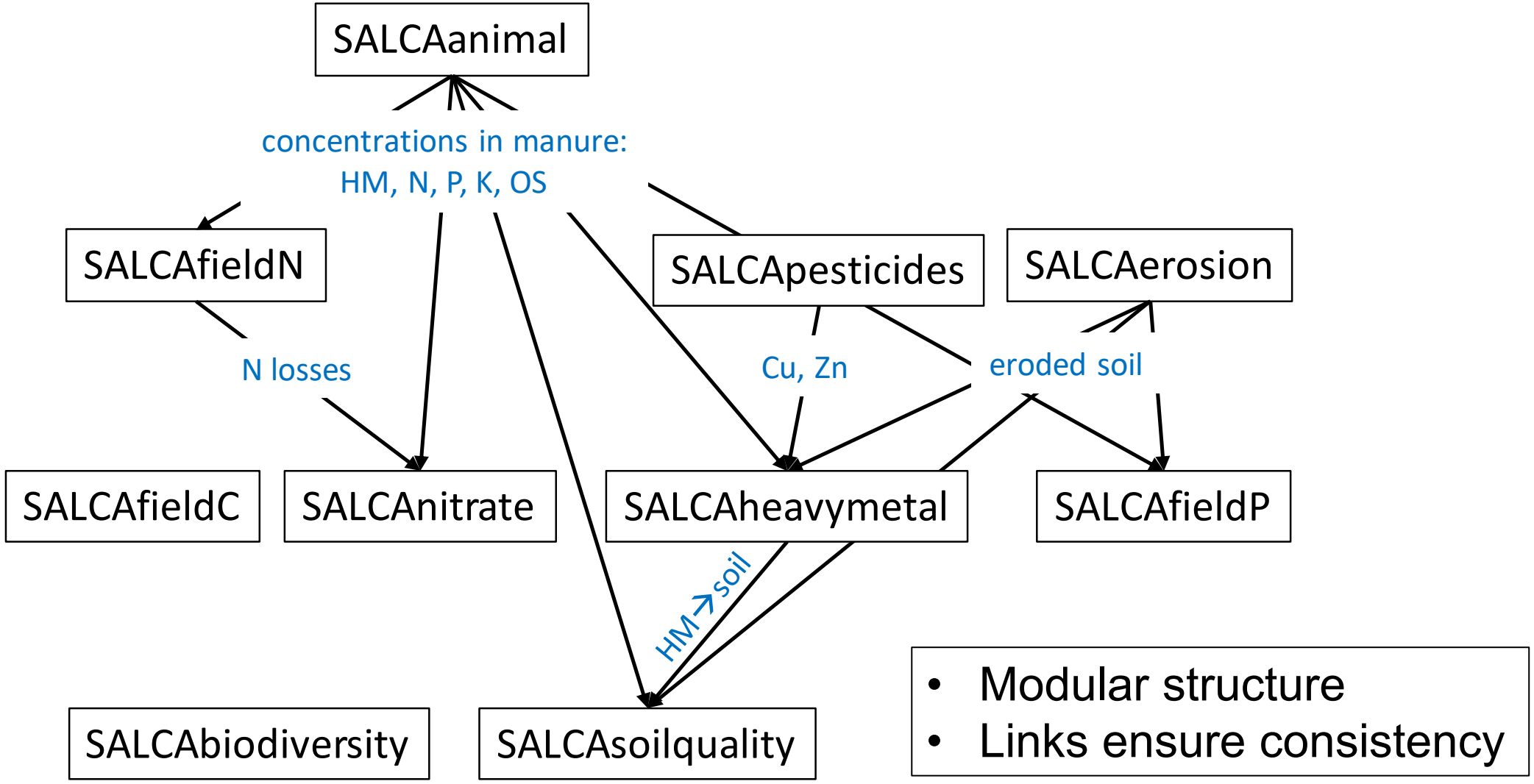
SALCA supports the 4 phases of an LCA:

1. **Goal and scope**
   a) Rules for the definition of system boundaries, functional unit and allocation for agricultural products, farms and the agrifood sector
2. **Life cycle inventory (LCI)**
   a) Models to calculate direct field and farm emissions relevant for agriculture, such as N and P emissions, methane, carbon dioxide, heavy metals, pesticides and soil erosion
   b) A database with LCI for inputs and processes for agrifood systems
   c) A software environment to collect input data, check their plausibility, and calculate agricultural LCAs in a robust and efficient manner
3. **Life cycle impact assessment (LCIA)**
   a) Midpoint impact assessment methods specific to agricultural applications due to direct land use (biodiversity and soil quality)
   b) Selection of impact assessment methods specific to agricultural systems
4. **Interpretation**
   a) A concept for analysing and interpreting LCA results
   b) A concept to communicate the results, conclusions and recommendations

Nemecek T., Roesch A., Bystricky M., Jeanneret P., Lansche L., Stüssi M., Gaillard G., 2023. Swiss Agricultural Life Cycle Assessment: A method to assess the emissions and environmental impacts of agricultural systems and products. Int. J LCA 29, 433–455. https://doi.org/10.1007/s11367-023-02255-w

