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Applications of LCA and methodological challenges in ***Czech agri-food systems***

Jaroslav Bernas

LABORATORY of LIFE CYCLE ASSESSMENT

LCA studies can serve as a tool for **reducing the environmental impact** of companies, as motivational aspects in communication with the customer, as motivational tools for environmental policy (e.g., agriculture), for increasing competitiveness, or for development and research.

With the help of LCA, it is possible to compare the environmental impacts of products with regard to their function or evaluate the environmental impacts with respect to the entire product life cycle.

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IGB
Leibniz Institute of Freshwater Ecology and Inland Fisheries

UNIVERSITY OF AGRICULTURE IN KRAKOW

INRAE

UNIVERSITÄT BAYREUTH

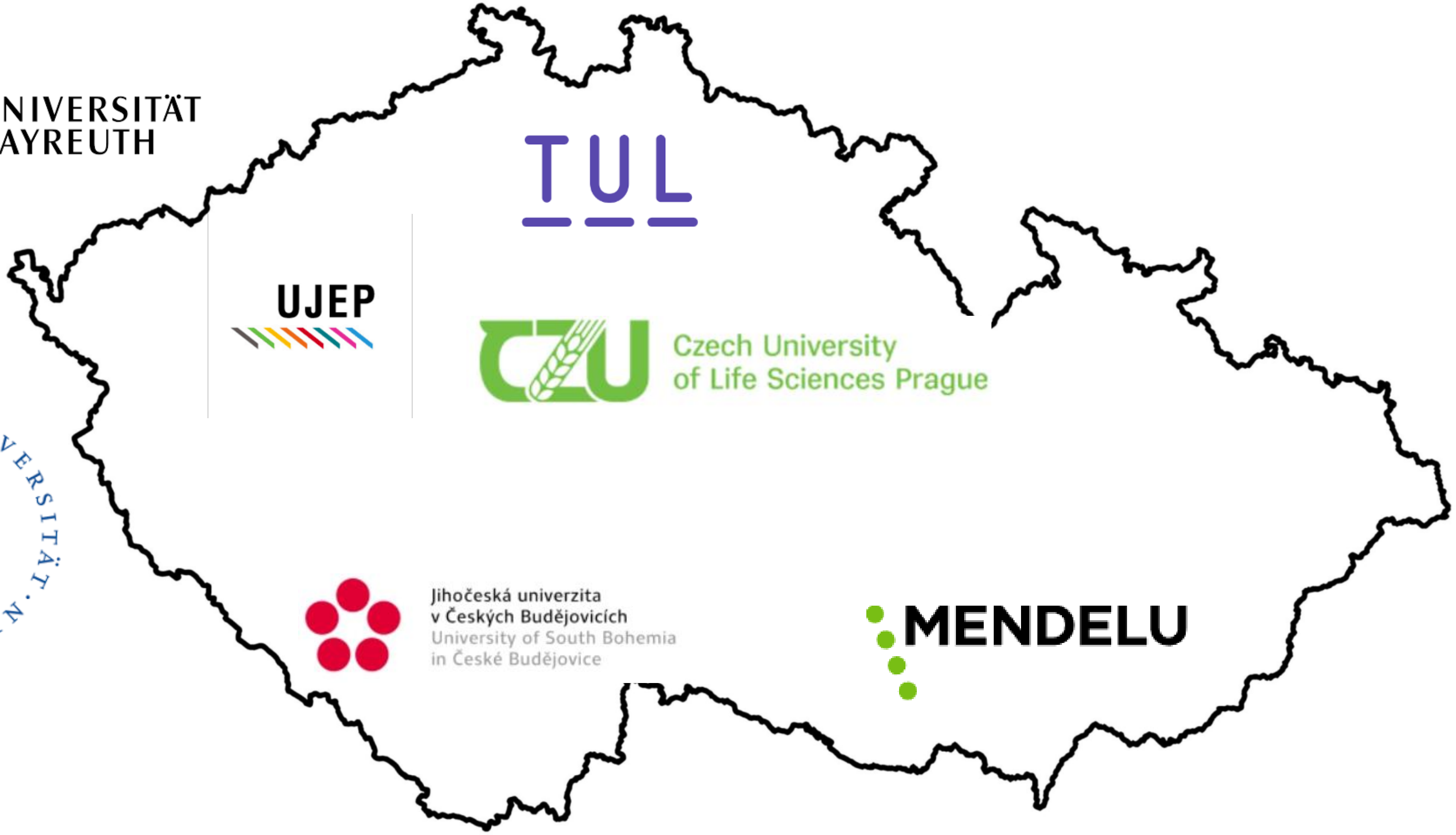
BİLECİK ŞEYH EDEBALİ UNIVERSITY

UND
UNIVERSITY OF NORTH DAKOTA

1967
TRƯỜNG ĐẠI HỌC NÔNG LÂM HUẾ

UF
UNIVERSITY of FLORIDA

HUMBOLDT-UNIVERSITÄT ZU BERLIN



BİLECİK ŞEYH EDEBALİ ÜNİVERSİTESİ

Agroscope

UNIVERSITAT DE BARCELONA

BOKU UNIVERSITY

Universität für Weiterbildung Krems
DONAU UNIVERSITÄT KREMS

ISPARTA UNIVERSITY OF APPLIED SCIENCES

Laboratory options

- **LCA study**: Development of an LCA study when determining the goal and scope of the study, inventory of related data, assessment of environmental impacts, and interpretation of results in accordance with ISO 14040 and 14044.
- **Water footprint**: Calculation ofthe water footprint according to ISO 14046.
- **Carbon footprint**: Quantification of the carbon footprint of the product according to ISO 14067 and the carbon footprint of the organization according to ISO 14064.
- **Ecodesign**: Evaluation of sustainability and environmental design based on the LCA study and requirements of ISO 14045.
- **Critical review** for Lice Cycle Assessment (LCA) in accordance with ISO 14071.

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BACKGROUND

Department of Agroecosystems

University of South Bohemia in České Budějovice

Laboratory of LCA

Faculties

- Faculty of Economics
- Faculty of Arts
- Faculty of Education
- Faculty of Science
- Faculty of Fisheries & Protection of Waters
- Faculty of Theology
- Faculty of Health and Social Sciences
- Faculty of Agriculture and Technology

Content

- **Examples of LCA application**
  - **Cup plant (Perennial cropping)**
  - **Circular feed in aquaponics and carp ponds**
  - **Starch potatoes with nutrient recovery from process water**
  - **Indoor hemp production**
  - **Optimisation of nitrogen fertilisation in wheat systems under Pannonian conditions**
  - **Paddy rice**
  - **Environmental footprint of pet animals**
  - **…**

- From Cradle to Farm gate

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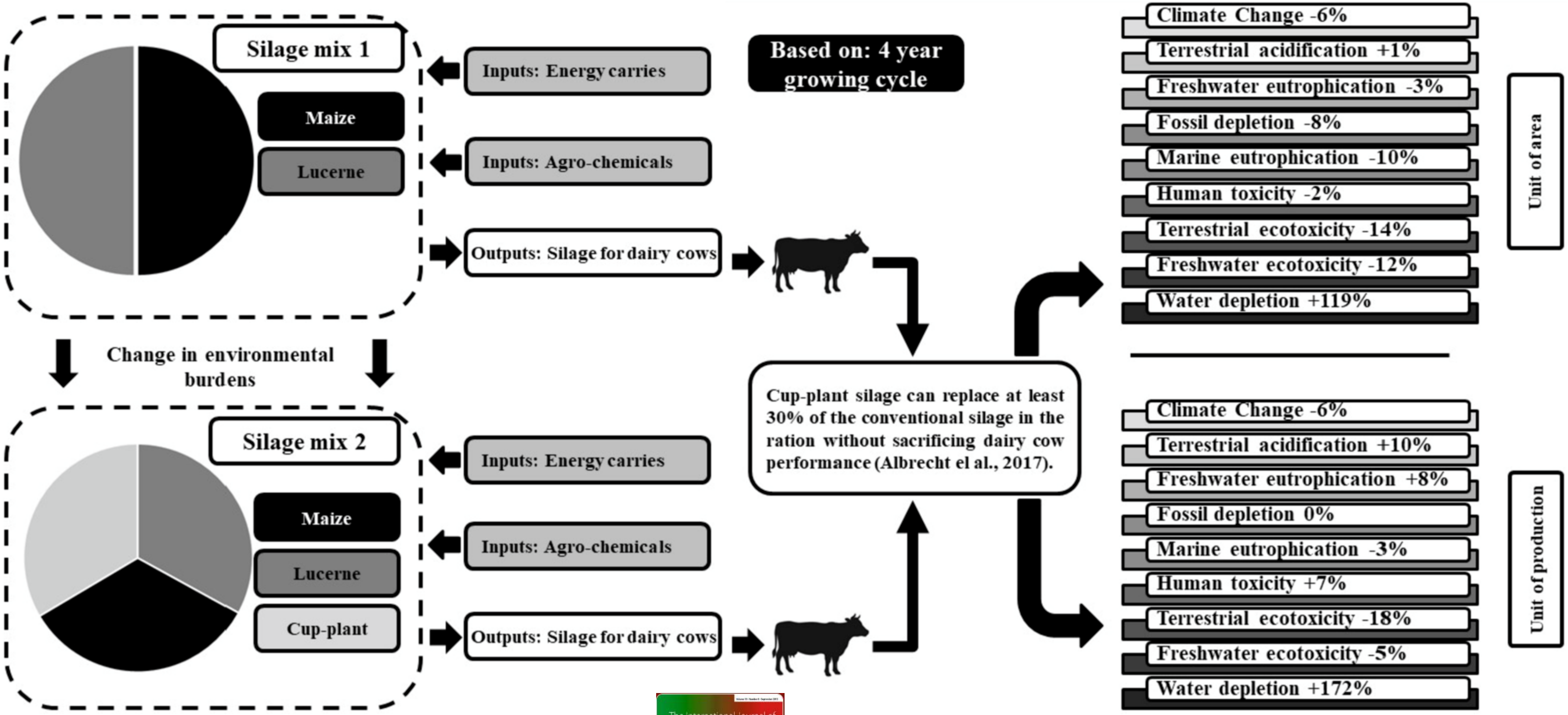
CUP PLANT
Cleaner production of biomass for silage



Bernas, J., Bernasová, T., Gerstberger, P., Moudrý, J., Konvalina, P., & Moudrý Jr, J. (2021). Cup plant, an alternative to conventional silage from a LCA perspective. The International Journal of Life Cycle Assessment, 26(2), 311-326.

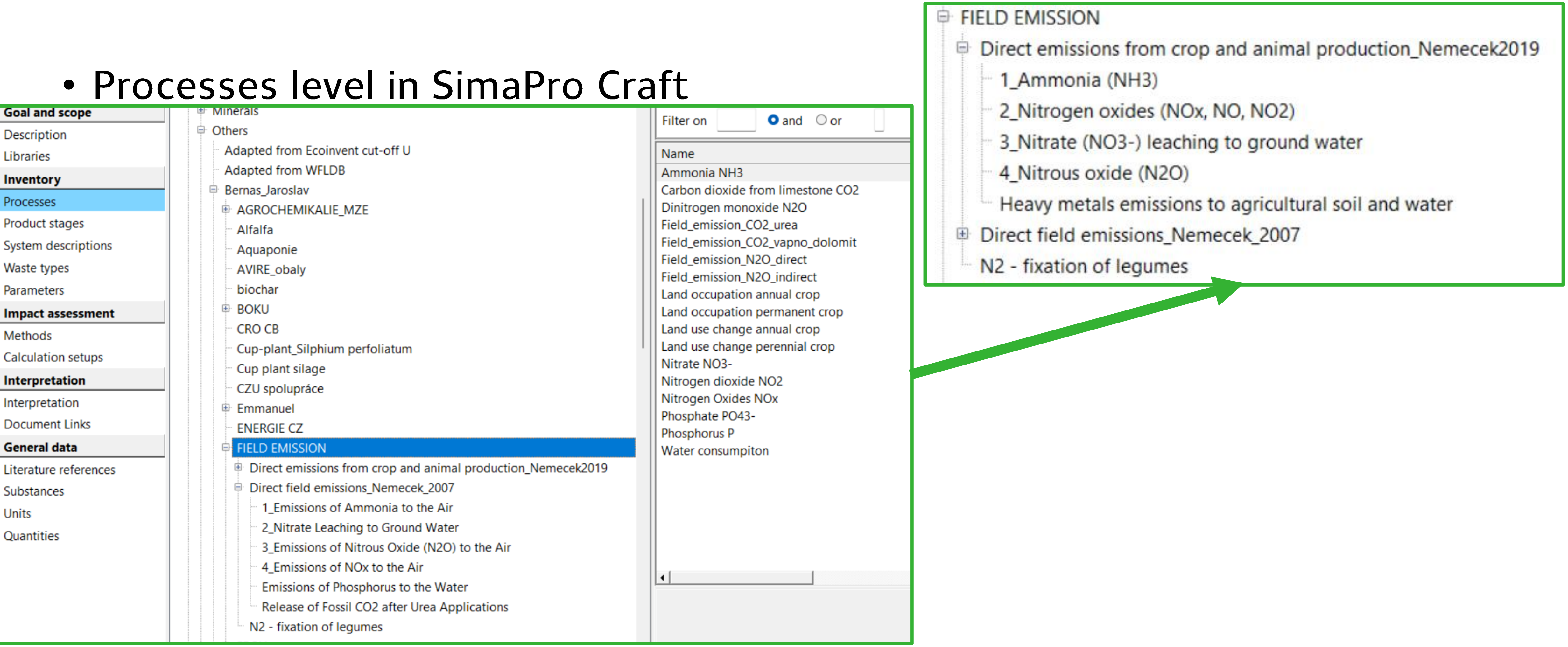
CUP PLANT
Cleaner production of biomass for silage

- Perennial cropping system – how?
- Yield level (10 years of cultivation)
- Heavy metals (input x output) – farm level (SALCA)
- Field emission and perennial cropping system
- Manure via WFLDB
- SimaPro Craft – calculators based on WFLDB
- Database combination
- Sequestration in SimaPro

Alternative for silage maize

Inventory is stopped at storage. Spreading impacts are allocated to the user of the manure.
Emissions of CH4, N2O (direct and indirect) and NH3 to air. Emission of nitrate to groundwater.

