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HEALTHY FOOD SYSTEMS FOR A HEALTHY PLANET

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The sustainability and nutritional profile of alternative protein sources

Including protein quality and nutrient density in LCIA of novel foods

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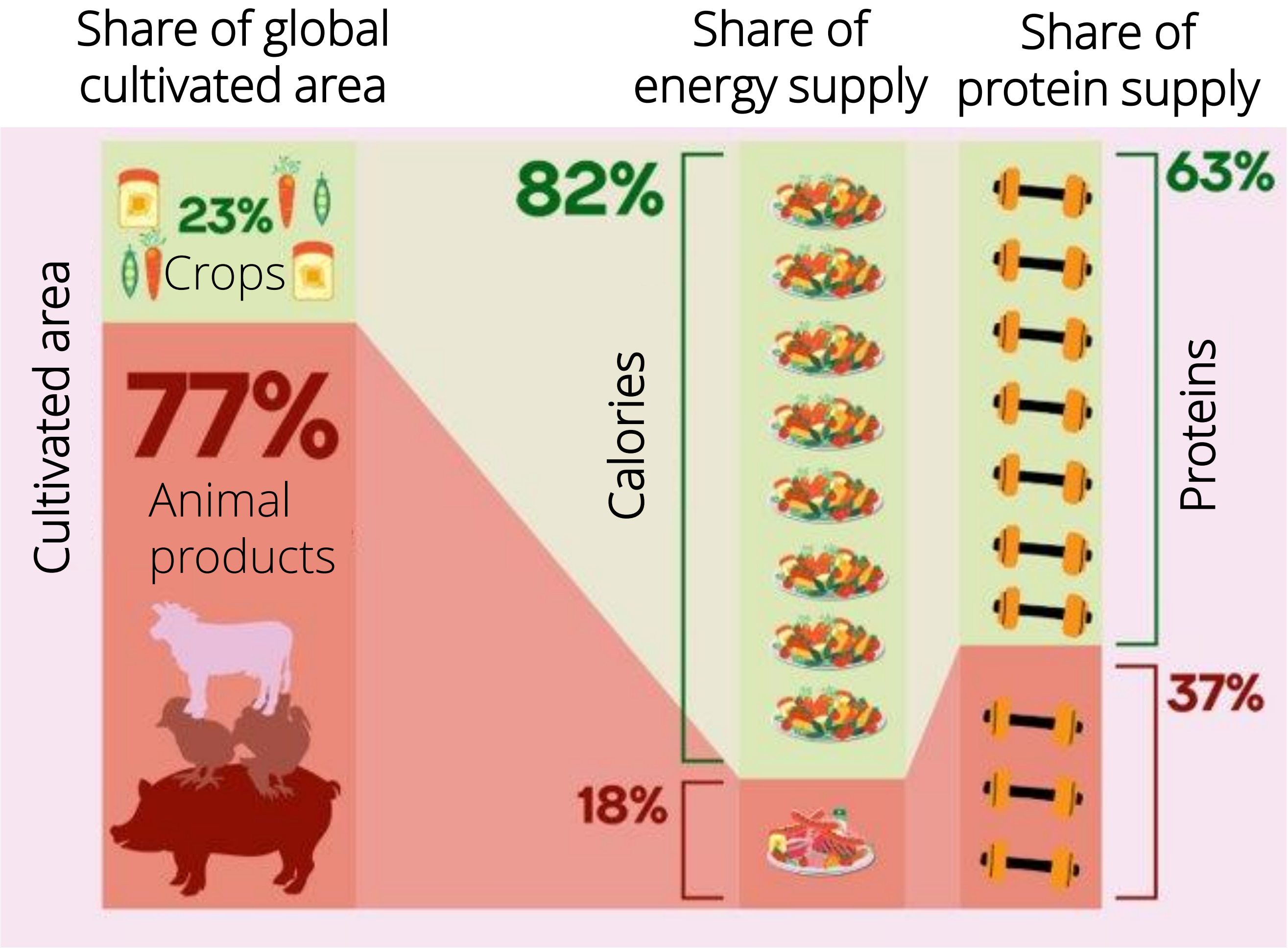
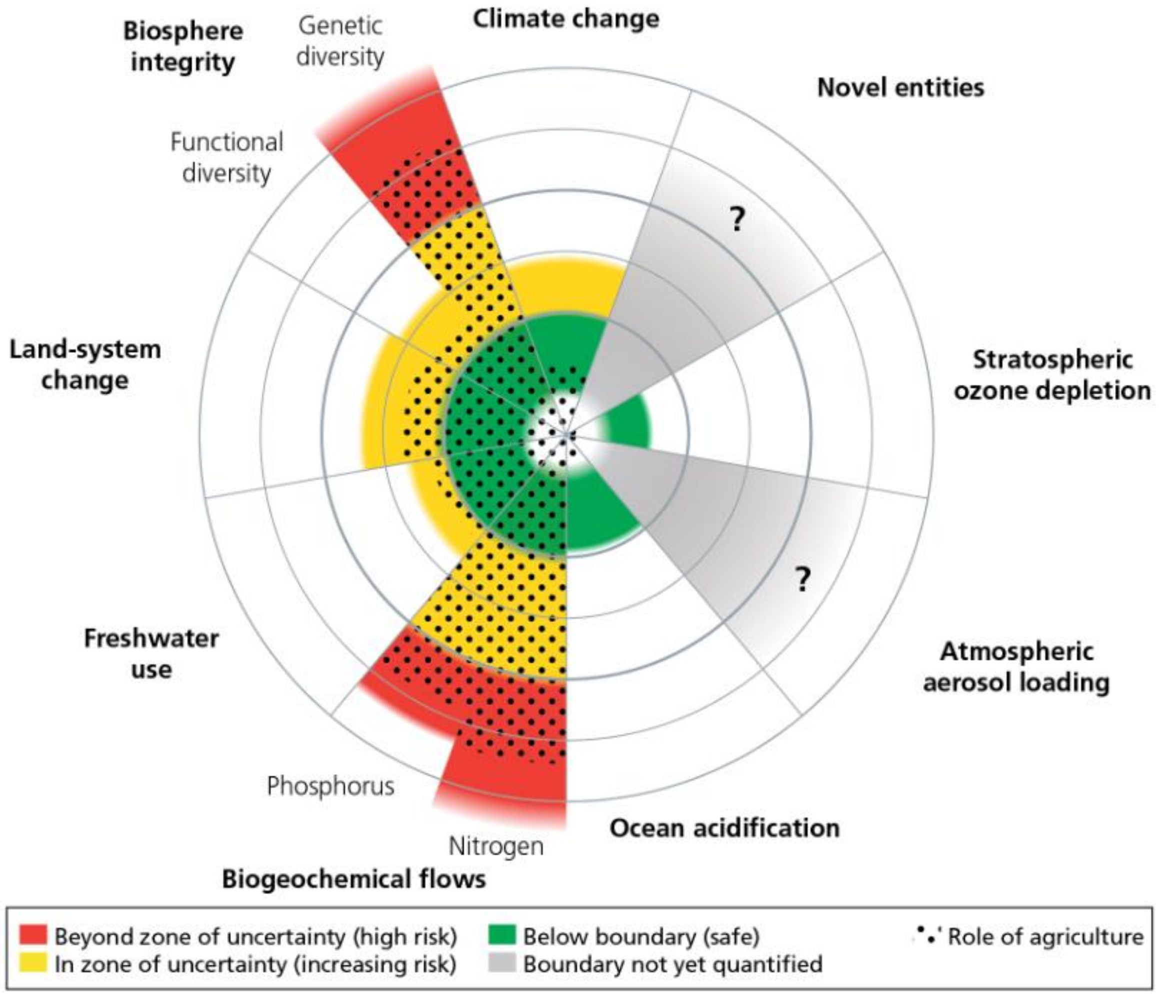
Food system impacts