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SALCA models and data flow



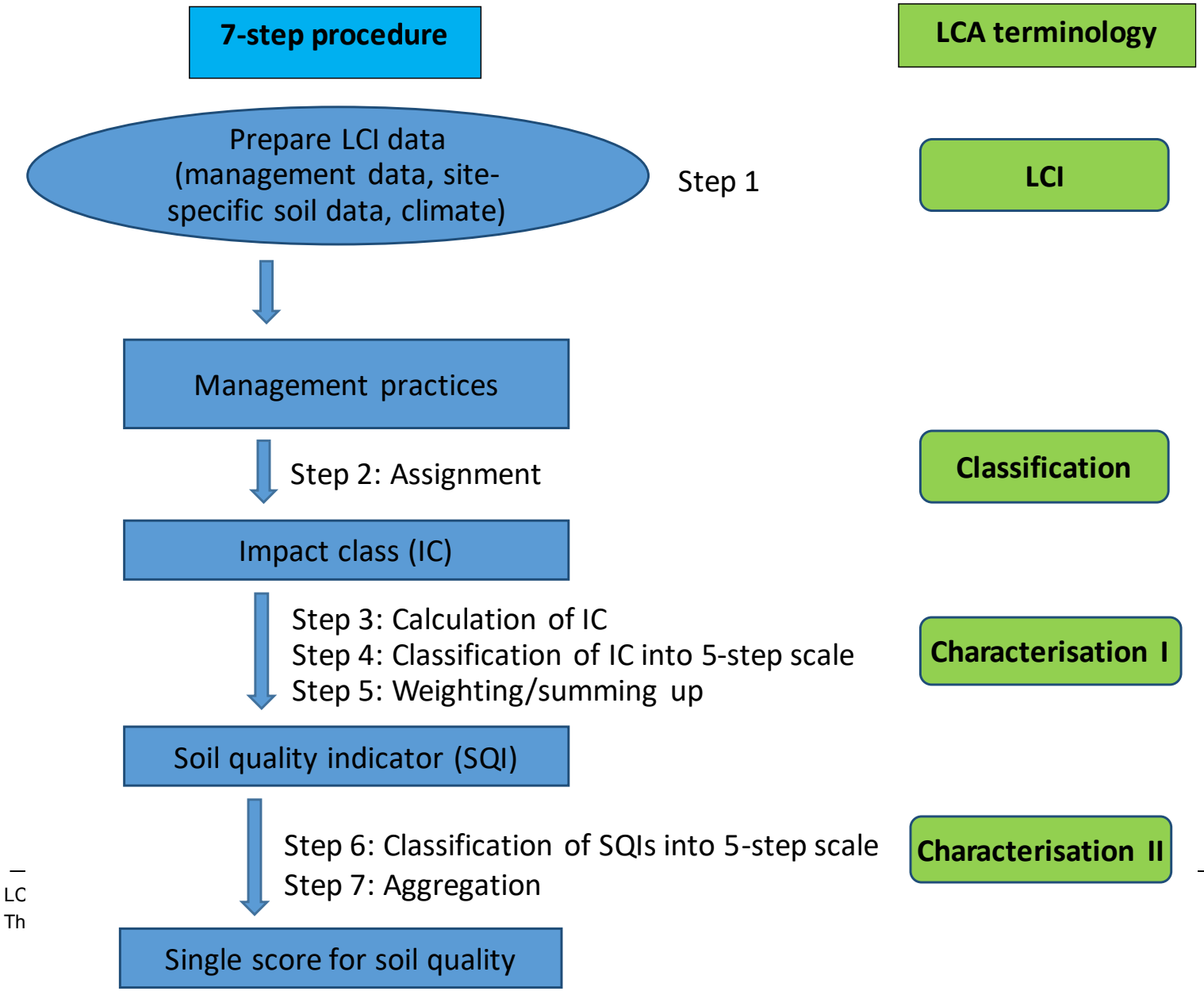
- Modular structure
- Links ensure consistency

Nemecek et al. (2024) https://doi.org/10.1007/s11367-023-02255-w

Python code: https://github.com/agroscope-ch/salca

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SALCAsoilquality: impacts on soil quality



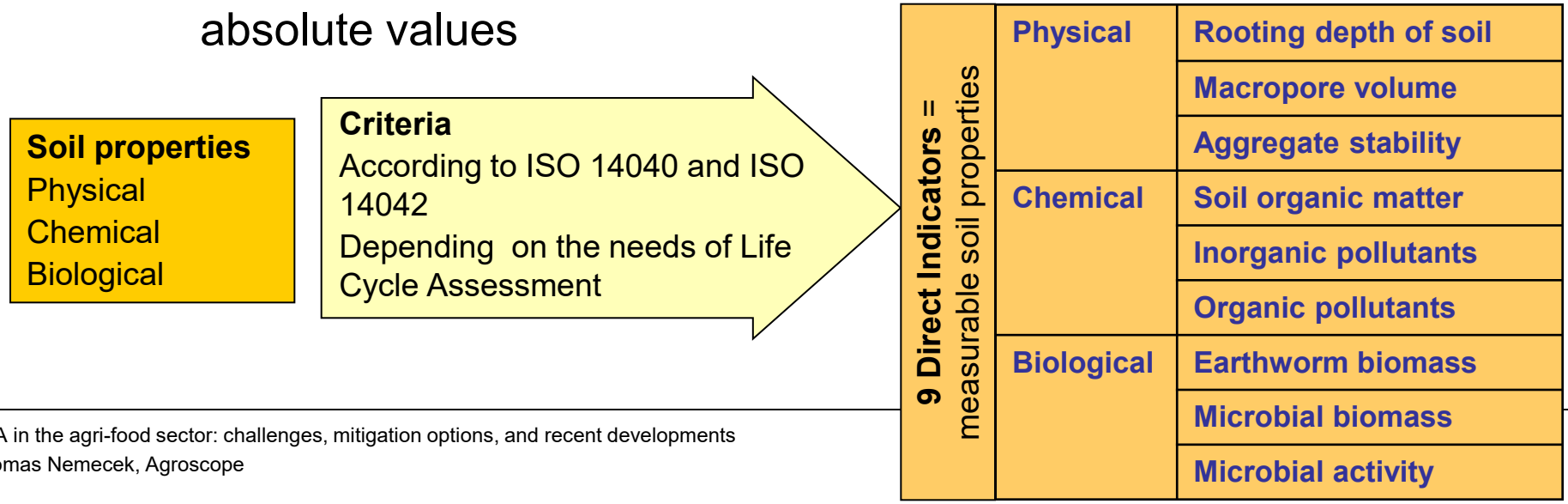
Soil quality indicators	
P: Potential plant rooting depth	Physical
P: Macropore volume	Physical
P: Aggregate stability	Physical
C: Organic carbon	Chemical
C: Heavy metals	Chemical
C: Organic pollutants	Chemical
B: Earthworm biomass	Biological
B: Microbial biomass	Biological
B: Microbial activity	Biological

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SALCAsoilquality: impacts on soil quality

- Spatial system boundary = farm;
- Temporal system boundary = crop rotation period (6-8 years)
- Management data of all plots of a farm in a single year are considered as representative for a whole crop rotation
- Only influences of agricultural management practices are included, not immissions
- The development trend of soil properties is assessed, not absolute values



Source: Oberholzer et al. (2006)