- Processes level in SimaPro Craft



Documentation | Input/output | **Parameters** | System description

Input parameter	Value	Distribu	SD2 or 2SD	Min	Max	Hide	Comment
P	0	Undef...				☐	P = precipitation + irrigation [mm/year]
c	20	Undef...				☐	c = clay content [%]
L	1.2	Undef...				☐	L = rooting depth [m]
S	0	Undef...				☐	S = nitrogen supply through fertiliser [kg N/h
U	0	Undef...				☐	U = nitrogen uptake by crop [kg N/ha]
Corg	1.5	Undefined				☐	Corg (%) More specific values can be used, where avail converted into mass fraction by the formula: Corg [%] = Corg [t/3000 m3] * (1 / 1.3 t m-3) Carbon content [t C/ha in upper 30cm= t/300 Cool temperate dry: 38 t C/ha
V	3000	Undefined				☐	soil volume V [m3/ha] V is taken to be 5000 m3 , which means that t assuming the same carbon content for 30-50
Db	1300	Undefined				☐	bulk density Db [kg/m3] Bulk density is taken to be 1300 kg/m3, which
CN	11	Undefined				☐	C/N ratio rC/N [dimensionless] The C/N ratio literature research (Batjes 2008; Scheffer 2002; Eggleston et al. 2006) and consultation of experts (pers. comm. J. Leitfeld, Agroscope).
Rnorg	0.85	Undefined				☐	ratio of Norg to Ntot (total soil nitrogen) rNorg [dimensionless] The C/N ratio expresses the ratio of Corg and Ntot. The ratio rNorg is needed calculate Norg from Ntot, which is calculated in a first step applying the C/N ratio. rNorg is assumed to be 0.85 (Scheffer 2002).
Norg	4520	Undefined				☐	zadat udaj z NorgEquation Celkový obsah dusíku (Nt) v orniční vrstvě půd České republiky se pohybuje většinou v rozmezí hodnot 0,1-0,2 %, může však kolísat ve značném rozmezí (0,03% - 0,5 %). Lze vypočítat, že v orniční vrstvě je asi 3000 - 9000 kg N/ha.

Add line

Calculated parameter	Expression	Comment
N	(21.37)+(P/(c*L))*((0.0037*S)+(0.0000601	N = leached NO3-N [kg N/(ha*year)]
NorgEquation	(Corg/100*V*Db)/CN*Rnorg = 4.52E3	Norg = nitrogen in organic matter [kg N/ha]
NO3	N*4.4268 = 94.6	How to convert between NO3 and NO3-N: To convert Nitrate (NO3) to Nitrate-Nitrogen (NO3-N), multiply by 0.2259. To convert Nitrate-nitrogen (NO3-N) to Nitrate (NO3), multiply by 4.4268.

Add line

WFLDB

3.9.7.2 *The SQCB-NO_3 model*

Geographic scope of application: Non-European countries.

The SQCB-NO_3 model is reported in Faist Emmenegger *et al.* (2009) and is an adaption of a formula developed by de Willigen (2000) and used and validated by Roy *et al.* (2003). The formula calculates the leaching of NO_3-N and is a simple regression model of the form:

$$N = 21.37 + \frac{P}{c * L}\left[0.0037 * S + 0.0000601 * N_{org} - 0.00362 * U\right]$$

where:

N	= leached NO_3-N	[kg N/(ha*year)]
P	= precipitation + irrigation	[mm/year]
c	= clay content	[%]
L	= rooting depth	[m]
S	= nitrogen supply through fertiliser	[kg N/ha]
N_{org}	= nitrogen in organic matter	[kg N/ha]
U	= nitrogen uptake by crop	[kg N/ha]

[14] Since the model is applied only to Europe, the Southern hemisphere does not need to be considered.

Manure management at farm, cattle, solid storage, cool, per kg DM (WFLDB)/GLO U
Manure management at farm, cattle, solid storage, temperate, per kg DM (WFLDB)/GLO U
Manure management at farm, cattle, solid storage, warm, per kg DM (WFLDB)/GLO U

Emissions calculated based on dry matter content (assumed equal to volatile solids, VS, by simplification), based on IPCC 2006, FAO 2010 and EMEP/EEA 2014.
Cool: Temperature below 15 °C
Temperate: Between 15 and 25°C
Warm: Above 25°C

Manure collected at farm has an N content of 0.045 kg N /kg DM manure. Average between lactating cows and other animals (max 0.051, min 0.036, according to ASAE 2005 and Nennich 2005)
Default DM content: 12% in liquid manure
Inventory is stopped at storage. Spreading impacts are allocated to the user of the manure.
Emissions of CH_4, N_2O (direct and indirect) and NH_3 to air. Emission of nitrate to groundwater.

Data Quality Rating (DQR): 2.3 (i.e. good quality)

American Society of Agricultural Engineers (ASAE) (2005) Manure production and characteristics. St Joseph, MI, USA.
Nennich TD, Harrison JH, VanWieringen LM, et al (2005) Prediction of manure and nutrient excretion from dairy cattle. J Dairy Sci 88:3721–33. doi: 10.3168/jds.S0022-0302(05)73058-7

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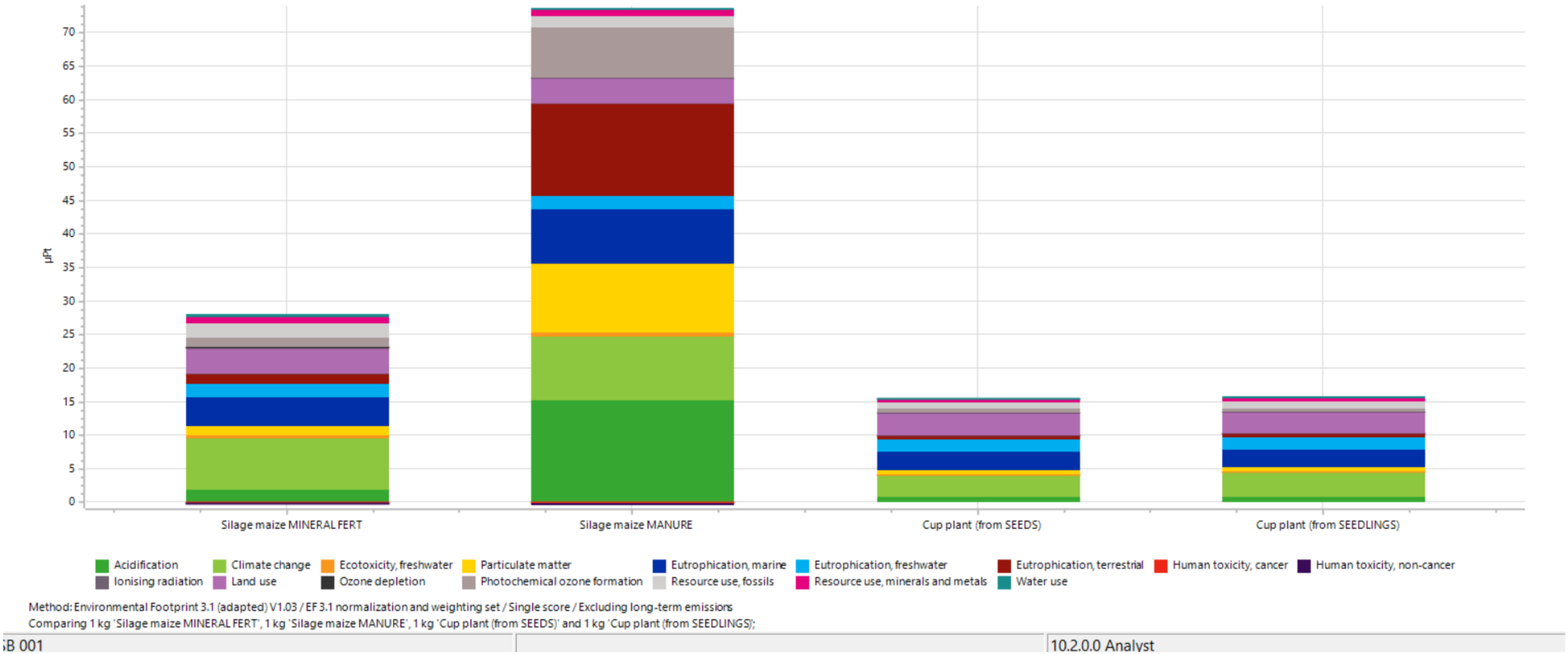
Cleaner production of biomass for silage



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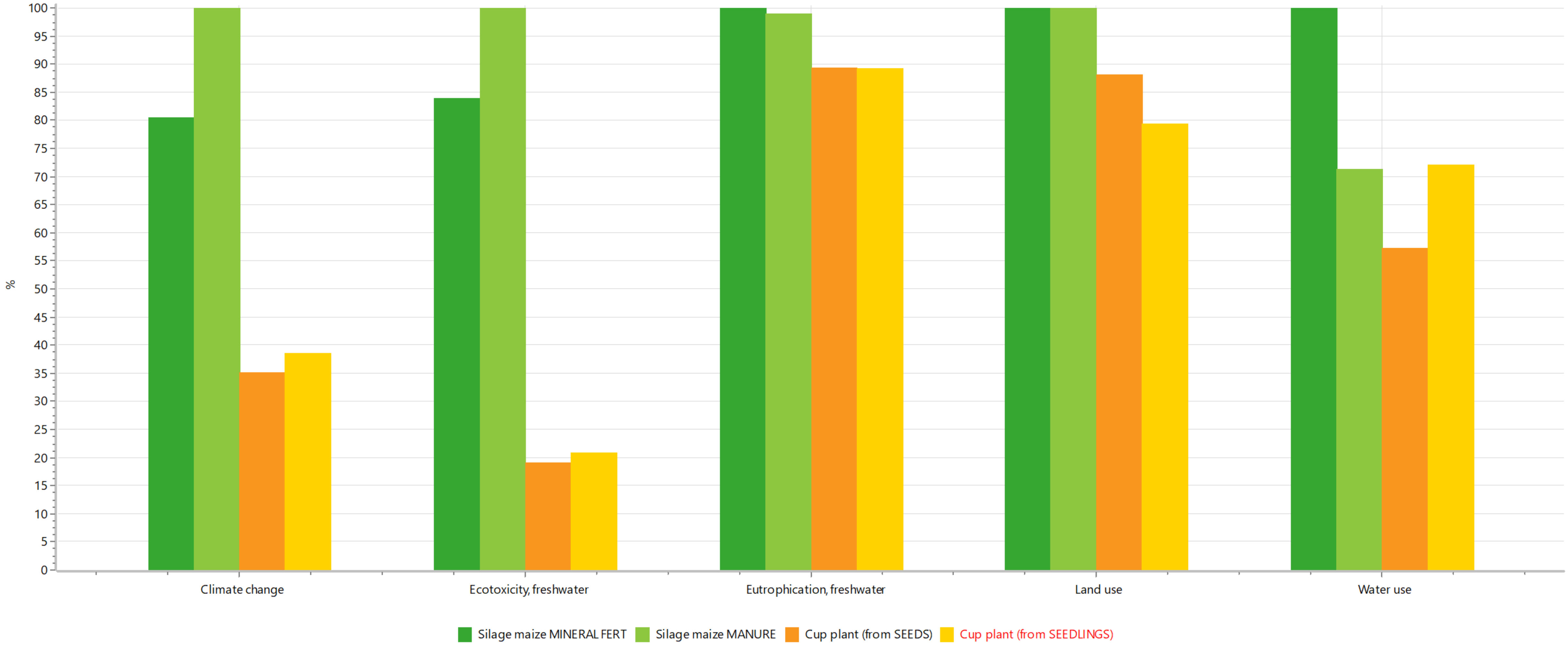