- Production of animal products require a lot of space but provide only
  - 18% of global calories and
  - 37% of global proteins
- By 2050
  - global milk consumption is expected to increase by 80% while
  - global meat consumption increases by 86%.



https://www.moment.at/story/weniger-fleisch-essen

Environmental impacts of agriculture



Rockström et al. 2009, Steffens et al. 2015, Campbell et al. 2017, WWF Living Planet Report 2020

- Many planetary boundaries are already transgressed
- Agricultural production / food production is one of the main contributors
- Alternative proteins are believed to bear the potential for being a sustainable alternative to animal based protein sources

Objective & challenges

Background:

Most LCA studies compare alternative proteins based on mass, neglecting energy density, nutrient content and protein quality

Objective:

Compare the environmental profile of alternative protein sources with regards to nutrient composition and protein quality, for 25 alternative protein sources in several impact categories.

Challenges:

Data sources

Comparison across food groups: Which is the adequate functional unit?

Data sources

- Main data source:
  - Agribalyse 3.1 for environmental data
  - Ciqual/USDA for nutritional data
- Gap filling with literature data and own calculations
- Life cycle stages: Cradle-to-consumer

Item	Description	Datasource
Microbial protein	Solein	(Mazac et al., 2023), (Järviö et al., 2021)
Insect protein	Insect Meal (Hermetia illucens)	(Mazac et al., 2023), (Smetana et al., 2019)
Mycoprotein	Quorn (Fusarium spp.)	(Mazac et al., 2023), (Smetana et al., 2015)
Cellbased meat	Cultured Meat (low) - assumed 19% protein + 0% fat	(Tuomisto et al., 2022), (Mazac et al. 2023)
Precision fermented milk	LCA model based on literature data; Preliminary results	(Quandt et al. under preparation)

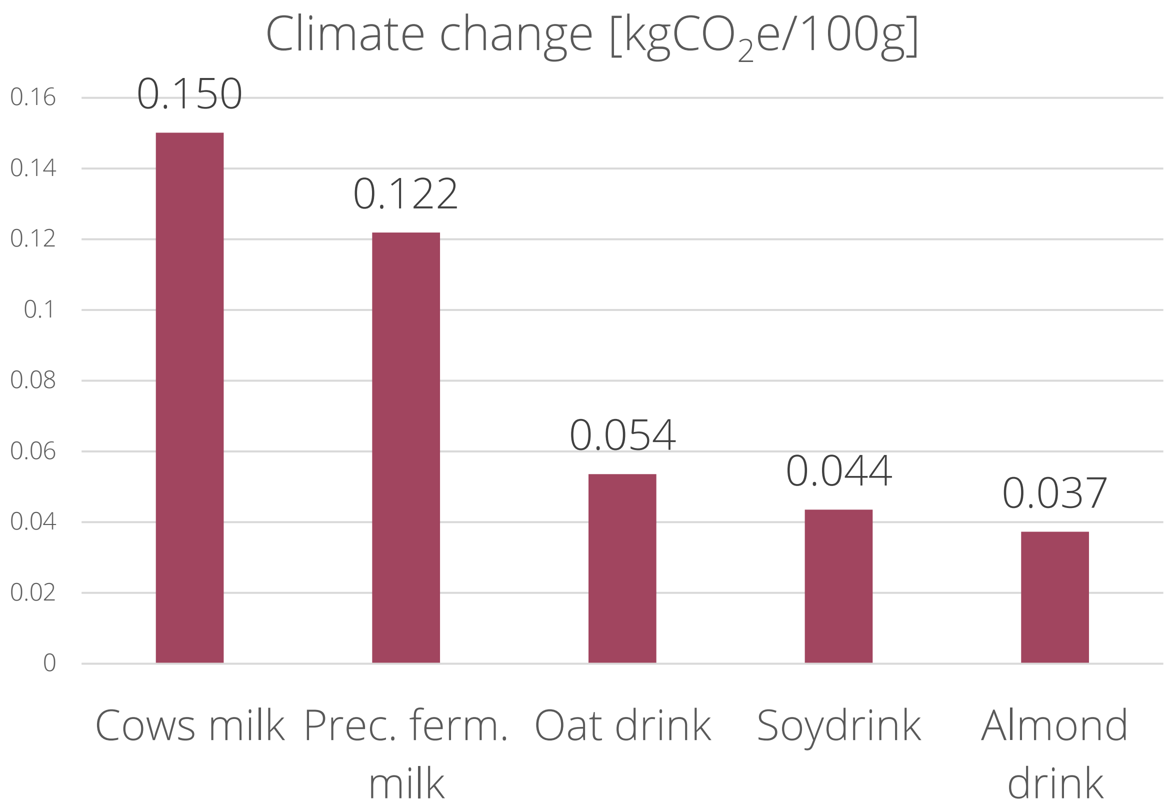
Impact categories

- Selection of the impact categories
- Methods according to EF 3.1
- Biodiversity impact based on BVI-Method
- Data sources LCIA: Agribalyse 3.1, BVI2AGR, Literature, own calculations using OpenLCA

Category	Method	Unit	Reference
Climate change	IPCC 2021	CO_2e	IPCC 2021
Biodiversity loss	BVI	$BVI*m^2*a$	Lindner et al. 2019, 2020
Water scarcity	AWARE	m^3 world eq.	(Boulay et al., 2015)
Energy use (non-renewable)	Non-renewable energy use	MJ	(van Oers et al., 2018)
Soil degradation	LANCA	Pt	(Bos et al., 2016)
Eutrophication (terr., marin, freshwater)	Acc. Exceedance	kg Neq, kg Peq, mol Neq	(Seppälä et al., 2006), (Posch et al., 2008)
Acidification	Acc. Exceedance	Mol H+eq	
FW Ecotoxicity	UseTox	CTUe	(Fantke et al., 2017)

