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Agroecology and Sustainable Food Systems

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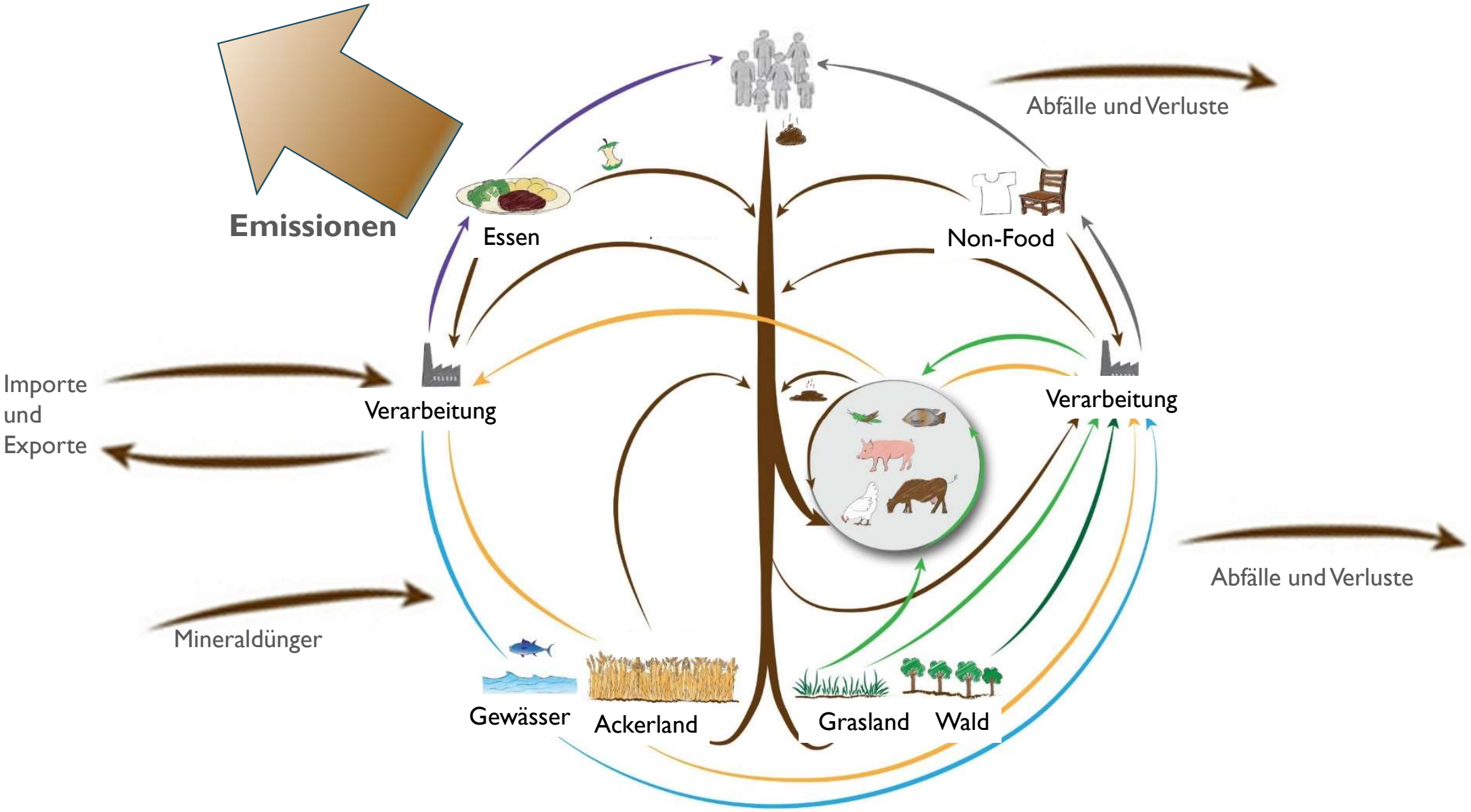
Guest lecture in the master course on "Nature-Based Solutions for Climate Change Adaptation and Mitigation"