Method: Environmental Footprint 3.1 (adapted) V1.03 / EF 3.1 normalization and weighting set / Characterization / Excluding long-term emissions
Comparing 1 kg 'Silage maize MINERAL FERT', 1 kg 'Silage maize MANURE', 1 kg 'Cup plant (from SEEDS)' and 1 kg 'Cup plant (from SEEDLINGS)';

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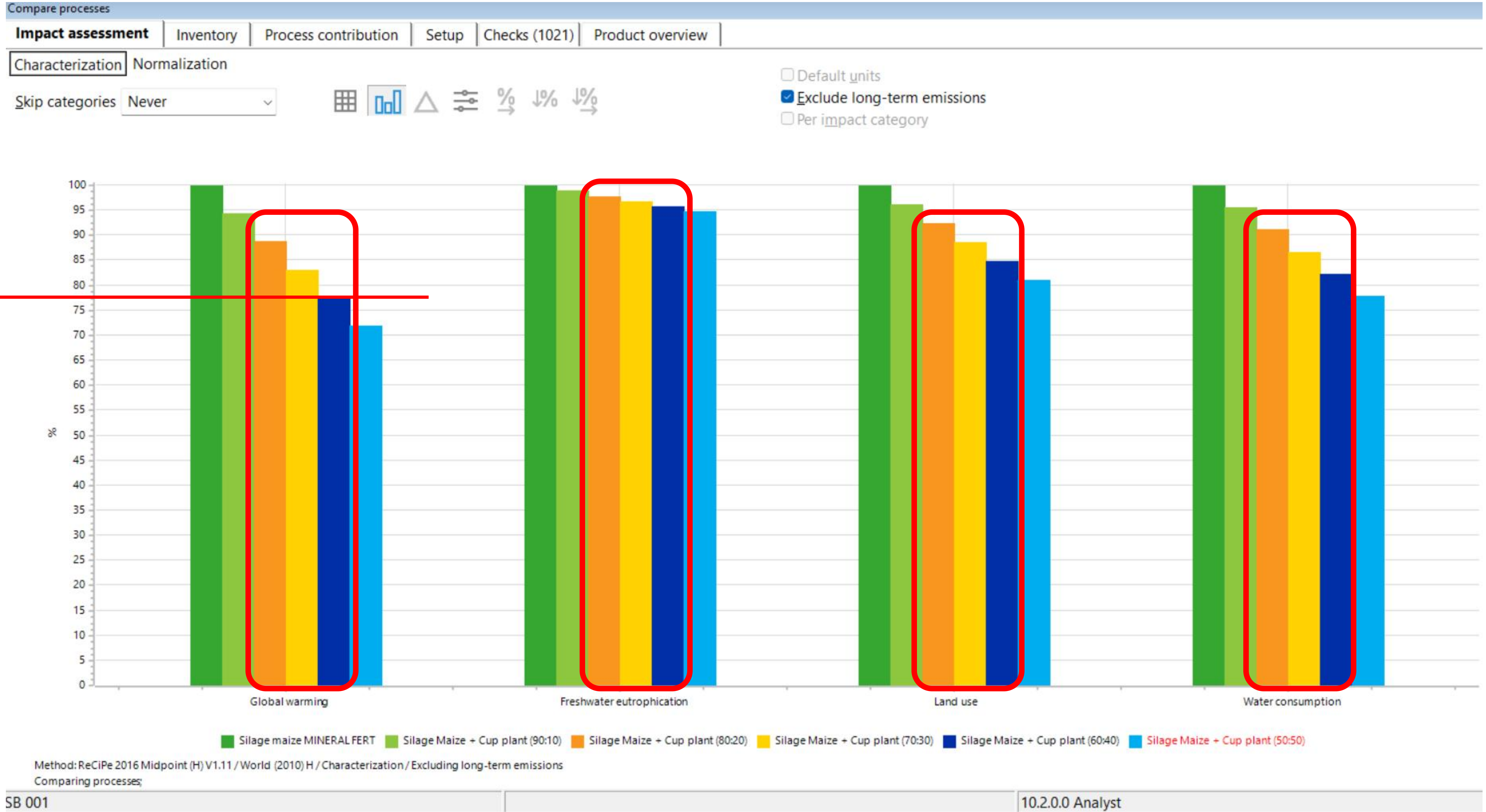

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Circular feed in aquaponics and carp ponds

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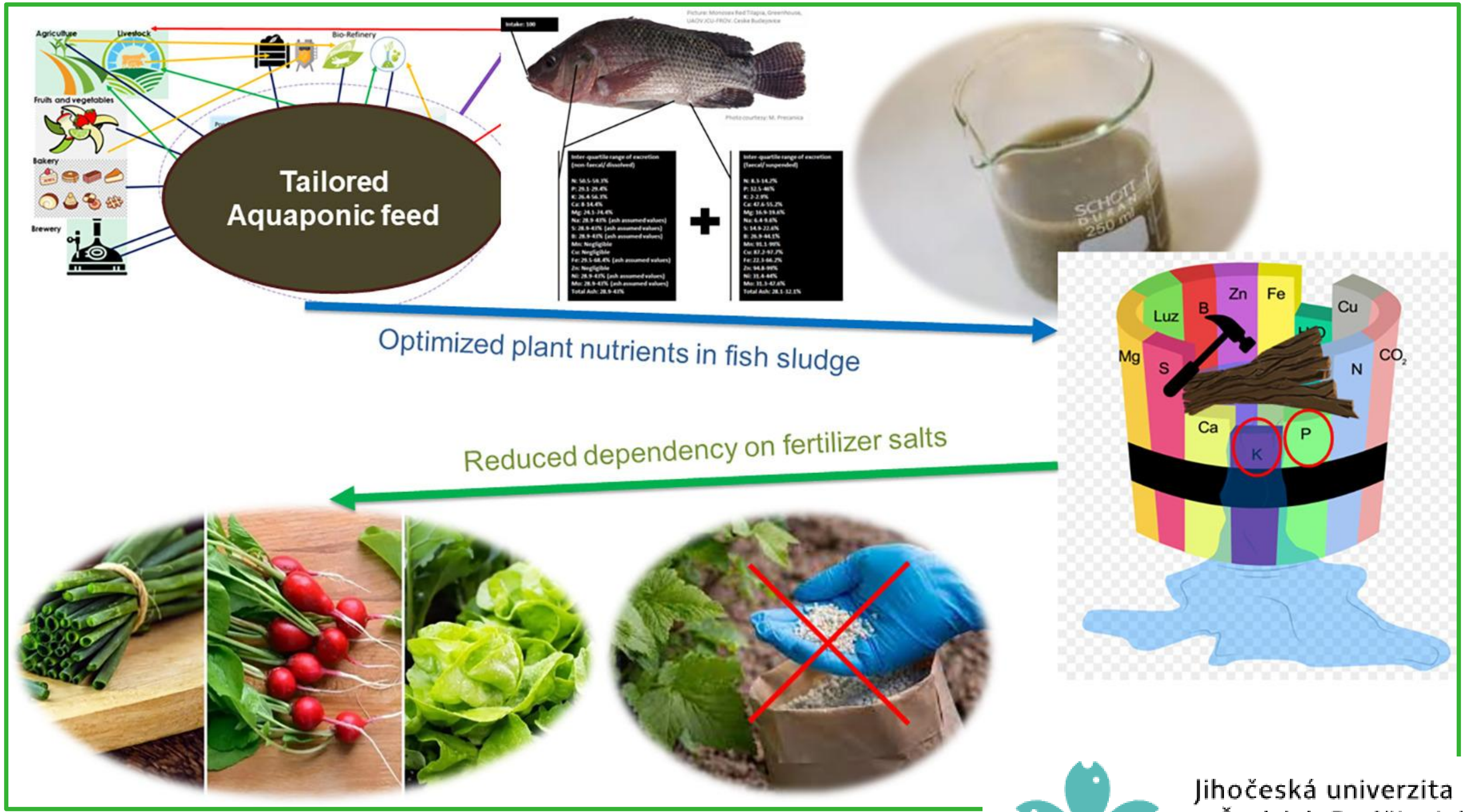
Fish feed for aquaponic systems

- **General idea**
  - By-products
  - Wasted food
  - Circularity
  - Plant nutrients
  - Meat quality
  - Water quality
  - …



Roy, K., Bernas, J., Gebauer, R., Tellbuscher, A. A., Nikl, O., Shaw, C., ... & Mraz, J. (2025). Environmental impact assessment of fish feed for aquaponic systems to introduce higher phosphorus and potassium in value-added fish sludge. Aquaculture, 599, 742142.

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Fish feed for aquaponic systems

The average prices of main and co-products or by-products were reflected used for economy allocation principle				
main products	market price of main products (czk/kg or czk/l)	co-products/by-products on food waste level	market price co-products/by-products on food waste level (czk/kg)	coefficients
rolls/bread/buns	115	breadcrumbs	6	0.052
sugar	20	sugar beet pomace	10	0.500
muesli	100	muesli	5	0.050
roasted coffee beans	700	coffee grounds	10	0.014
whiskey - Czech production	500	corn DDGS	31	0.062
czech beer	80	malt	8.5	0.106
rapeseed oil	36	rapeseed expeller	3.3	0.092
sunflower oil	45	sunflower expeller	7.5	0.167
fish meat	250	fish meal (freshwater)	35	0.140
chicken meat	200	feather meal	59	0.295
czech beer	80	yeast	76	0.950
chicken meat	200	chicken meat and bone meal	25	0.125

Circular feed in aquaponics and carp ponds

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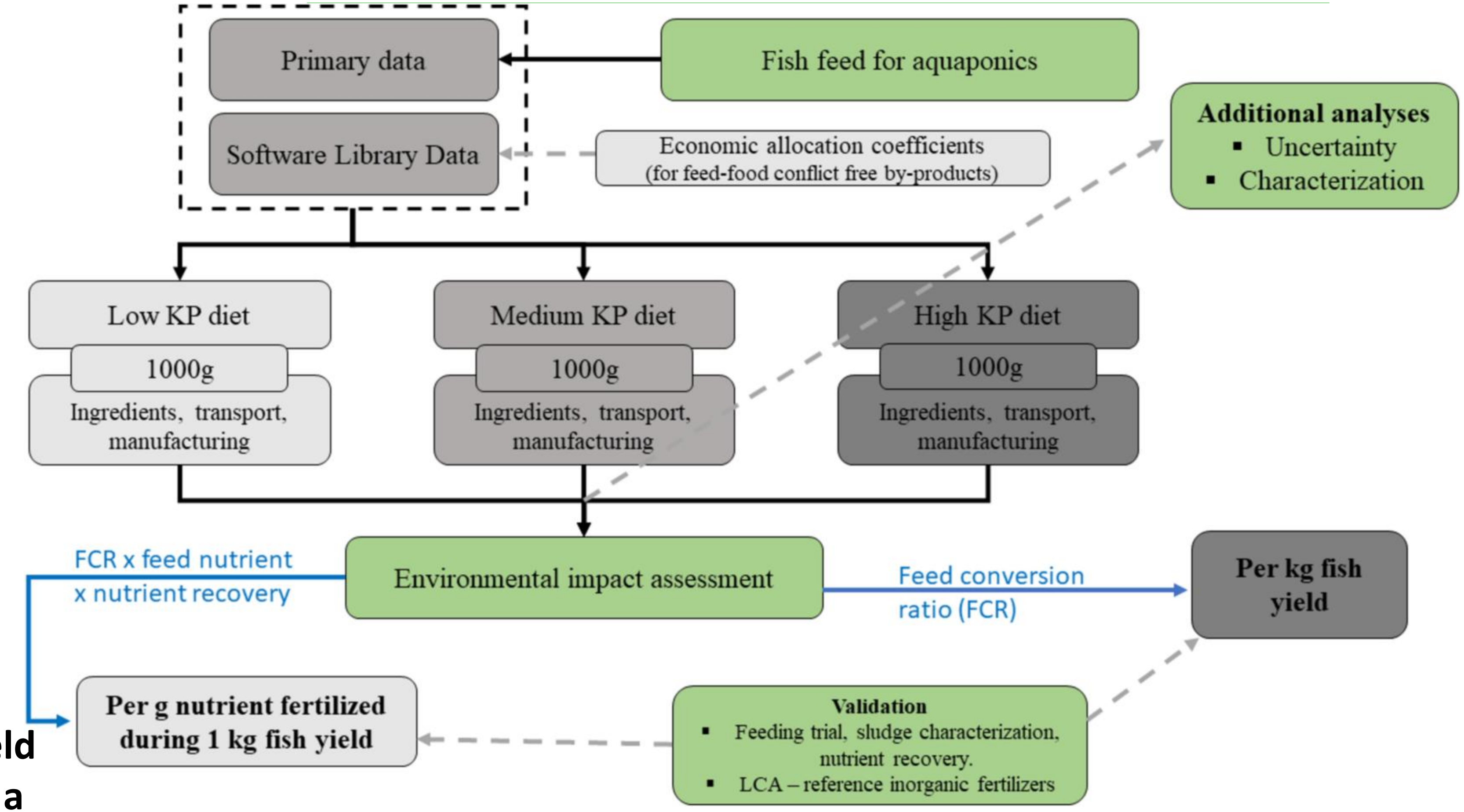
- Three similar protein (41 ± 2 %) and energy (342 ± 3 kcal 100 g^{-1}) feeds with graded P and K levels were validated in a **tilapia-based aquaponic facility** for 35 days, followed by a **life cycle impact assessment (LCIA)** per unit fish yield and plant nutrient fertilization during fish yield



On one hand, it did not reduce the environmental impact per unit fish yield (as more feed was needed to produce a unit fish yield), but greatly reduced the environmental impact of inorganic plant fertilization (as more nutrients were loaded per unit feeding).