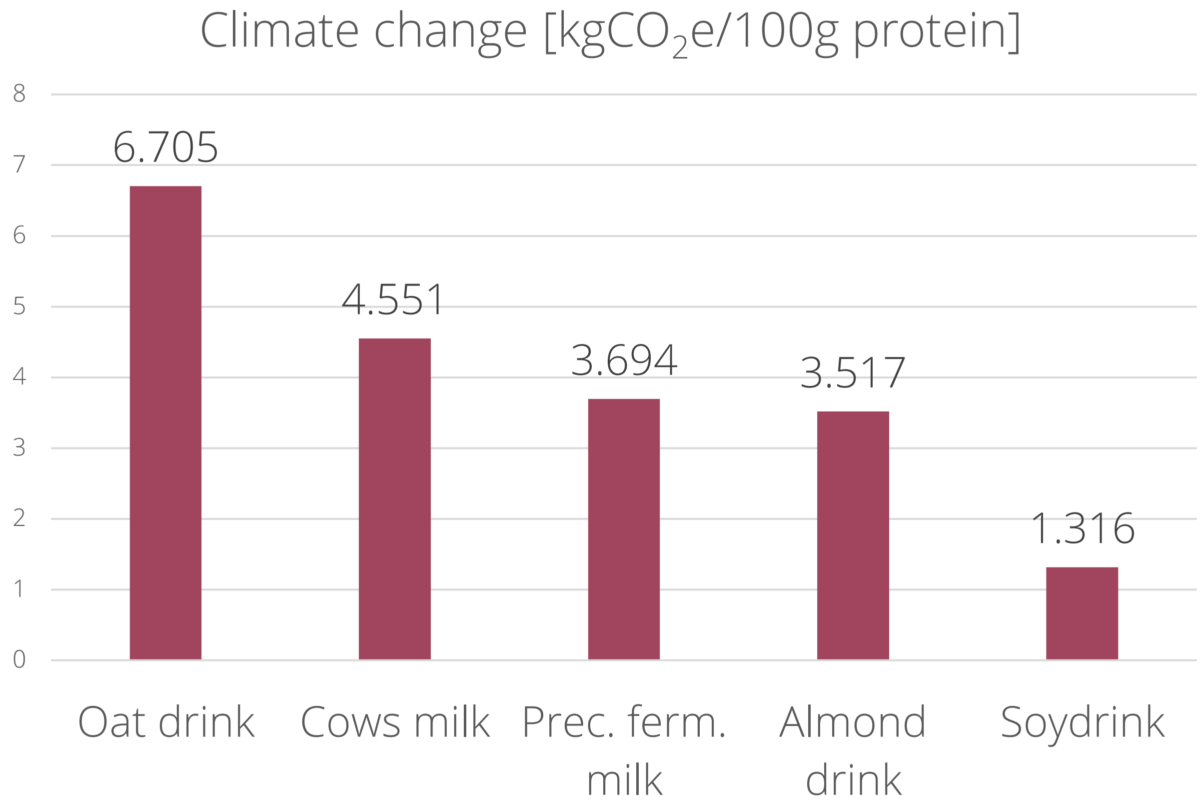
Functional unit – Why is it important?

Mass based FU



-> Cows milk has highest impact

Protein based FU



-> Oat drink has highest impact

Selecting a functional unit

- What are the (physiological) functions of food?
  1. Provide energy -> energy based FU
  2. Provide body building blocks -> protein based FU
  3. Protection and regulation -> nutrient density based FU

- What is the function of alternative protein sources?
  Being „sustainable“ alternatives to conventional/animal based protein sources.