Wyss Academy for Nature, University of Berne, February 8, 2024

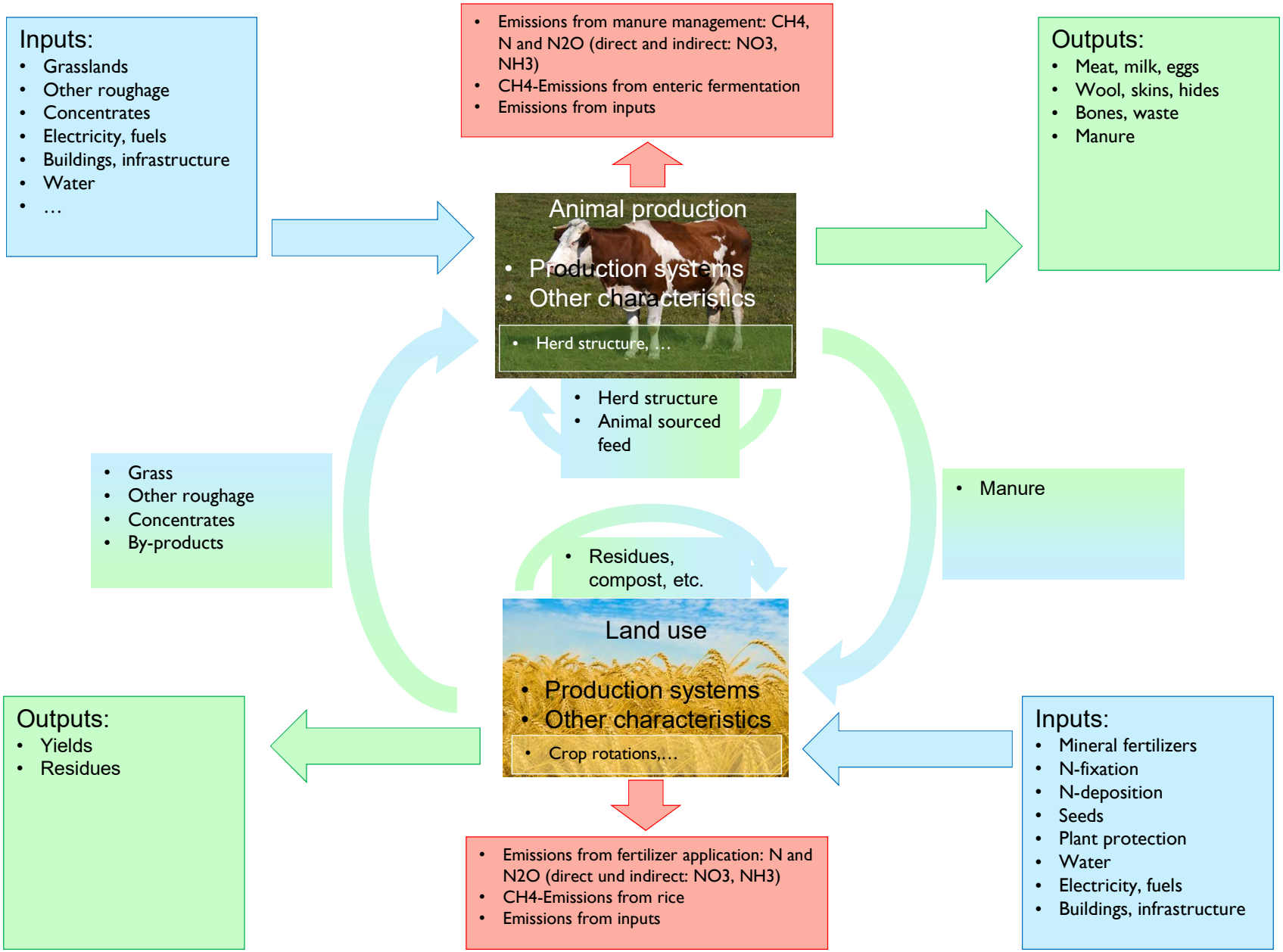
Learning Goals

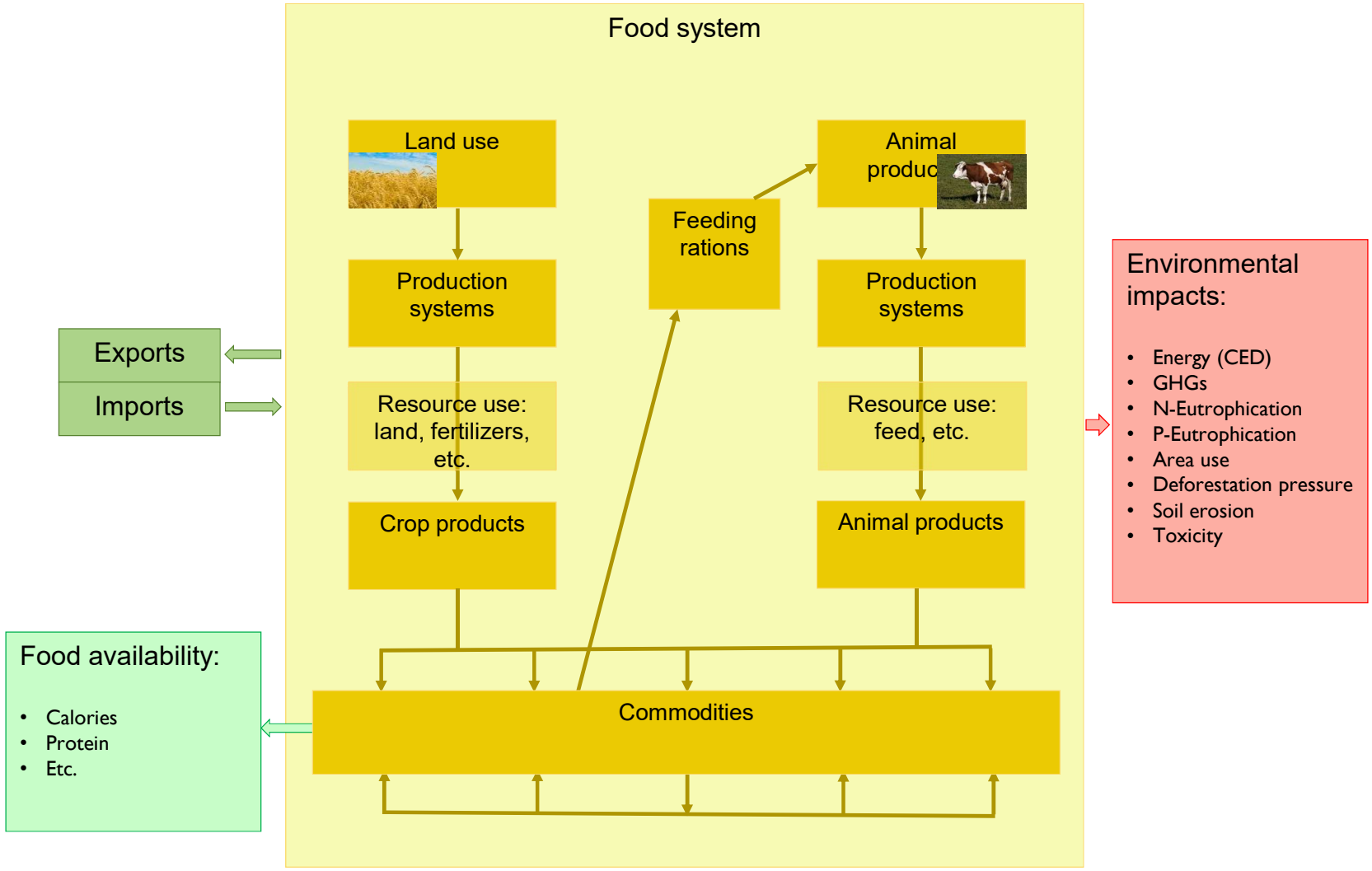
- You can explain what a circular food system is.
- You can explain and critically assess the key aspects of agroecology.
- You can explain how reducing the size of the food system allows for sustainable production.
- You can explain why sustainable agriculture cannot be addressed independently of consumption patterns, or, stated differently, why we need a food-systems approach when talking about sustainable agriculture.