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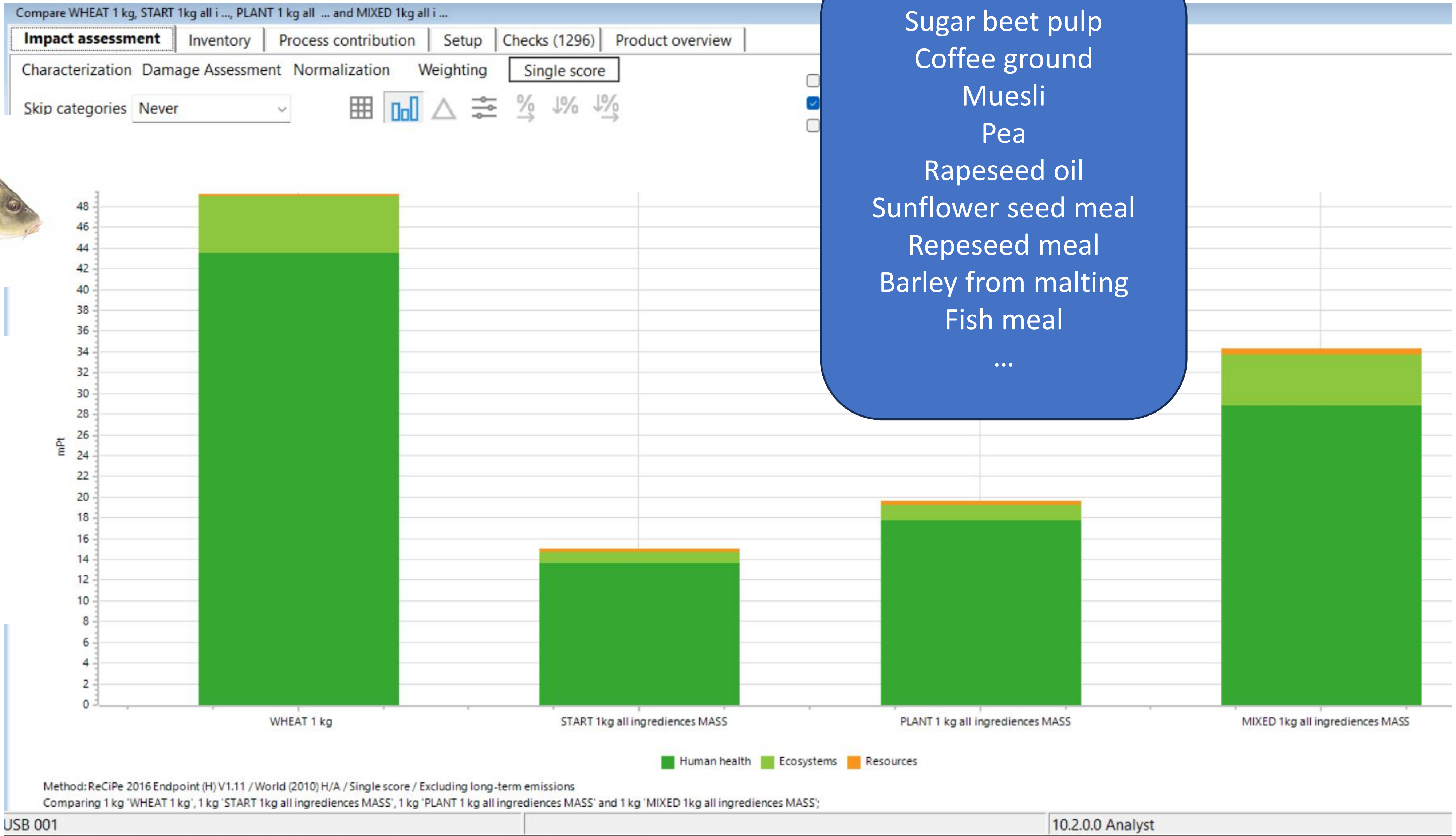
Carp ponds

Impact per kg of feed/pellet

Breadcrubms
Sugar beet pulp
Coffee ground
Muesli
Pea
Rapeseed oil
Sunflower seed meal
Repeseed meal
Barley from malting
Fish meal
...



Starch potatoes with nutrient recovery from process water

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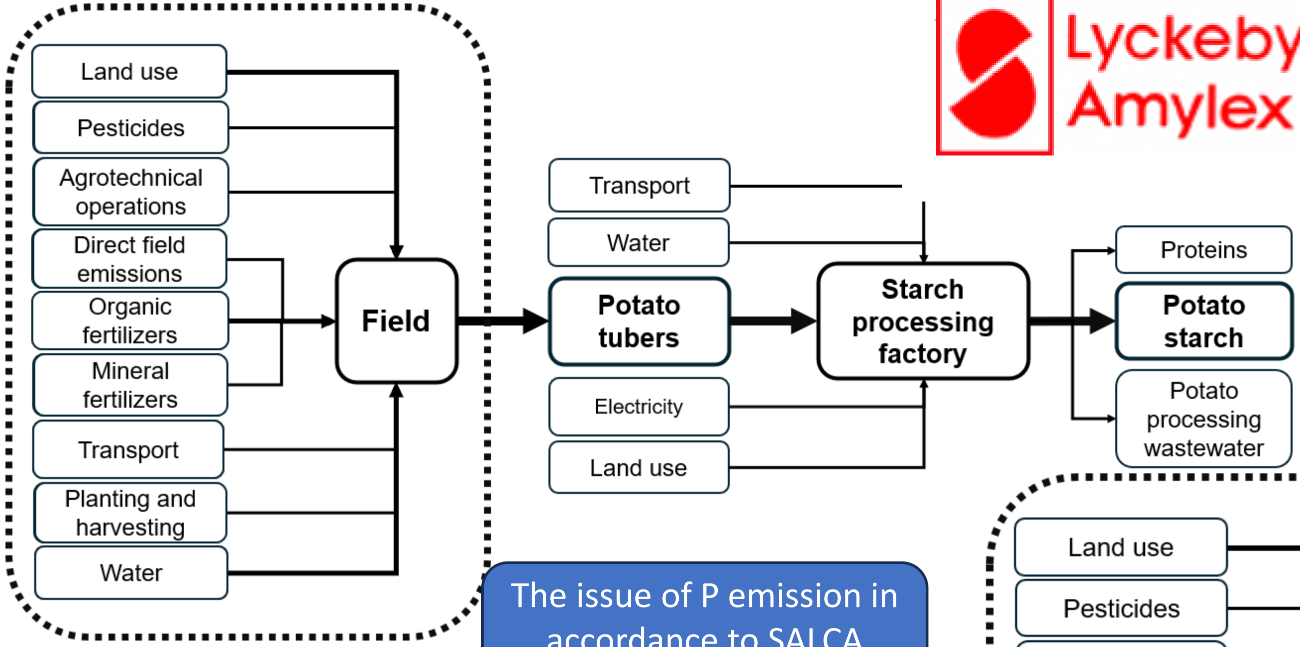
Lyckeby Amylex



Alternative to K fertilizer
+
Related volume of N and P fertilizer

The issue of P emission in accordance to SALCA model

3.9.8.2 Phosphate run-off to surface water

Run-off to surface water was calculated in a similar way to leaching to ground water:

P_{ro} = $P_{rol} * F_{ro}$

P_{ro} = quantity of P lost through run-off to rivers [kg/(ha*a)]

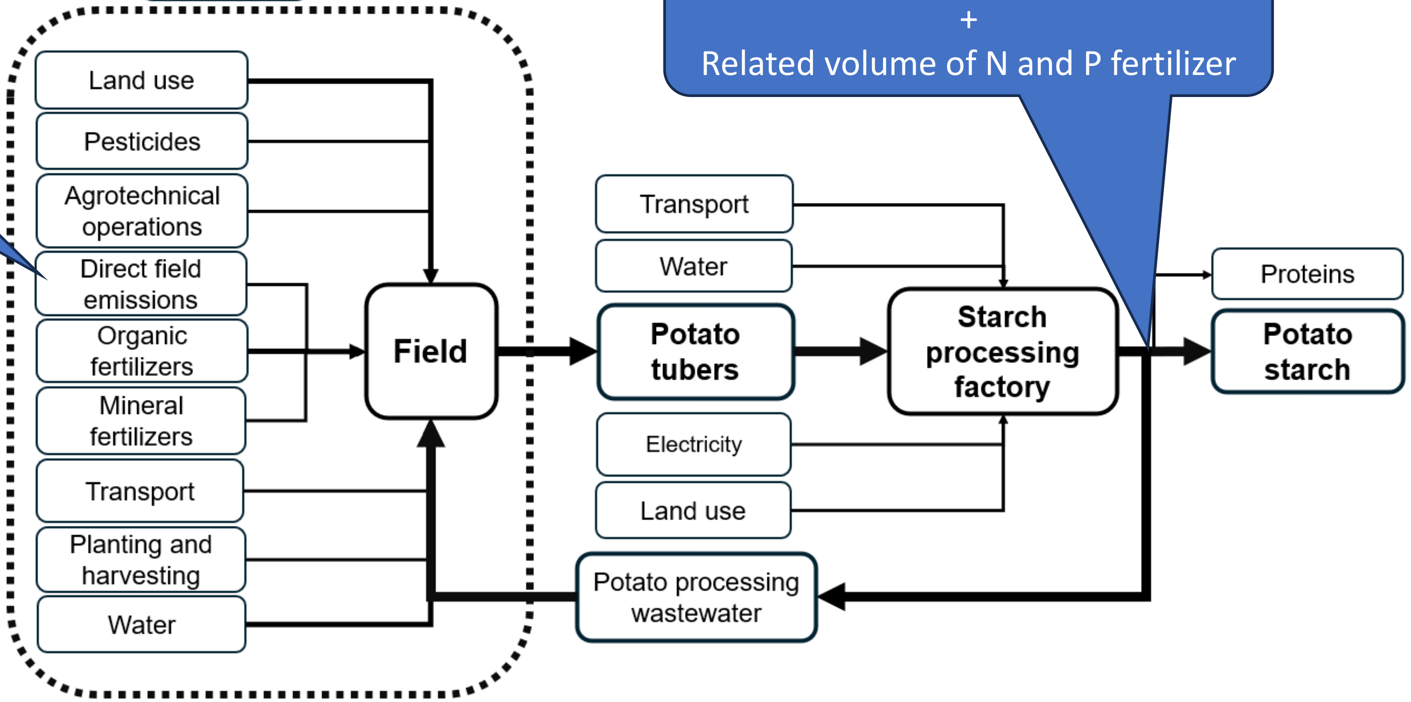
P_{rol} = average quantity of P lost through run-off for a land use category [kg/(ha*a)], which is
0.175 kg P/(ha*a) for arable land,
0.25 kg P/(ha*a) for intensive permanent pastures and meadows and
0.15 kg P/(ha*a) for extensive permanent pastures and meadows

F_{ro} = correction factor for fertilization with P [dimensionless], calculated as:

F_{ro} = $1 + 0.2/80 * P_2O_{5min} + 0.7/80 * P_2O_{5sl} + 0.4/80 * P_2O_{5man}$

P_2O_{5min} = quantity of P_2O_5 contained in mineral fertiliser [kg/ha]
P_2O_{5sl} = quantity of P_2O_5 contained in slurry or liquid sewage sludge [kg/ha]
P_2O_{5man} = quantity of P_2O_5 contained in solid manure [kg/ha]

The values of P_2O_5-content for slurry and manure were taken from Flisch *et al.* (2009) or other national sources.