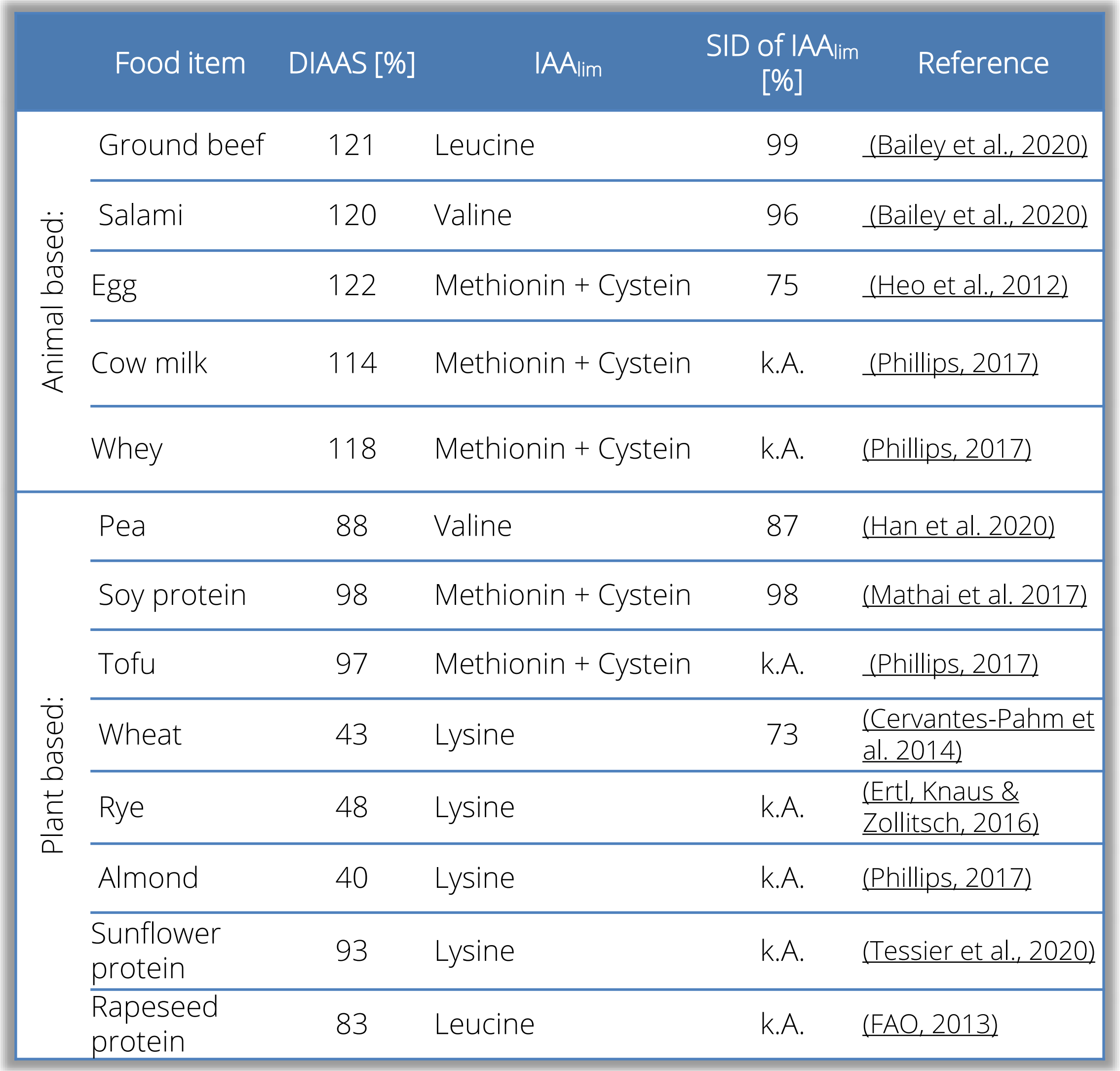
- Here, FU is defined as the
  environmental impact per unit of **protein quality adjusted nutrient density**