SALCAsoilquality: impacts on soil quality

Example: slurry application

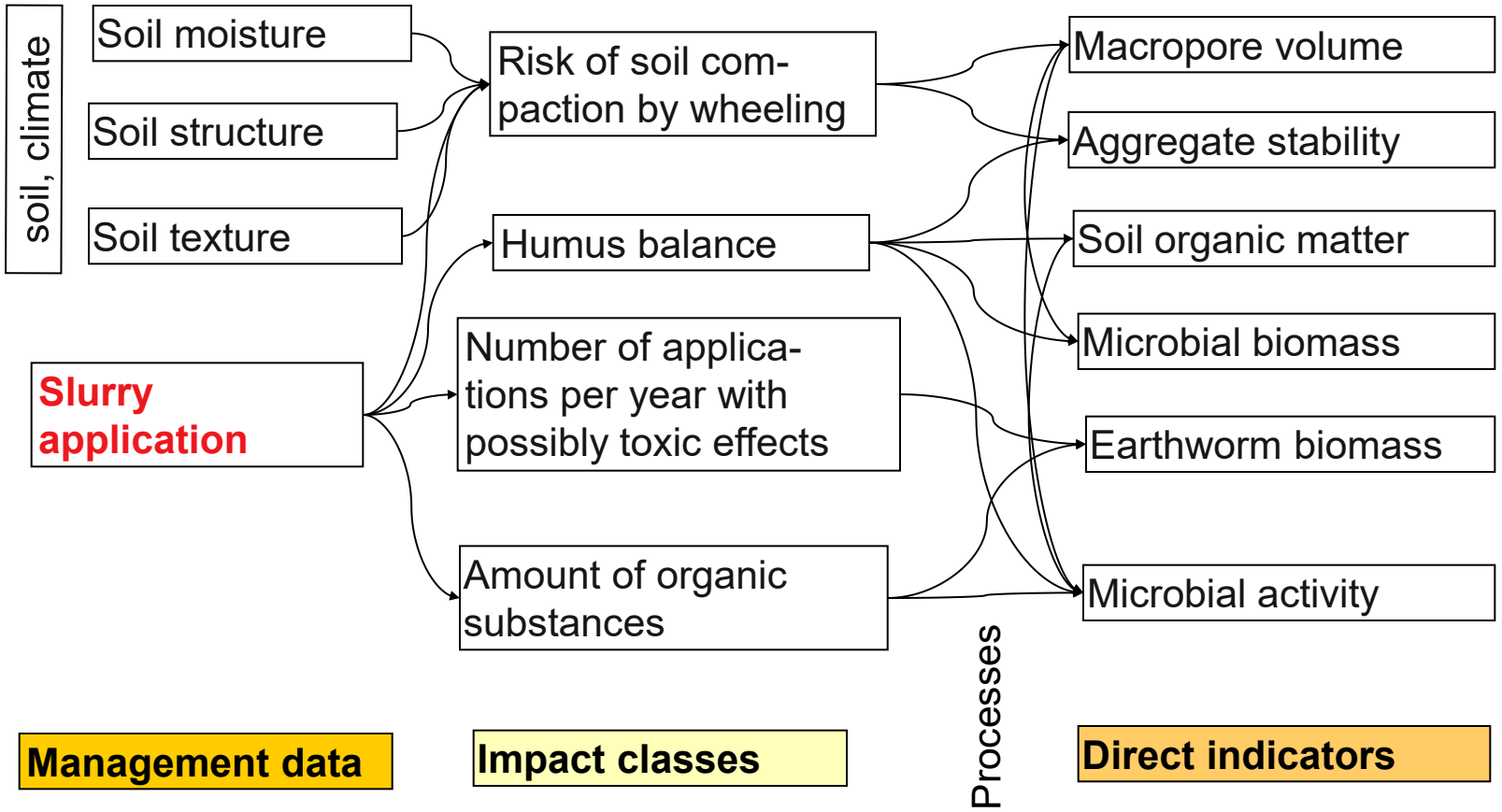
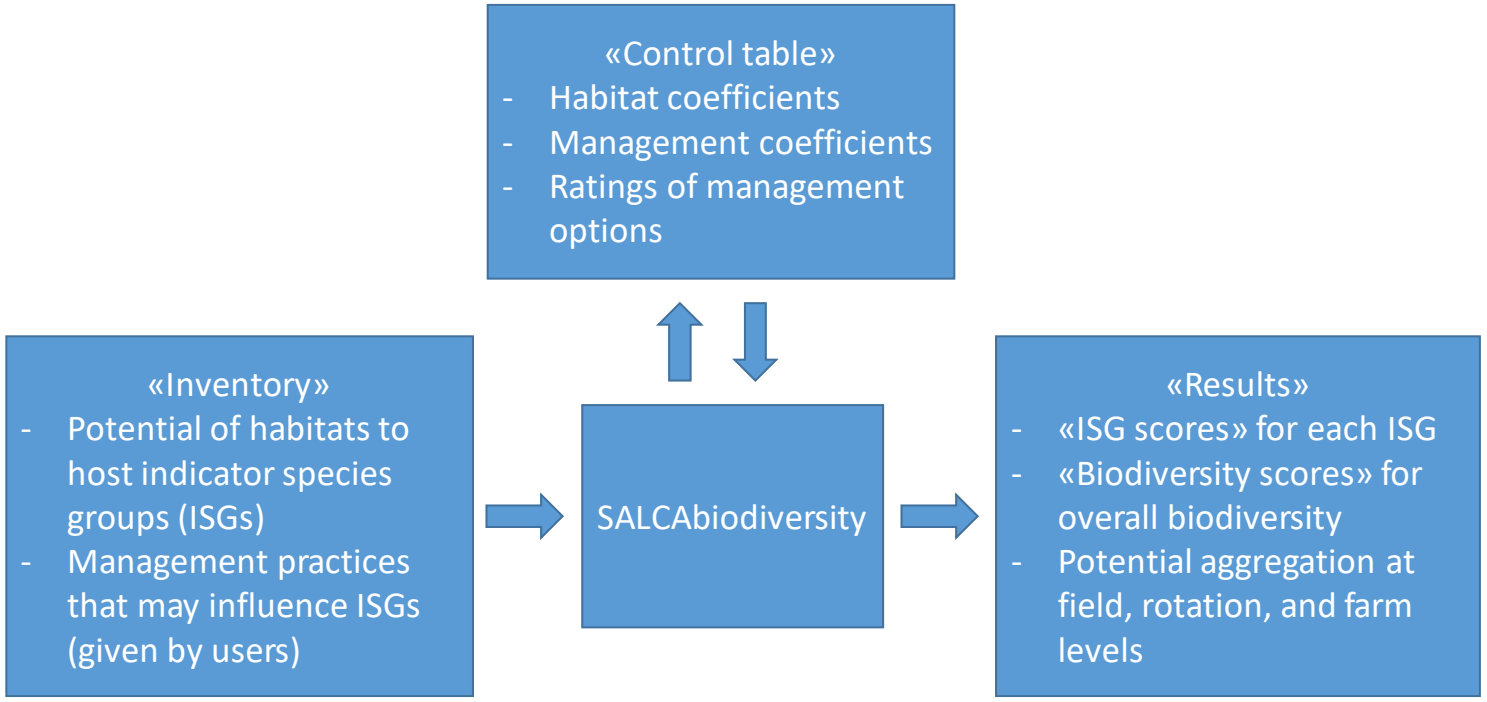