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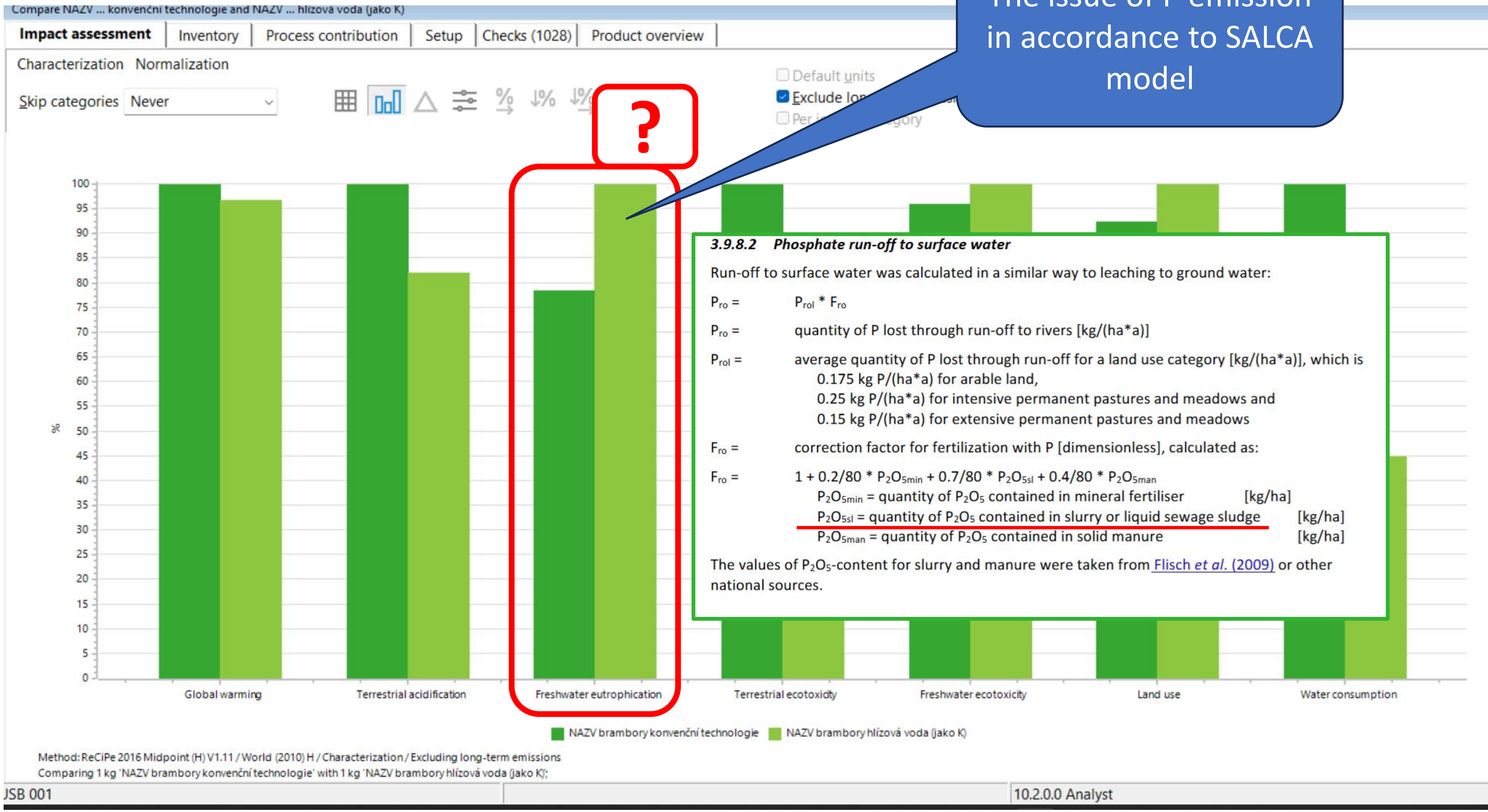
Starch potatoes with nutrient recovery from process water

The issue of P emission in accordance to SALCA model



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Indoor hemp production

Rethinking Efficiency: How Increased Electricity Use Can Reduce Environmental Impacts in Controlled Hemp Cultivation

- Environmental impacts were evaluated per 1 kg of dried hemp inflorescence.
- Four indoor cultivation strategies with varying fertilizer and lighting inputs were compared using life cycle assessment.
- Regional electricity mix, particularly from lignite-based sources, was the dominant contributor across most environmental impact categories.
- Treatments with higher lighting intensity chieved lower environmental impacts per 1 kg of dried hemp inflorescence due to higher yields.

Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Waste type	Allocation	Category	Comment
electricity production mix cz (vlastni model)	E = 1	kWh	Energy	not defined	100 %	Others\Bernas_Jaroslav\ENERGIE CZ	https://mpo.gov.cz/assets/cz/energetika/st ergie/2025/1/Obnovitelne-zdroje-energie- Energostat
Add line							

Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line							

Inputs

Inputs from nature	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line								

Inputs from technosphere: materials/fuels	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line							

Inputs from technosphere: electricity/heat	Amount	Unit	Distribution	SD2 or 2SD
Electricity, high voltage {CZ}| electricity production, hard coal | Cut-off, U	CU = 0.034	kWh		
Electricity, high voltage {CZ}| electricity production, lignite | Cut-off, U	HU = 0.385	kWh		
Electricity, high voltage {CZ}| electricity production, nuclear, pressure water reactor | Cut-off, U	JE = 0.371	kWh		
Electricity, high voltage {CZ}| electricity production, natural gas, conventional power plant | Cut-off, U	P = 0.069	kWh		
Electricity, high voltage {CZ}| electricity production, hydro, run-of-river | Cut-off, U	V = 0.026	kWh		
Electricity, high voltage {CZ}| electricity production, hydro, pumped storage | Cut-off, U	Pr = 0.012	kWh		
Electricity, high voltage {CZ}| heat and power co-generation, wood chips, 6667 kW, state-of-the-art 2014 | Cut-off, U	B = 0.031	kWh		
Electricity, high voltage {CZ}| heat and power co-generation, biogas, gas engine | Cut-off, U	BP = 0.03	kWh		
Electricity, high voltage {CZ}| electricity production, wind, 1-3MW turbine, onshore | Cut-off, U	Ve = 0.008	kWh		
Electricity, low voltage {CZ}| electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted | Cut-off, U	S = 0.03	kWh		
Electricity, high voltage {CZ}| electricity production, deep geothermal | Cut-off, U	G = 0.004	kWh		

Documentation | Input/output | **Parameters** | System description

Input parameter	Value	Distribu	SD2 or 2SD	Min	Max	Hide	Comment
CerneUhli	3.4	Undef...				☐	%
HnedeUhli	38.5	Undef...				☐	%
JadernaEnergie	37.1	Undef...				☐	%
Plyn	6.9	Undef...				☐	%
Vodni	2.6	Undef...				☐	%
Precerpavaci	1.2	Undef...				☐	%
Biomasa	3.1	Undef...				☐	%
Bioplyn	3	Undef...				☐	% (ostatní OZE z Energostatu dle MPO)
Vetrna	0.8	Undef...				☐	%
Solarni	3	Undef...				☐	%
ENERGIE	1	Undef...				☐	kWh (V případě změny množství energie)
Geotermal	0.4	Undef...				☐	
Add line							

Calculated paramete	Expression	Comment
CU	(CerneUhli*ENERGIE)/100 = 0.034	
HU	(HnedeUhli*ENERGIE)/100 = 0.385	
JE	(JadernaEnergie*ENERGIE)/100 = 0.371	
P	(Plyn*ENERGIE)/100 = 0.069	
V	(Vodni*ENERGIE)/100 = 0.026	
Pr	(Precerpavaci*ENERGIE)/100 = 0.012	
B	(Biomasa*ENERGIE)/100 = 0.031	
BP	(Bioplyn*ENERGIE)/100 = 0.03	
Ve	(Vetrna*ENERGIE)/100 = 0.008	
S	(Solarni*ENERGIE)/100 = 0.03	

No	Scope	Error	Additional info

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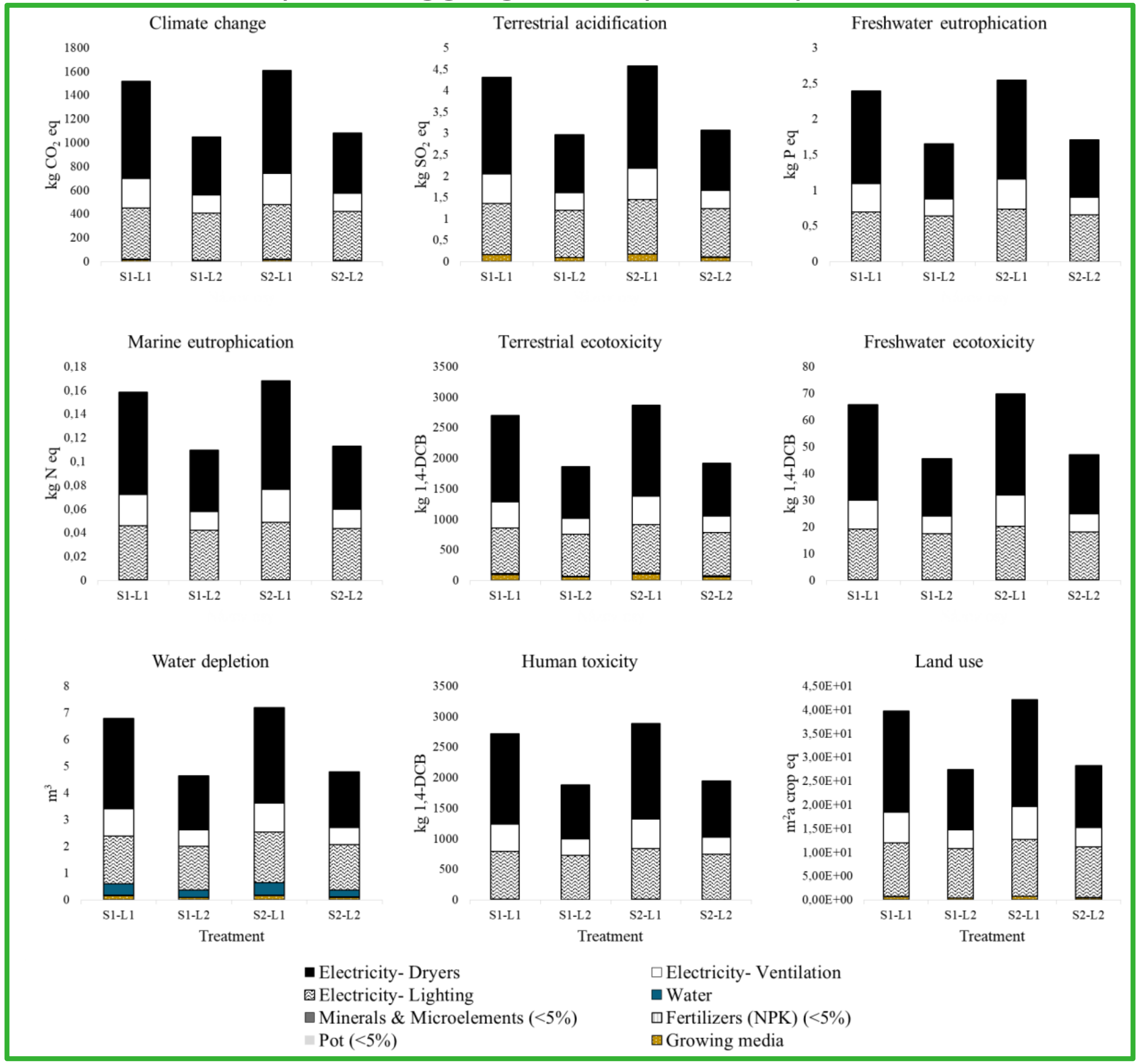
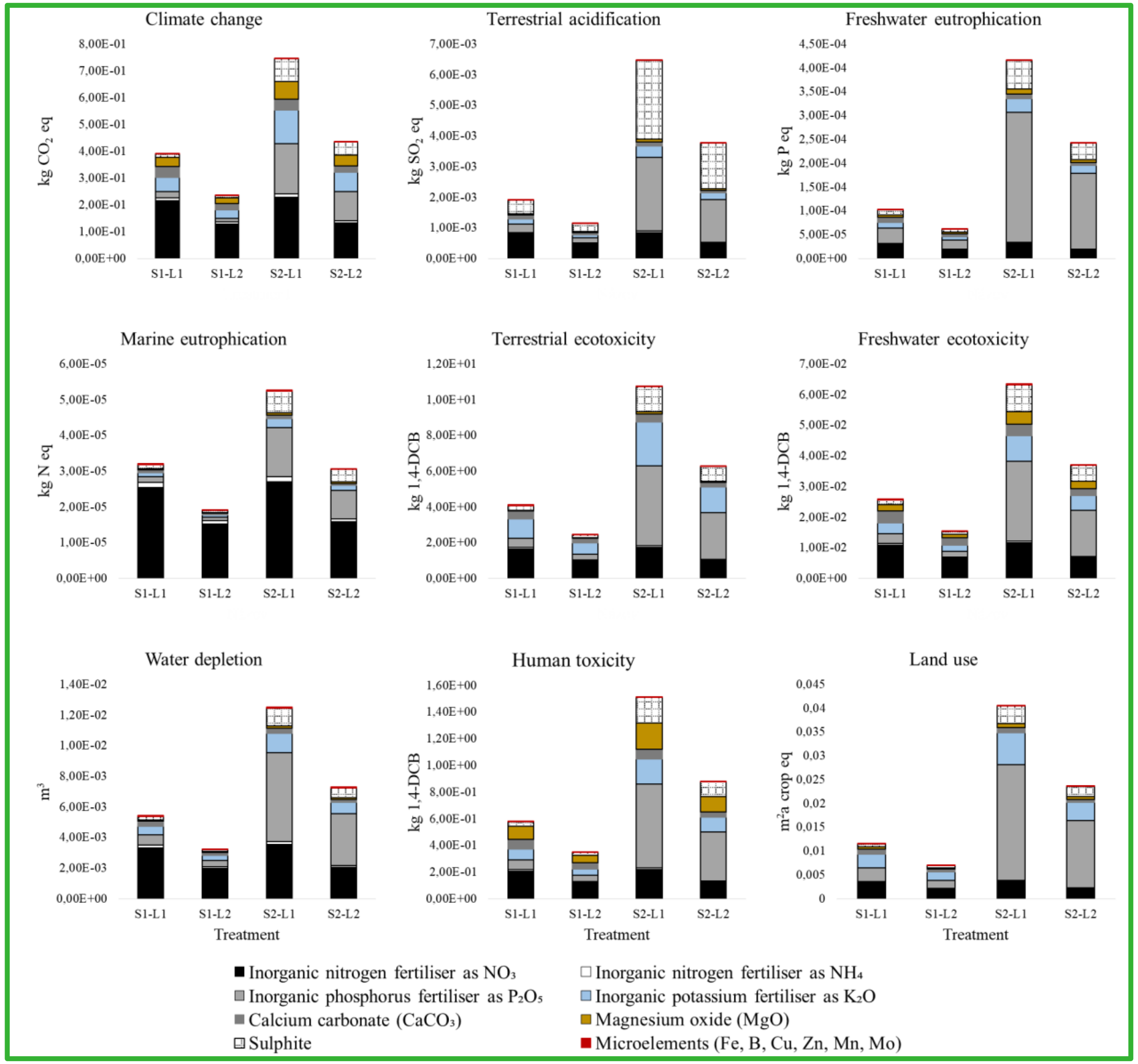
Indoor hemp production