Protein quality

- Protein quality differs among food items

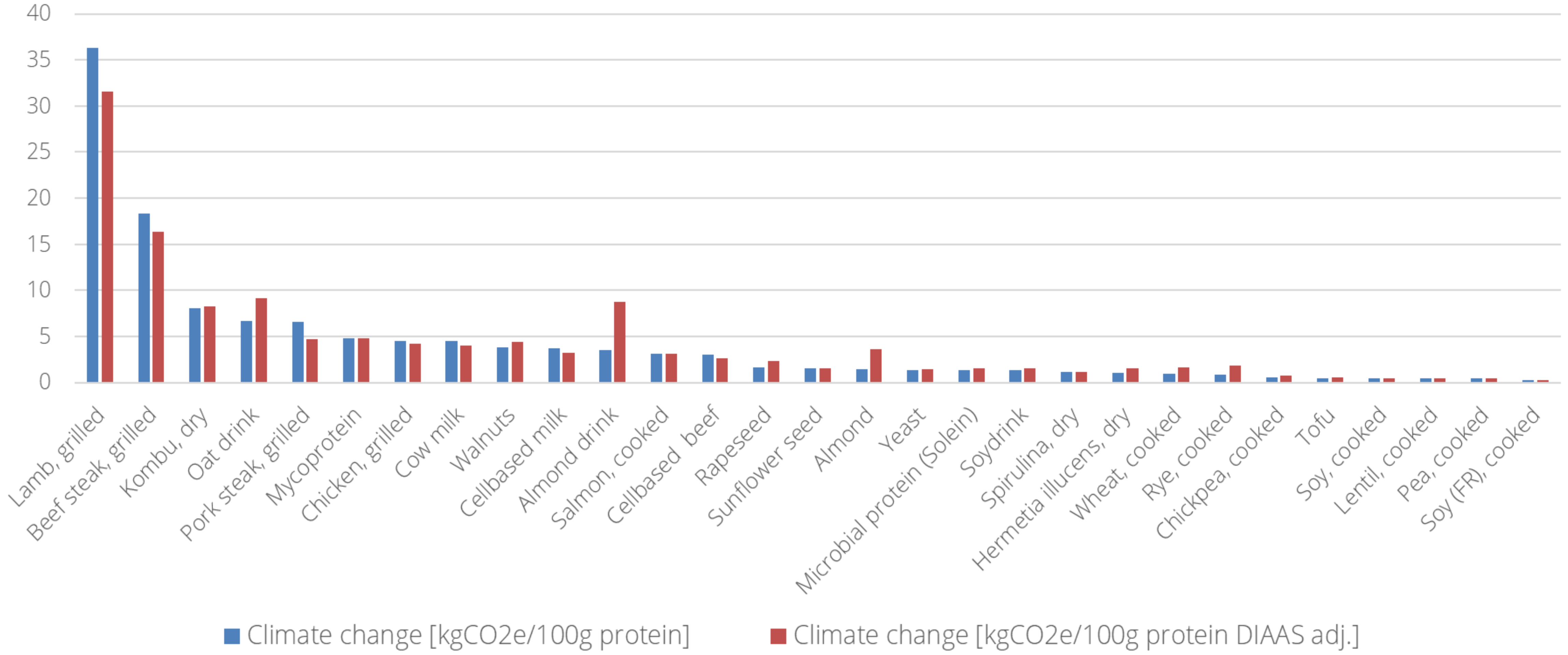
- Dietary indispensable amino acid score (DIAAS) is a measure for protein quality based on digestibility and availability of **essential amino acids**
- Calculating DIAAS:
    - determine ileal digestibility of essential amino acids **(SID)**
    - Compare the digestible amino acid content to the reference amino acid requirements for the target population (here: adults)
    - DIAAS is defined by limiting amino acid

- Animal based protein tends to have higher DIAAS than plant based protein



	Food item	DIAAS [%]	IAA_{lim}	SID of IAA_{lim} [%]	Reference
Animal based:	Ground beef	121	Leucine	99	(Bailey et al., 2020)
	Salami	120	Valine	96	(Bailey et al., 2020)
	Egg	122	Methionin + Cystein	75	(Heo et al., 2012)
	Cow milk	114	Methionin + Cystein	k.A.	(Phillips, 2017)
	Whey	118	Methionin + Cystein	k.A.	(Phillips, 2017)
Plant based:	Pea	88	Valine	87	(Han et al. 2020)
	Soy protein	98	Methionin + Cystein	98	(Mathai et al. 2017)
	Tofu	97	Methionin + Cystein	k.A.	(Phillips, 2017)
	Wheat	43	Lysine	73	(Cervantes-Pahm et al. 2014)
	Rye	48	Lysine	k.A.	(Ertl, Knaus & Zollitsch, 2016)
	Almond	40	Lysine	k.A.	(Phillips, 2017)
	Sunflower protein	93	Lysine	k.A.	(Tessier et al., 2020)
	Rapeseed protein	83	Leucine	k.A.	(FAO, 2013)

Climate change impact related to protein content



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Nutrient Rich Food Index (NRF)

- NRF is a single score index that evaluates the **overall nutritional density** of foods by comparing the density of **encouraging nutrients** to the density of **limiting nutrients**.