Figure 1: Example of impact assessment of a slurry application

SALCAbiodiversity: impacts of agricultural management on species richness

Indicator species groups:

- grassland and crop flora
- birds
- small mammals
- amphibians
- snails
- spiders
- carabid beetles
- butterflies
- wild bees
- grasshoppers

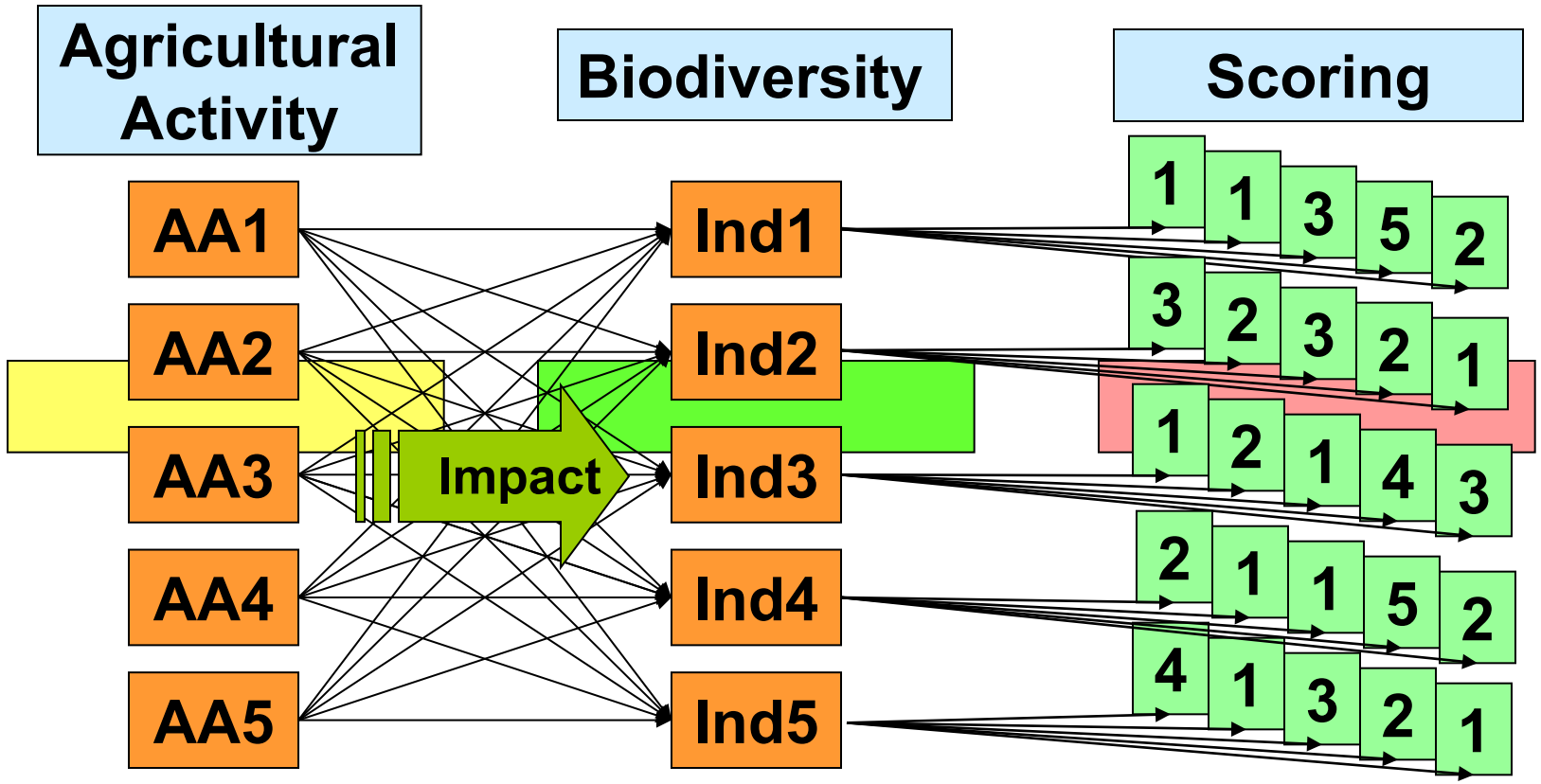


Indicators:

- overall species diversity within the 11 groups
- ecologically demanding species for amphibians, snails, spiders, carabid beetles, butterflies and grasshoppers
- Total biodiversity score

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SALCAbiodiversity



Source: Jeanneret *et al*. 2006

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Data collection: Approaches to analyse farming systems

	1) Long-term experiments	2) Pilot farm networks	3) Modelled Systems
Data sources	One ☺	One ☺	Many ☹
Representativeness	Low ☹	High (if sample large enough) ☺	High ☺
Variability	Low-medium	High	Low-medium
Need for assumptions	Medium 😐	Low ☺	High ☹
Costs of LCA study	Medium 😐	High ☹	Low ☺