Full system aggregated input analysis



Fertilizer-focused contribution analysis



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Optimal design of nitrogen application rate for facultative wheat using life cycle assessment

LCA; Winter wheat; Spring wheat; Fertilization rate;
Grain N yield

- Highlights
  - The environmental design of facultative wheat production was assessed.
  - The field experiments' results were used for agricultural LCA.
  - Optimization of N input can reduce the environmental impact.
  - Grain N yield was implemented as a functional unit.
  - Winter wheat tended to bring a lower environmental impact than spring wheat.
  - Zero N fertilization can bring a higher environmental impact than medium N fertilization.

Bernas, J., Koppensteiner, L. J., Tichá, M., Kaul, H. P., Klimek-Kopyra, A., Euteneuer, P., ... & Neugschwandtner, R. W. (2023). Optimal environmental design of nitrogen application rate for facultative wheat using life cycle assessment. European Journal of Agronomy, 146, 126813.

Primary dat

Experimental Farm Groß-Enzersdorf

BOKU-Start > Department of Agricultural Sciences > Experimental Farm Groß-Enzersdorf

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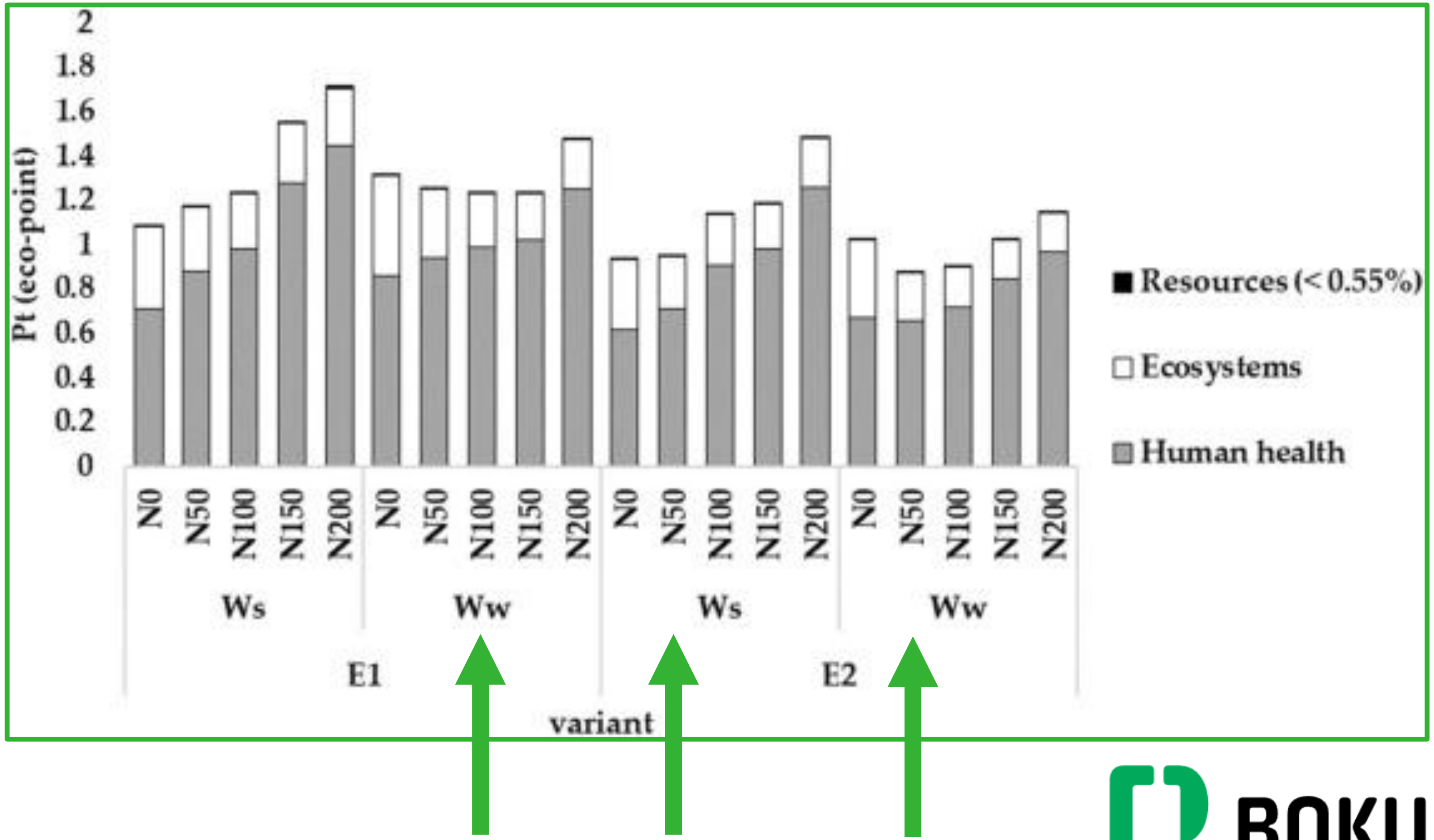
Optimal design of nitrogen application rate for facultative wheat using life cycle assessment

- Fig. 4. Environmental impact levels (trends) per 1 kg of grain N yield ha^{-1} (in eco-points). Pt = The value of 1 Pt (eco-point) is representative of one-thousandth of the annual environmental impact of one average European inhabitant; E1 = environment 1 (season 2019/2020); E2 = environment 2 (season 2020/2021); W_S = spring wheat; W_W = winter wheat; N0 = Control; N50, N100, N150, and N 200 = fertilization rates of 50, 100, 150 and 200 kg N ha^{-1}; SimaPro 9.3.0.2 software; ReCiPe 2016 Endpoint (H) V1.05 / World (2010) H; Cut-off System Model approach; Normalization/Weighting model.



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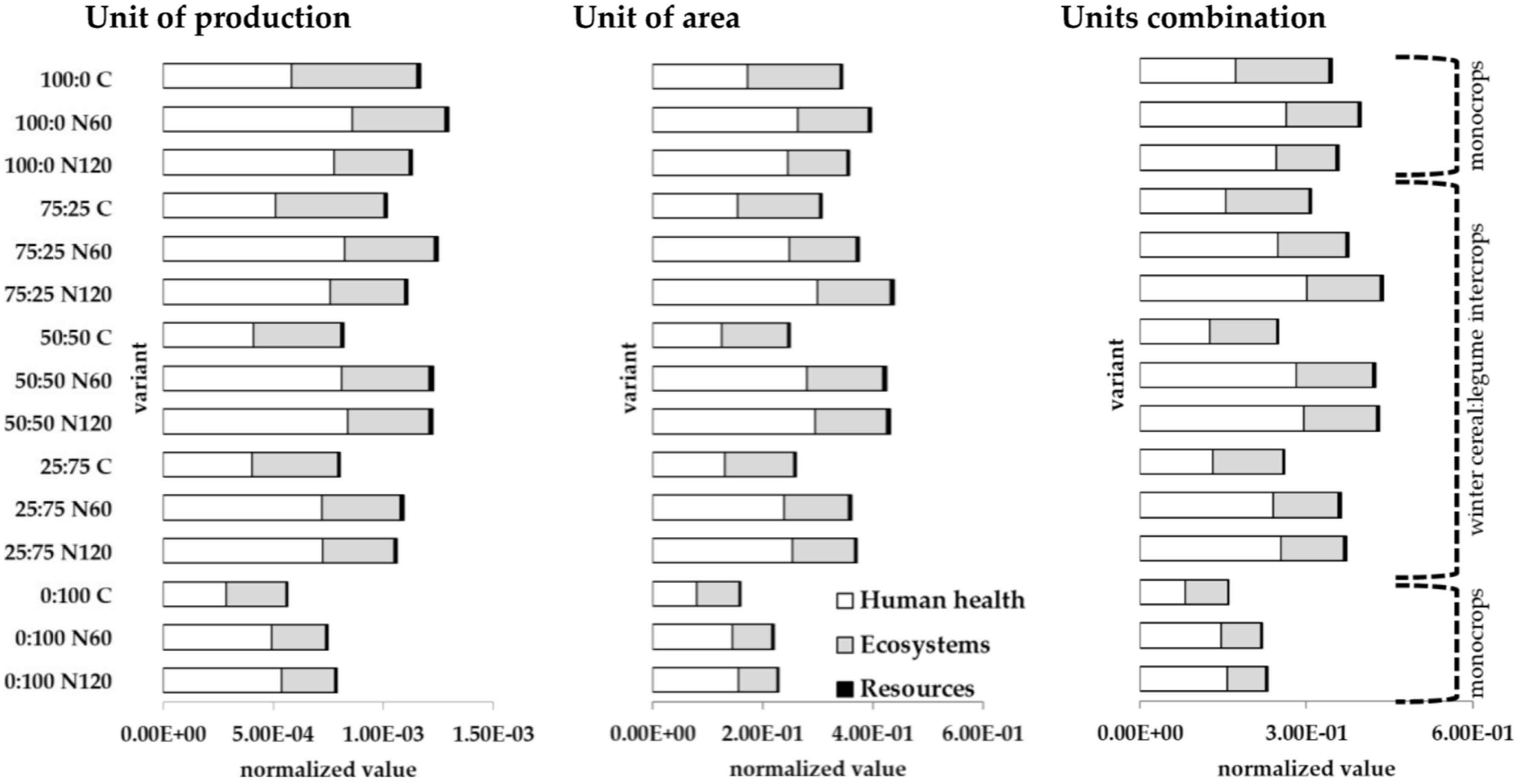
Sustainability Estimation of Oat:Pea Intercrops from the LCA Perspective

- Trends of the environmental impact (the combination of the unit of production; grain N yield respectively, and the unit of area; land demand for generating the same N yield, respectively);
- C = Control;
- N60 = variant with input of 60 kg N ha−1;
- N120 = variant with input of 120 kg N ha−1;
- Sowing ratios of oat:pea (%:%): 100:0, 75:25, 50:50, 25:75, and 0:100;
- Based on Normalization model; ReCiPe 2016 Endpoint (H) V1.05/World (2010) H/Official; Endpoint category: Resources, Ecosystems, Human health.