- Capping - cutting nutrient scores at 100 percent of RDV – is applied to avoid compensation via excess nutrients

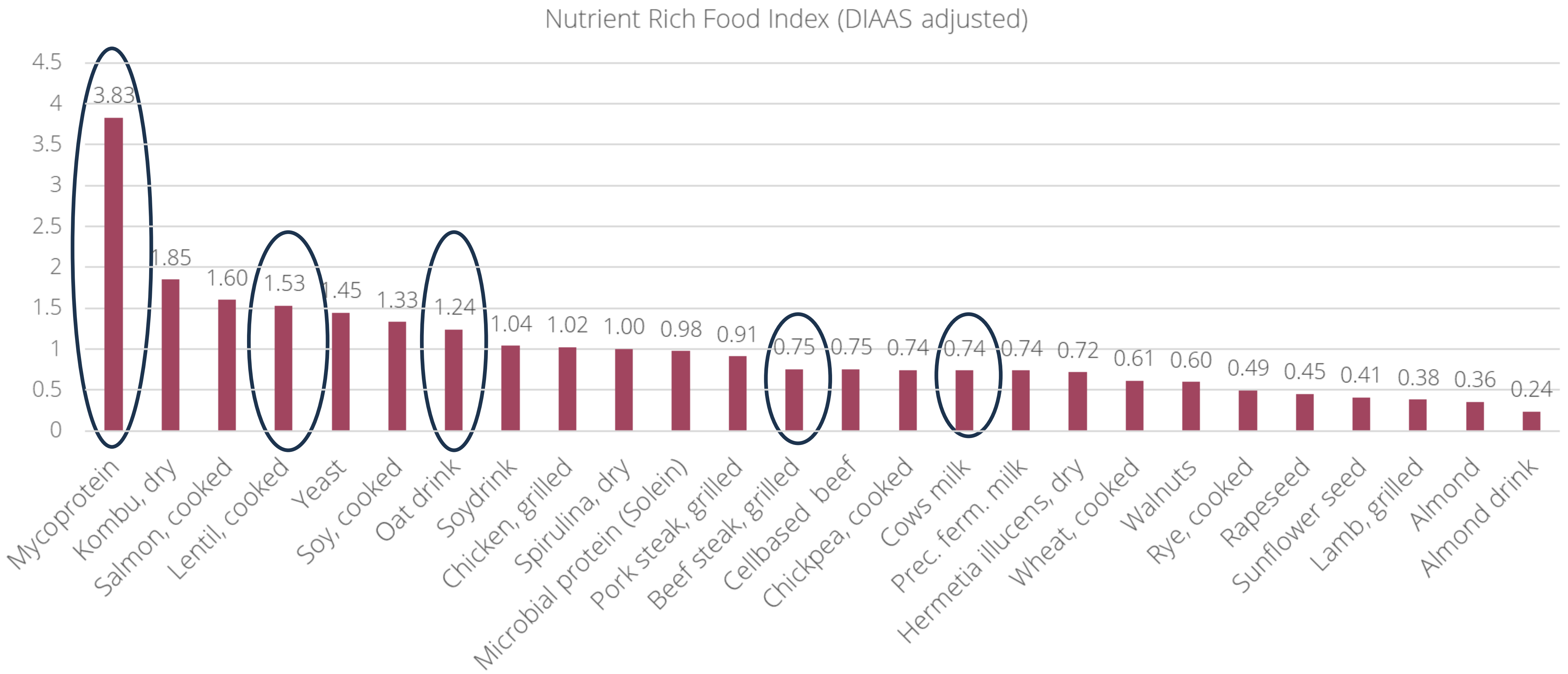
$$NRF12.2 = \underbrace{\sum_{i=1}^{i=12}\left(\frac{Nutrient_i}{RDV_i}\right)/ED * 100}_{\text{NR12}} - \underbrace{\sum_{i=1}^{i=3}\left(\frac{Nutrient_i}{MRV_i}\right)/ED * 100}_{\text{LIM2}}$$

- **encouraging nutrients (NR12):**
  - protein, fibre, ALA, calcium, iron, iodine, zinc, selenium, B2, B9, B12, D
  - **Includes potential critical nutrients in vegetarian/vegan diets**

- **limiting nutrients (LIM2):**
  - saturated fatty acids, sodium

- ED – Energy density
- RDV – recommended daily value
- MRV – maximum recommended value

NRF - Scores


Nutrient Rich Food Index (DIAAS adjusted)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
3.83
1.85
1.60
1.53
1.45
1.33
1.24
1.04
1.02
1.00
0.98
0.91
0.75
0.75
0.74
0.74
0.74
0.72
0.61
0.60
0.49
0.45
0.41
0.38
0.36
0.24
Mycoprotein
Kombu, dry
Salmon, cooked
Lentil, cooked
Yeast
Soy, cooked
Oat drink
Soydrink
Chicken, grilled
Spirulina, dry
Microbial protein (Solein)
Pork steak, grilled
Beef steak, grilled
Cellbased beef
Chickpea, cooked
Cows milk
Prec. ferm. milk
Hermetia illucens, dry
Wheat, cooked
Walnuts
Rye, cooked
Rapeseed
Sunflower seed
Lamb, grilled
Almond
Almond drink