The 3 approaches are complementary and contribute to a comprehensive analysis

Productivity, intensity and efficiency

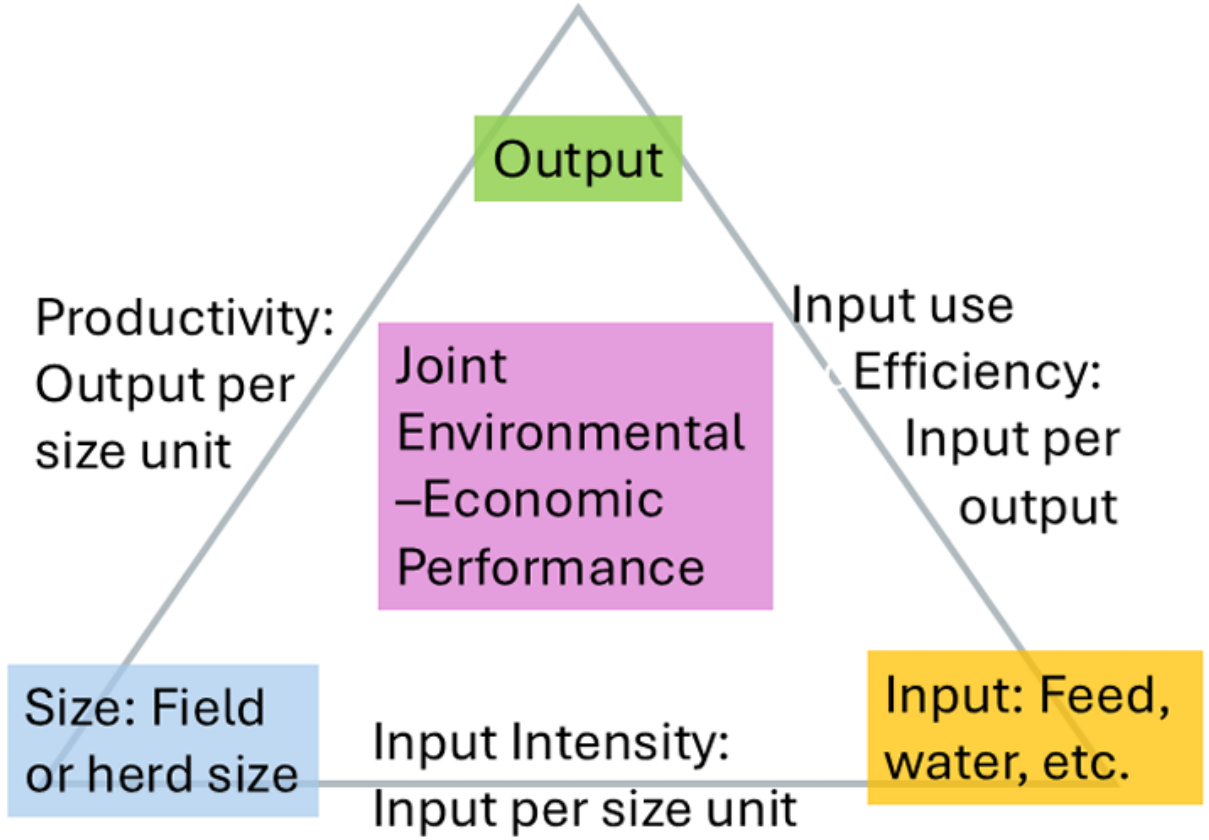
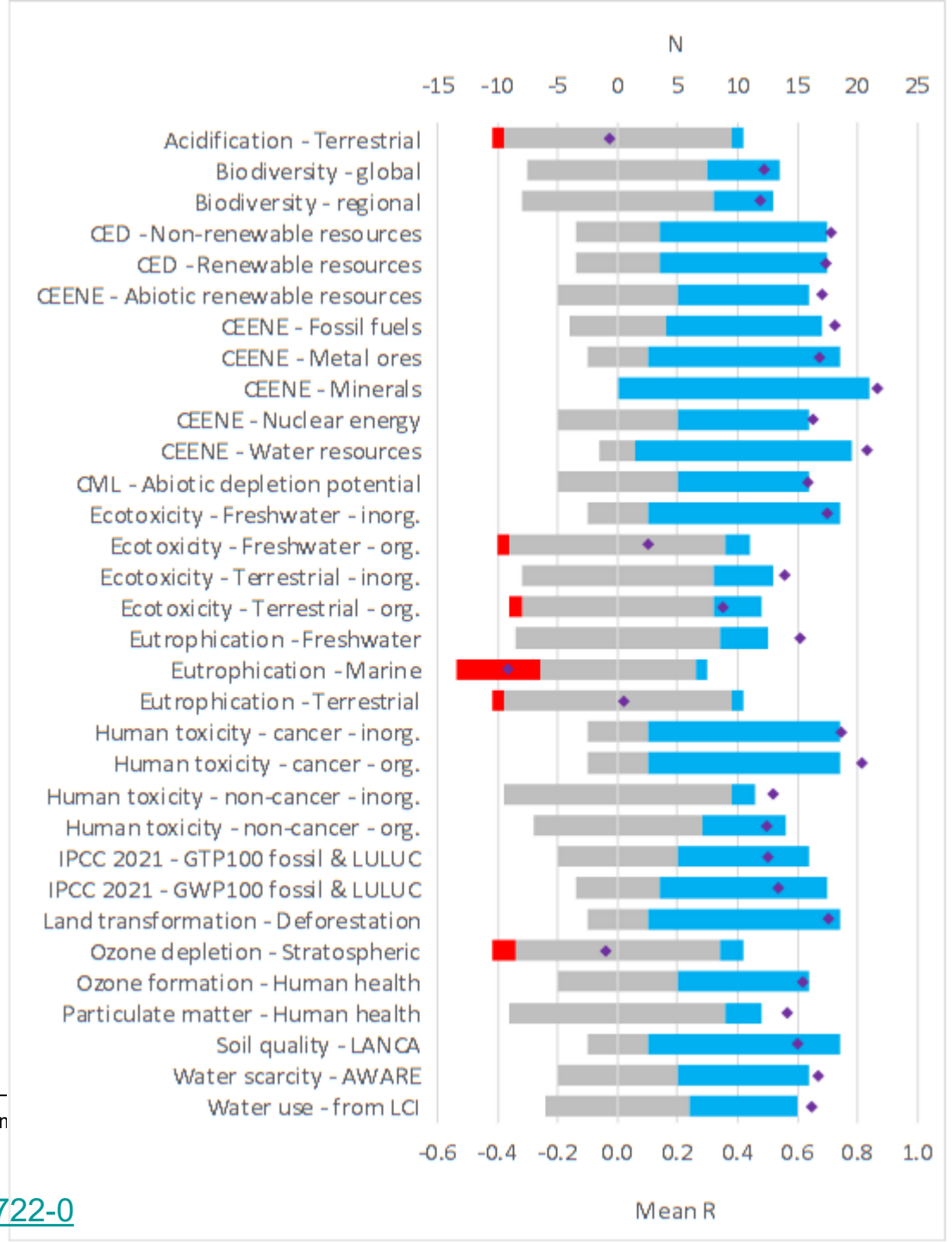


Figure 19: Schematic depiction of the relationship between input use efficiency, input intensity and productivity.