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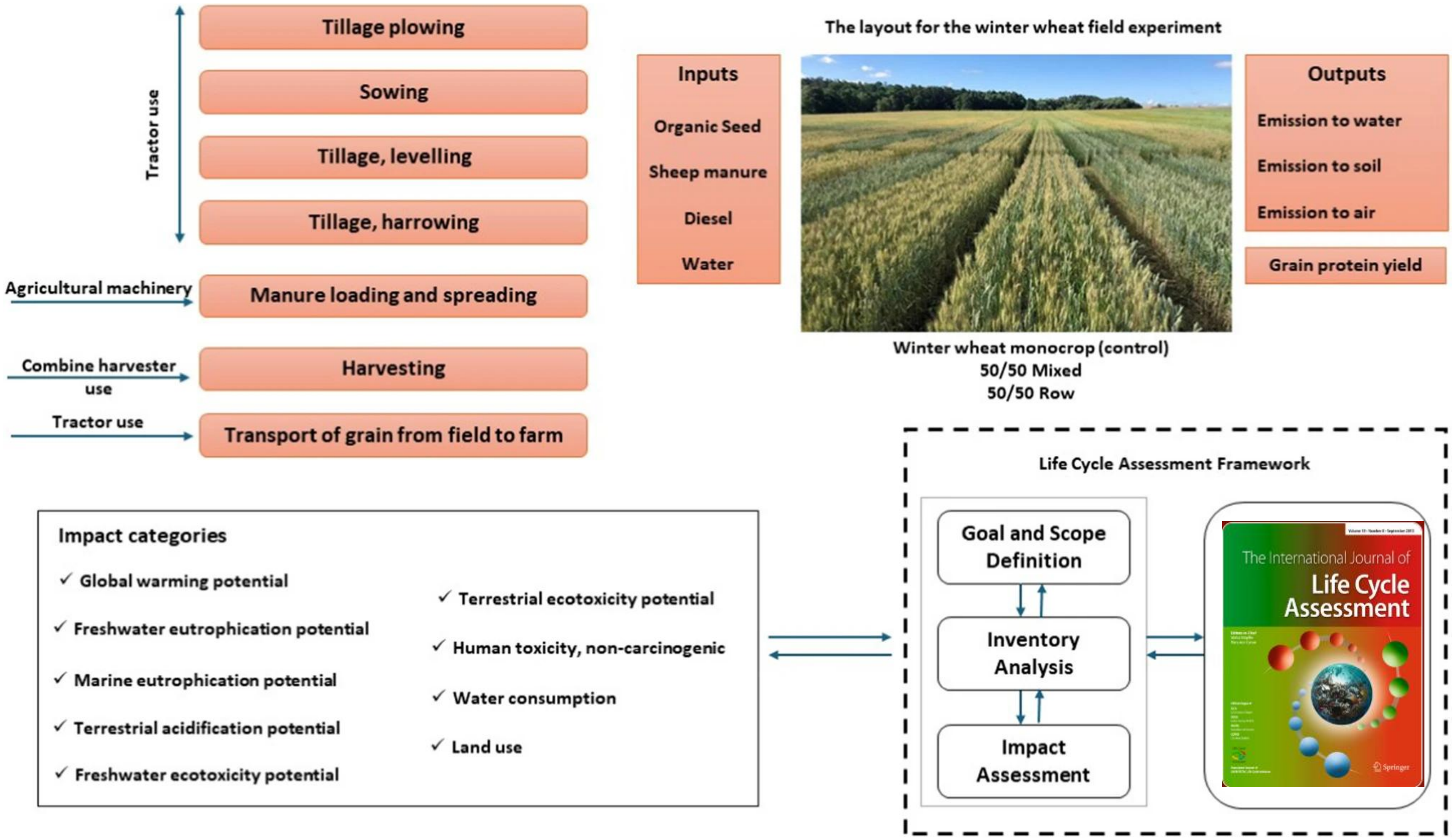
Hotspot detection in the cultivation of organic winter wheat variety mixtures

- Impact of variety mixture on the yield parameters – and envi. impact
- The results of this research can be used as an example of an environmental design application based on hotspot detection in organic agriculture from the LCA perspective.



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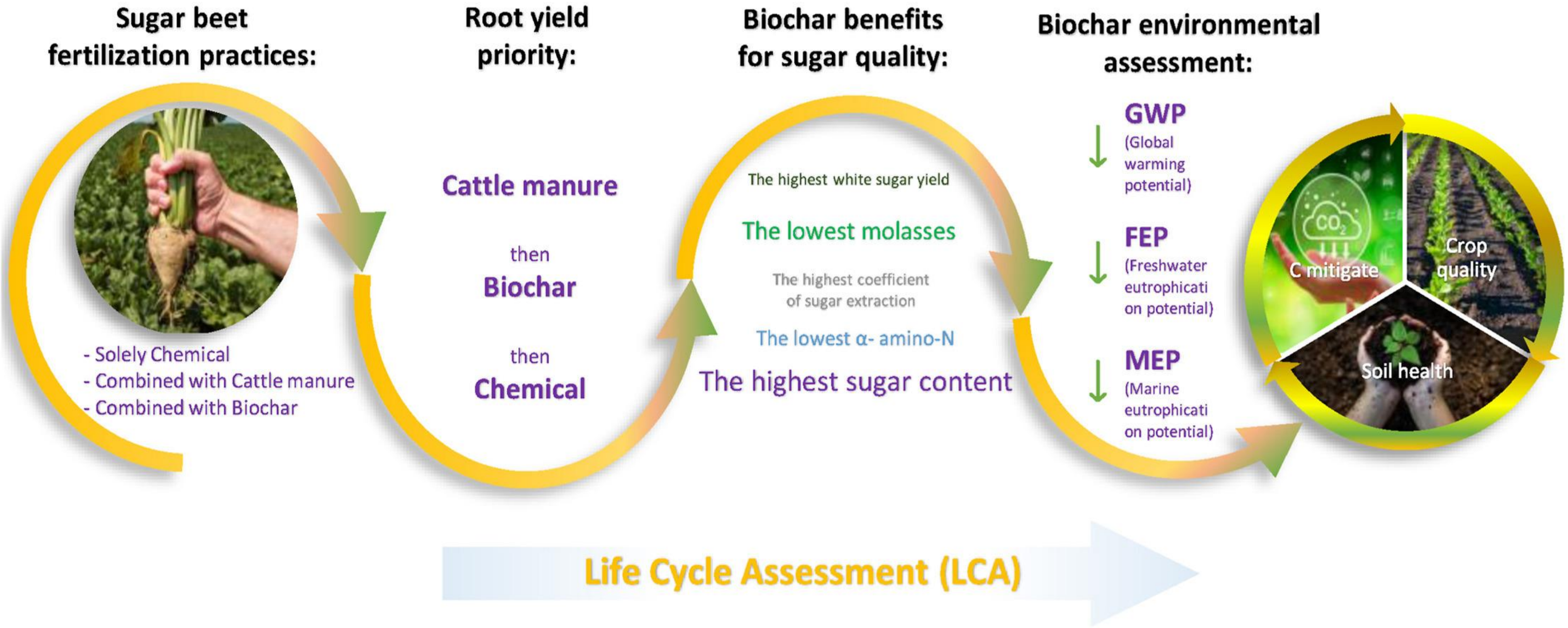
LCA of biochar and cattle manure application in sugar beet cultivation –

- LCA of biochar (B) and cattle manure (CM) applications at three different rates (5, 10, and 15 tons ha⁻¹) compared with conventional chemical fertilization (CH) in the autumn and spring sugar beet crops has been studied.

- The system boundaries for LCA analysis were set from the cradle to the sugar factory gate.