Selected results (I/II)

Impact per NRF (DIAAS adjusted)		Cows milk	PF milk	Oat drink	Soy drink	Almond drink
	Unit		Deviation to cow's milk [%]			
Climate change	[kgCO2e/NRF]	0,20	-19%	-79%	-79%	-23%
Biodiversity	[BVI*m2*a/NRF]	0,12	27%	-82%	1%	333%
Water scarcity	[m3 world e/NRF]	0,07	84%	-59%	-84%	641%
Fossil resource use	[MJ/NRF]	1,58	60%	-52%	-60%	115%
Land use	[m2*a/NRF]	0,18	-65%	-91%	-69%	132%
Eutrophication, freshwater	[kg P-Äq./NRF]	0,00	272%	-17%	-44%	130%
Eutrophication, marin	[kg N-Äq./NRF]	0,00	-46%	10%	-75%	17%
Eutrophication, terrestrial	[mol N-Äq./NRF]	0,01	-70%	-85%	-92%	-31%
Acidification	[mol H+-Äq./NRF]	0,00	-56%	-82%	-90%	-19%
Soil degradation	[Pt/NRF]	9,64	-73%	-64%	-73%	-2%
Ecotoxicity, freshwater	[CTUe/NRF]	1,91	94%	-74%	-79%	131%

When considering cows milk as a benchmark:

- Precision fermented (PF) milk leads to higher impacts regarding biodiversity, water scarcity, fossil resource use, freshwater eutrophication and ecotoxicity

- oat and soy drink have overall lower impacts than cows milk

- Almond drink leads in many categories to higher impacts especially in terms of biodiversity and water scarcity

Selected results (II/II)

Impact per NRF (DIAAS adjusted)	Pork	Beef	Cell. meat	Pea	Chick pea	Lentil	Soy	Tofu	Seitan	Insect	Spirulina	Solein	Myco protein	Walnut	Almond	Sunflower seed
	Absolute	Deviation to pork [%]														
Climate change	1,45	222%	-48%	-98%	-96%	-98%	-97%	-95%	-90%	-45%	-54%	-38%	-91%	-52%	-48%	-45%
Biodiversity loss	1,64	31%	k.A.	-97%	-95%	-99%	-96%	-92%	k.A.	k.A.	-96%	k.A.	k.A.	-40%	48%	120%
Water scarcity	1,02	-1%	-95%	-96%	-94%	-97%	-98%	-96%	k.A.	-97%	-70%	-73%	-87%	735%	759%	-57%
Fossil resource use	20,45	-33%	k.A.	-96%	-94%	-97%	-97%	-97%	-95%	k.A.	54%	k.A.	k.A.	-56%	-62%	-66%
Land use	1,68	349%	-85%	-93%	-90%	-98%	-94%	-87%	-83%	-84%	-98%	-95%	-98%	26%	23%	85%
Eutrophication, freshwater	0,00	14%	20%	-94%	-91%	-96%	-94%	-96%	-86%	-76%	-23%	3%	-68%	-47%	-16%	43%
Eutrophication, marin	0,01	126%	-95%	-94%	-90%	-95%	-96%	-95%	-87%	-61%	-79%	-99%	-99%	-57%	17%	8%
Eutrophication, terrestrial	0,12	145%	k.A.	-100%	-99%	-100%	-99%	-99%	-96%	k.A.	-89%	-98%	-99%	-73%	-41%	-78%
Acidification	0,03	139%	-83%	-99%	-98%	-99%	-99%	-99%	-96%	-35%	-63%	k.A.	k.A.	-71%	-40%	-80%
Soil degradation	84,86	285%	k.A.	-93%	-90%	-95%	-93%	-96%	-90%	k.A.	-97%	k.A.	k.A.	26%	26%	56%
Ecotoxicity, freshwater	21,94	2%	k.A.	-97%	-95%	-98%	-95%	-98%	-92%	k.A.	-80%	k.A.	k.A.	-68%	239%	-28%

Conclusion

- When conducting LCA studies on food products the selection of the functional unit is crucial
  - often used mass-based or protein-based FUs might lead to wrong conclusions
  - for comparisons across food groups aggregated indices are recommended
    - ➢ cf. Mc Laren et al. 2021, Green et al. 2021

- Inclusion of protein quality metric in nLCA can be recommended

- Plant based alternatives are in most cases the more „sustainable“ option

- Further research is necessary, in particular in terms of data availability for novel protein sources (e.g. cellbased agriculture)

QUESTIONS

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