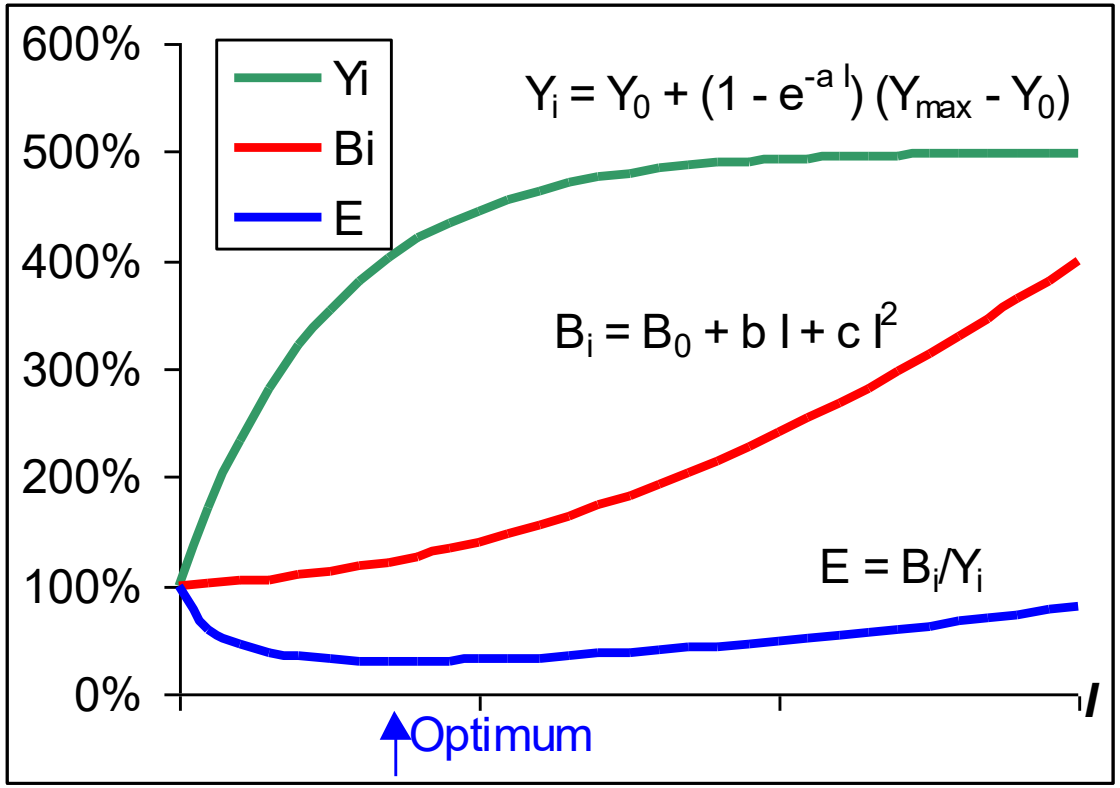
Pedolin *et al*. (under review) Clean. Circ. Bioeconomy

Correlations between agricultural land occupation and environmental impacts
→ Higher yields lead to lower impacts



Roesch et al. (2026) https://doi.org/10.1007/s11367-026-02722-0

Eco-efficiency analysis: Where is the optimal intensity?



I = input or intensity

Yi = yield function

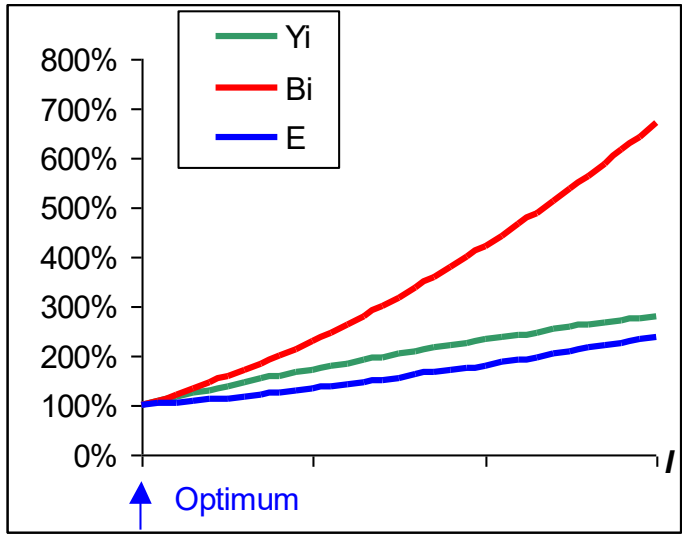
Bi = environmental impact function

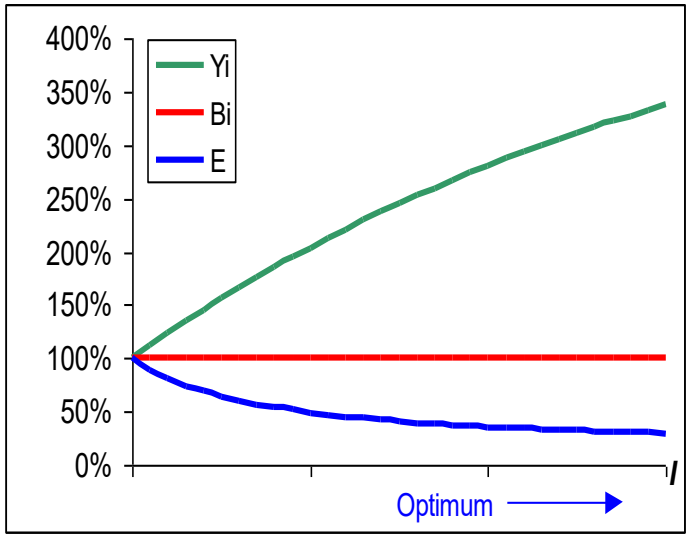
E = eco-efficiency function (low values are favourable)

Nemecek *et al*. (2005) FAL Schriftenreihe 58.

Where is the optimal intensity?