- Quality x quantity x envi. impact



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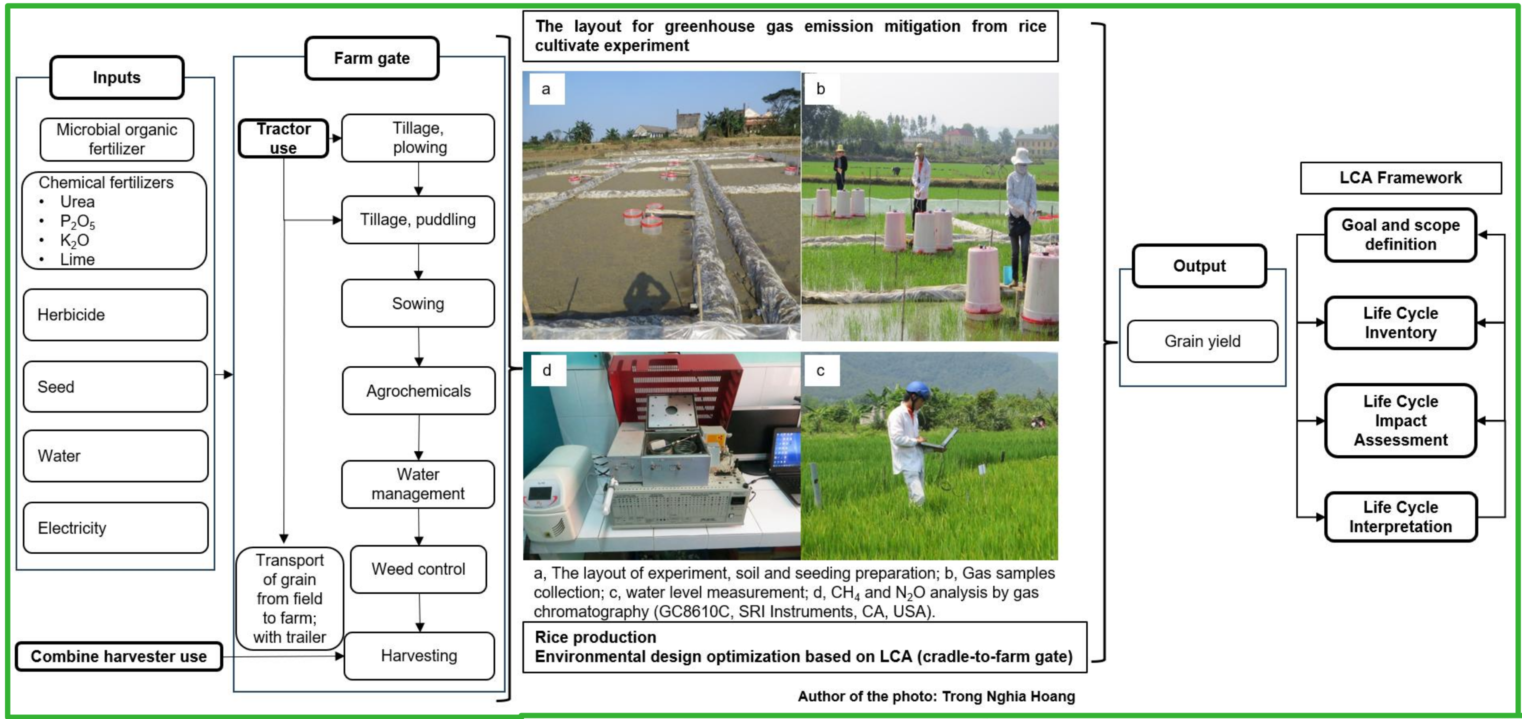
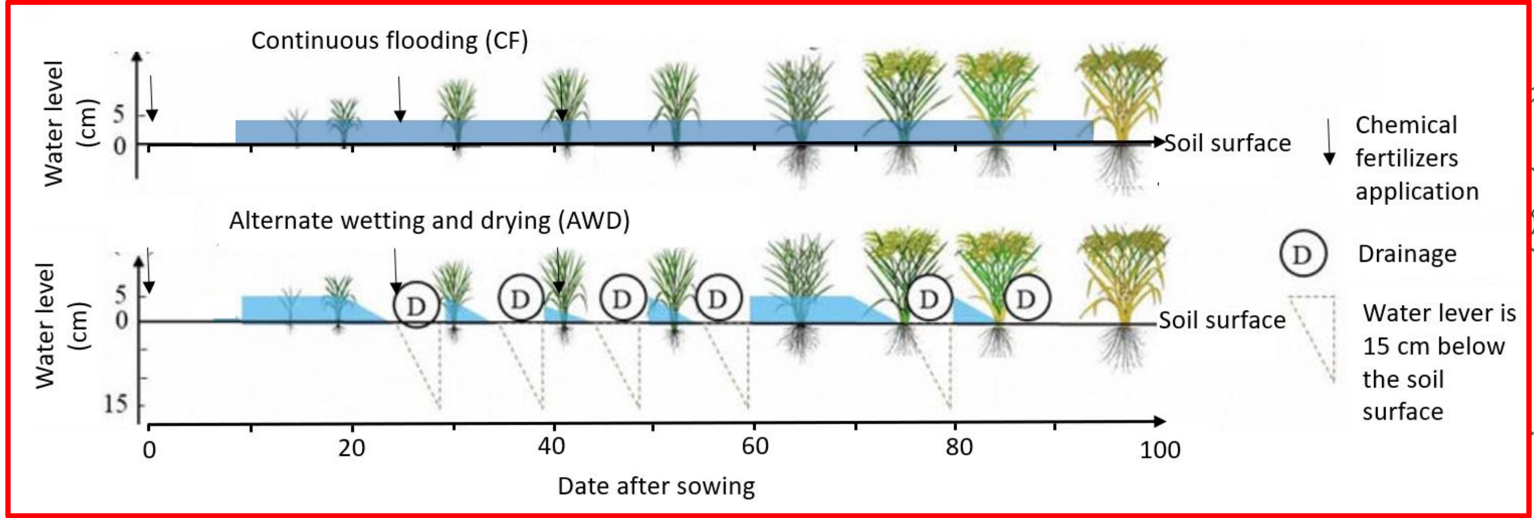
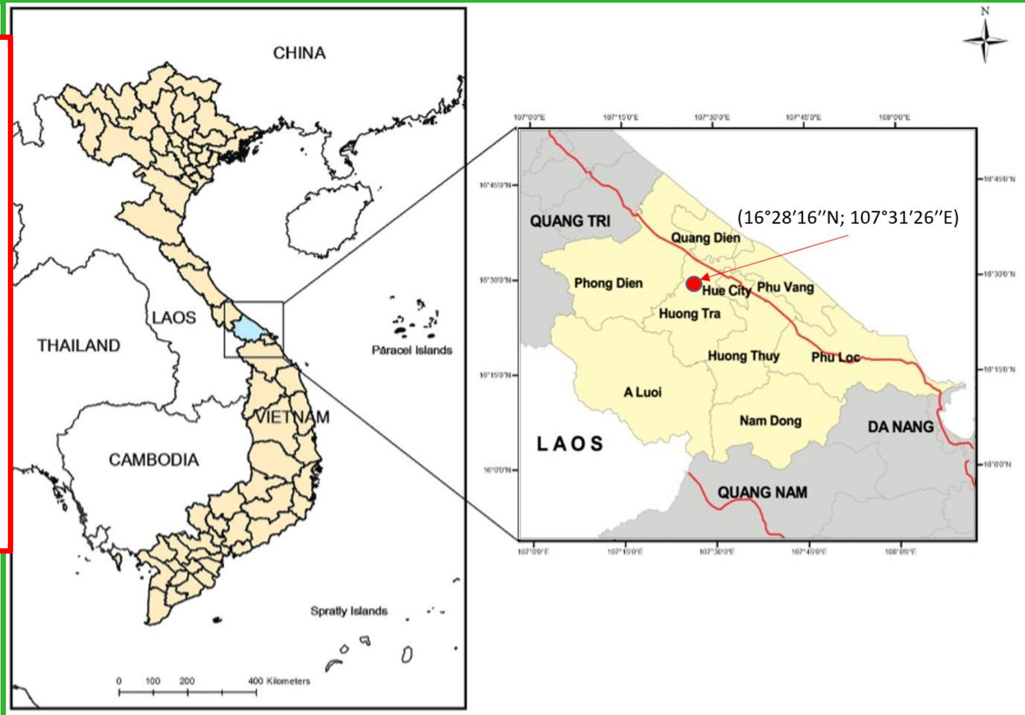
Paddy rice

Environmental impact of paddy rice cultivation under wetting and drying management of cultivation from the perspective of LCA





Yield level, N2O, CH4



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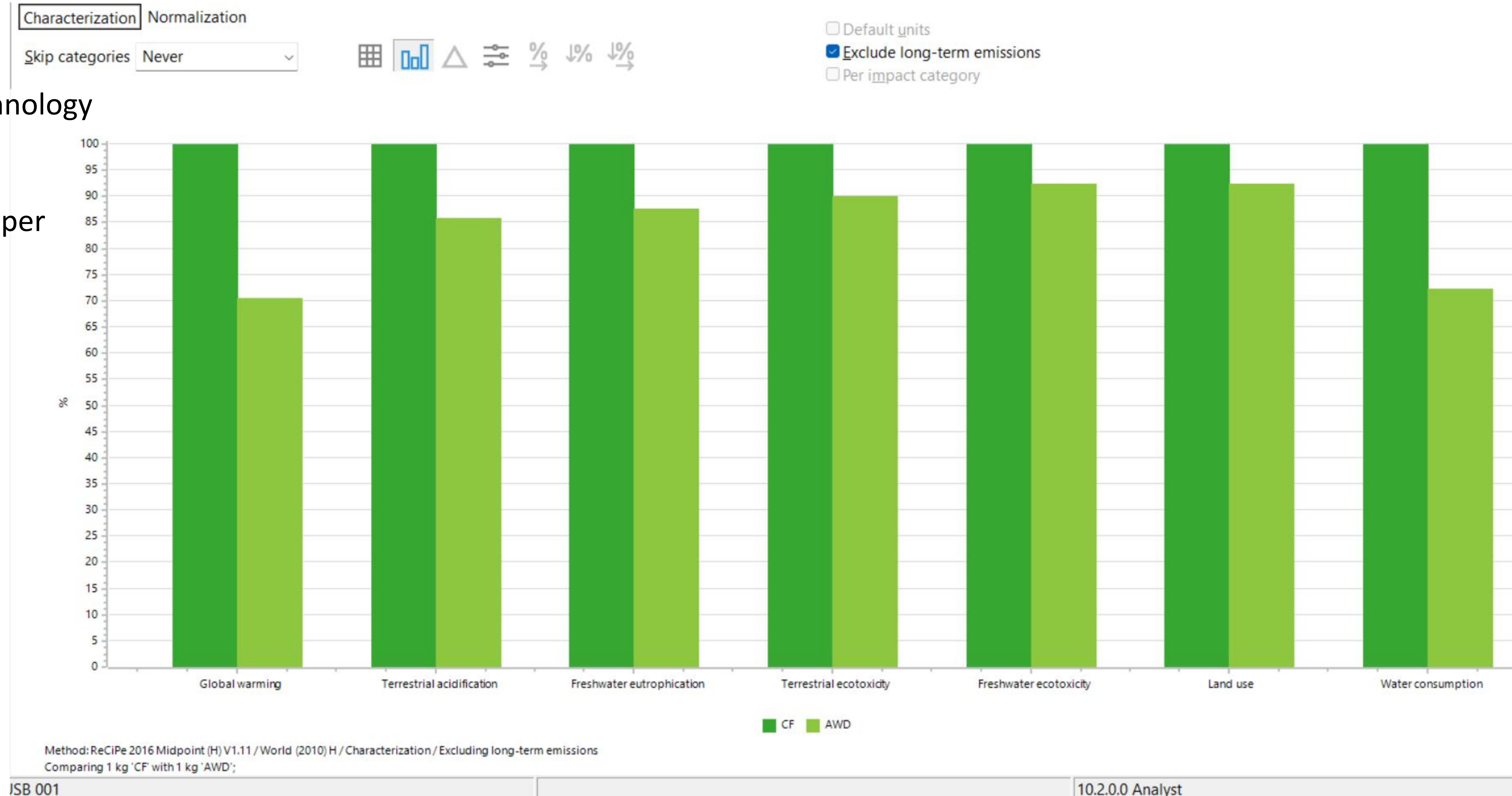
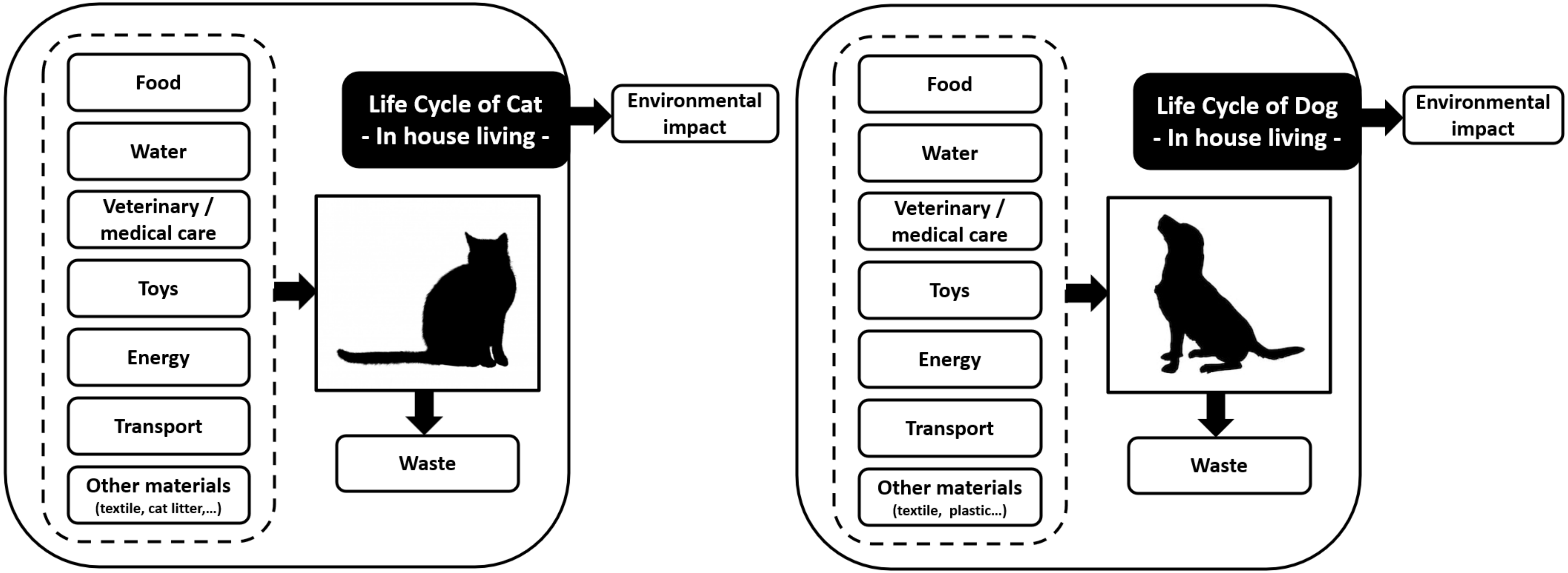
Paddy rice

Same agrotechnology

Draft of the paper




Food
Water
Veterinary / medical care
Toys
Energy
Transport
Other materials
(textile, cat litter,...)
Life Cycle of Cat
- In house living -
Environmental impact
Waste
Food
Water
Veterinary / medical care
Toys
Energy
Transport
Other materials
(textile, plastic...)
Life Cycle of Dog
- In house living -
Environmental impact
Waste

Targets

- Soya been
- Fishery issue
- Mushroom – human risk assessment
- Energy efficiency (BOKU)
- Novel method of refining aseptic waste packages
- Beet root (intensity of cultivation)
- Alternate floristical materials/substrates
- Alcohol consumption – impact on the environment
- Carbon footprint in the campus (transport) – part of the ESG of JU

Thank you for your attention

Jaroslav Bernas

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ZEMĚ
PROGRAM APLIKOVANÉHO VÝZKUMU MINISTERSTVA ZEMĚDĚLSTVÍ
2017-2025

NAZV (QL24010101) -Innovations in potato cultivation technology for starch production with respect to the circular economy

- Cup – plant
- Issue při práci
- Heavy metals – farm level
- Perenial cropping systém
- Yield
- Field emission při perenial cropping
- Srážky – rok nebo sezona
- SimaPro aplikace SALCA a WFLDB
- Kombinace databazi v jednom modelu
- Rybářský článek
- Issue při práci
- Ekonomika – faktory pro zohlednění zátěže – nechtěli jsme od nuly
- Joel Aubin – konzultace metodiky
- Aplikace v peletách
- Příprava H2020