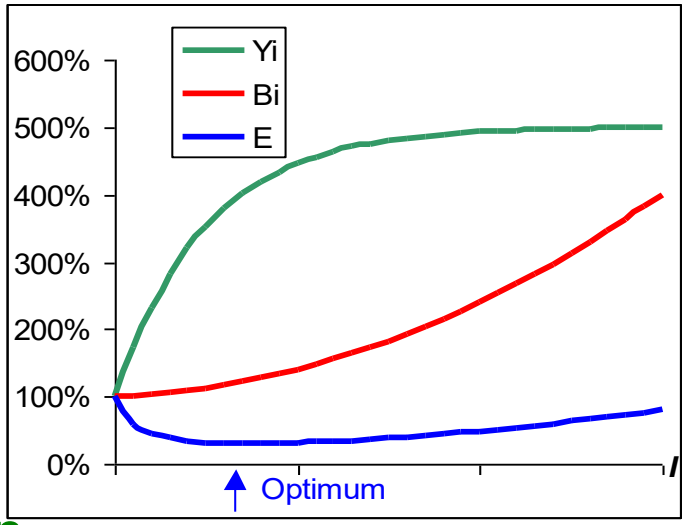
Increasing

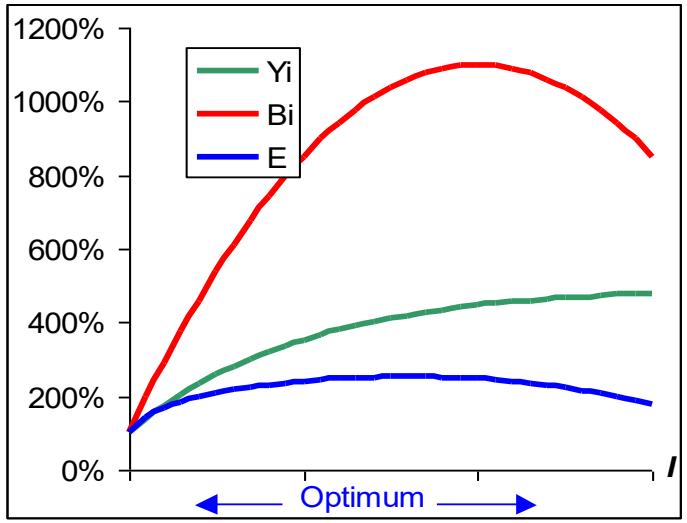




Decreasing

Convex





Concave

I = input or intensity

Yi = yield function

Bi = environmental impact function

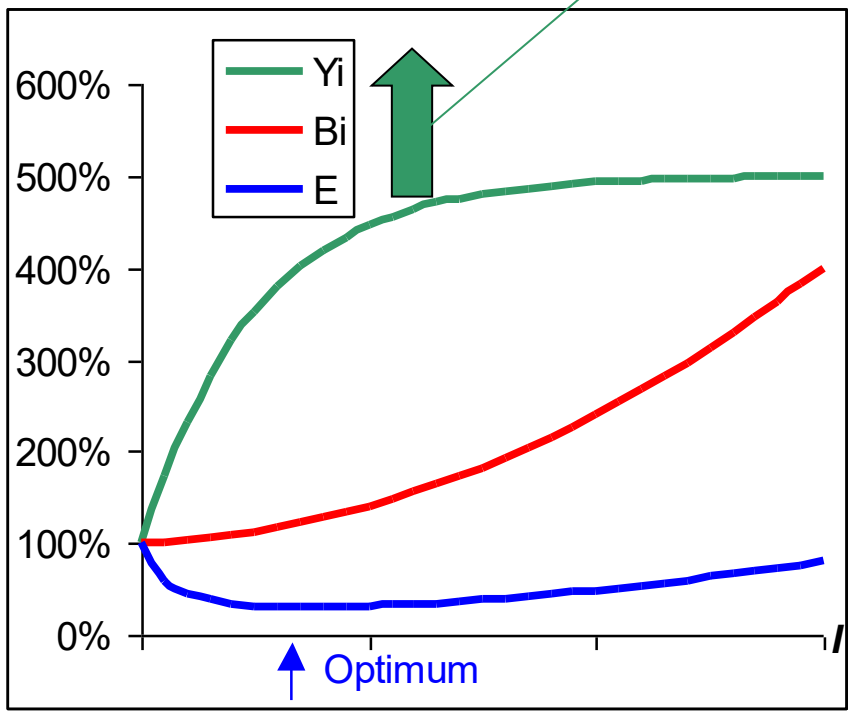
E = eco-efficiency function (low values are favourable)

Nemecek *et al*. (2005) FAL Schriftenreihe 58.

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Consequences for eco-efficiency

organic farming / low-input systems
→ optimisation **output**-oriented



intensify

extensify

conventional / high-input systems
→ optimisation **input**-oriented

Nemecek *et al*. (2005) FAL Schriftenreihe 58.

Some limitations of LCA of agricultural systems possible solutions

- Not able to cover all environmental impacts
  → Needs comprehensive methods
- Not able to discriminate between systems
  → Needs specific methods (for the foreground system)
- Product LCA is unable to reflect the whole system
  → Extend the system boundaries → Use system LCA
- Ecosystem services not covered
  → Combine with ecosystem service assessment

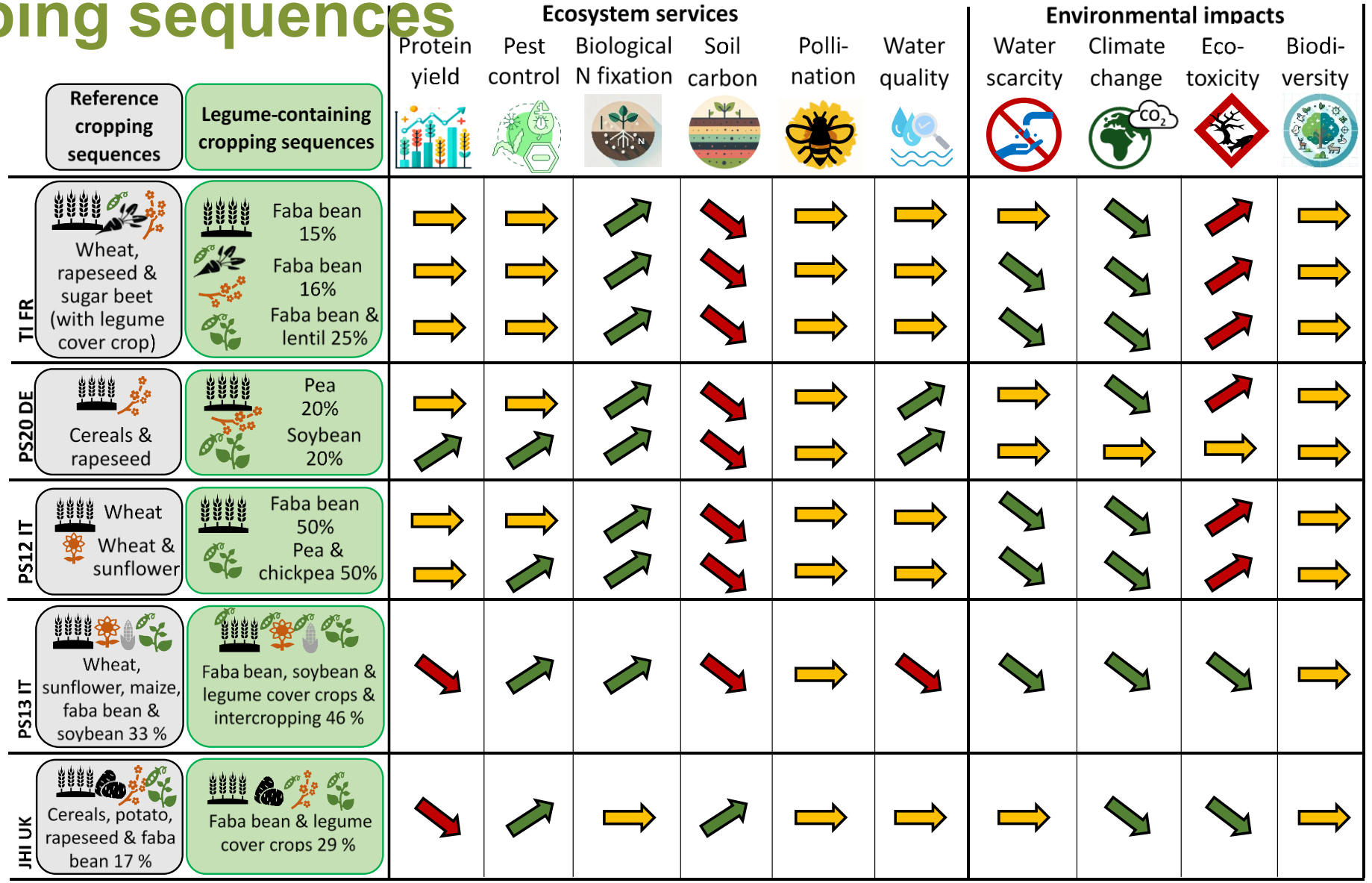
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Combining LCA with ecosystem service assessment

	Class	Method to be used
Provisioning	1.1.1.1 Cultivated terrestrial plants grown for nutritional purposes	Yield measurement: kg DM yield, kg protein yield
	1.1.1.2 Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)	Not relevant for the current pilot studies
	1.1.1.3 Cultivated plants (including fungi, algae) grown as a source of energy	Not relevant for the current pilot studies
Regulation & Maintenance	2.2.1.1 Control of water erosion rates	Erosion (C-factor) based on RUSLE (Lago-Olveira et al. 2023)
	2.2.2.1 Regulation runoff and base flows	LANCA Infiltration reduction potential, $m^3/(m^2*a)$ (Bos et al. 2016)
	2.3.2.1 Pollination	Land use impact on pollinator abundance (Alejandre et al. 2023)
	2.3.2.4 Maintaining or regulating refuge habitats	SALCA-BD: habitat value (Jeanneret et al. 2014)
	2.3.2.5 Maintaining or regulating feeding grounds	SALCA-BD: habitat value (Jeanneret et al. 2014)
	2.3.3.1 Pest control (including invasive species)	SALCA-BD: Spiders, Carabids (Jeanneret et al. 2014)
	2.3.4.2 Decomposition and fixing processes and their effect on soil quality	BNF equation (Korsaeth & Eltun 2000), DNDC (UniPG)
	2.3.4.3 Maintenance of soil structure by biological agents and ecological processes	SALCA-SQ macropore volume (Oberholzer et al. 2012)
	2.3.5.1 Regulation of the chemical condition of freshwaters by living processes	P and N leaching assessed using SALCAnitrate and SALCAfieldP models
	2.3.6.1 Regulation of chemical composition of atmosphere and oceans, including maintaining rainfall patterns through evapotranspiration at the sub-continental scale	Soil humus balance according to SALCA-SQ soil carbon content calculation (Oberholzer et al. 2012)

Joensuu *et al*. (unpublished)

Effect on key ES and EI indicators of adding legumes to the cropping sequences



Joensuu *et al.* (unpublished)

Ecosystem services

= Difference compared to the reference more than -10%

= Difference compared to the reference more than +10%

Environmental Impacts

= Difference compared to the reference more than +10%

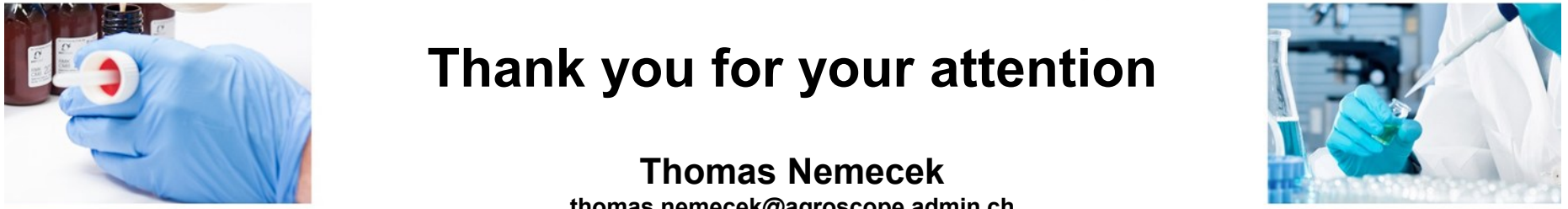
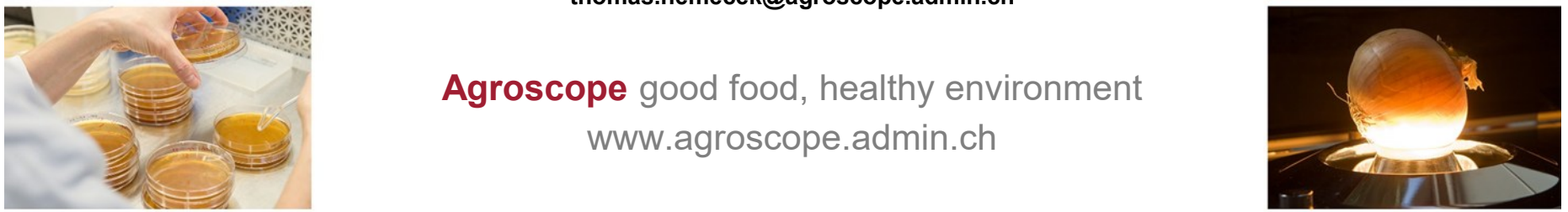
= Difference compared to the reference more than -10%

Some take-aways

- Variability of environmental impacts is high
- Organic/low-input production has lower impacts per area, but this advantage is partly undermined by lower yields
- Comparison of farming systems are best done at system level (cropping system, farm, food system)
- Referring environmental impacts to the product is a shift in paradigm (choice of functional unit)
- Is LCA suited for the assessment of non-conventional and agro-ecological systems? Yes, but it needs
  - A comprehensive assessment
  - Specific methods
  - Extension with ecosystem services assessment

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Thank you for your attention

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