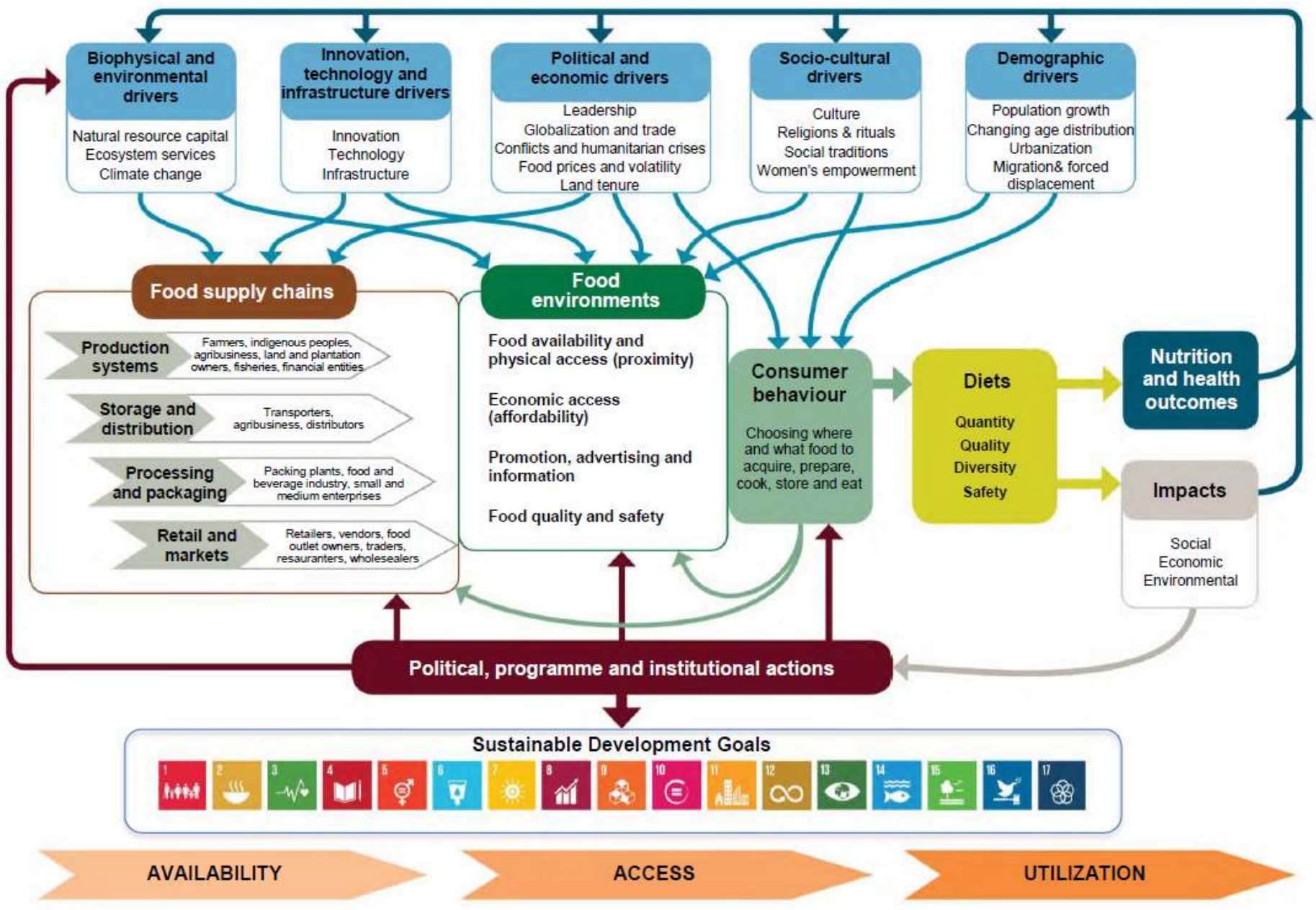
FiBL



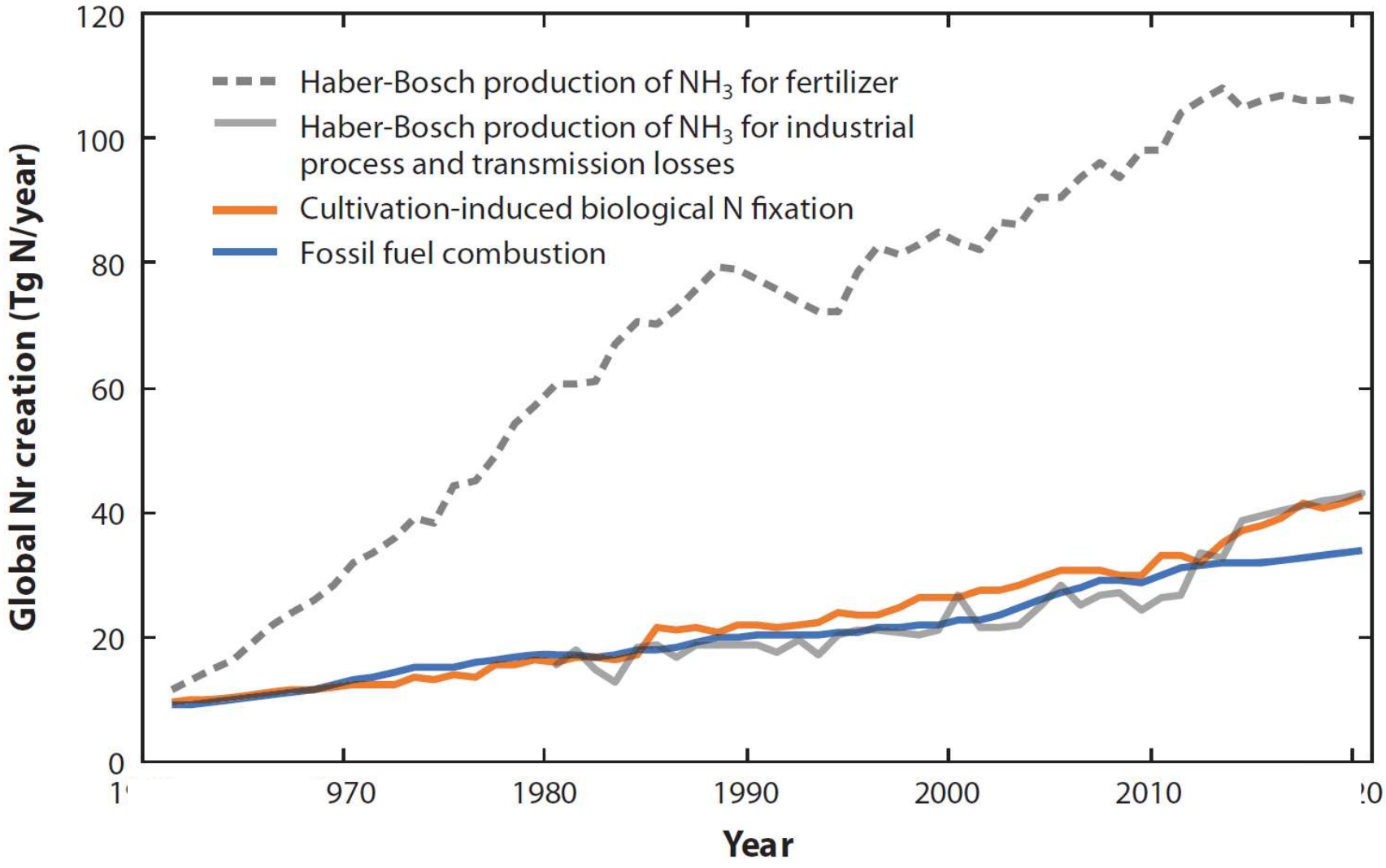
Muscat et al. 2021


Inputs:
• Grasslands
• Other roughage
• Concentrates
• Electricity, fuels
• Buildings, infrastructure
• Water
• …
• Emissions from manure management: CH4, N and N2O (direct and indirect: NO3, NH3)
• CH4-Emissions from enteric fermentation
• Emissions from inputs
Outputs:
• Meat, milk, eggs
• Wool, skins, hides
• Bones, waste
• Manure
Animal production
• Production systems
• Other characteristics
• Herd structure, …
• Herd structure
• Animal sourced feed
• Grass
• Other roughage
• Concentrates
• By-products
• Manure
• Residues, compost, etc.
Land use
• Production systems
• Other characteristics
• Crop rotations,…
Outputs:
• Yields
• Residues
• Emissions from fertilizer application: N and N2O (direct und indirect: NO3, NH3)
• CH4-Emissions from rice
• Emissions from inputs
Inputs:
• Mineral fertilizers
• N-fixation
• N-deposition
• Seeds
• Plant protection
• Water
• Electricity, fuels
• Buildings, infrastructure

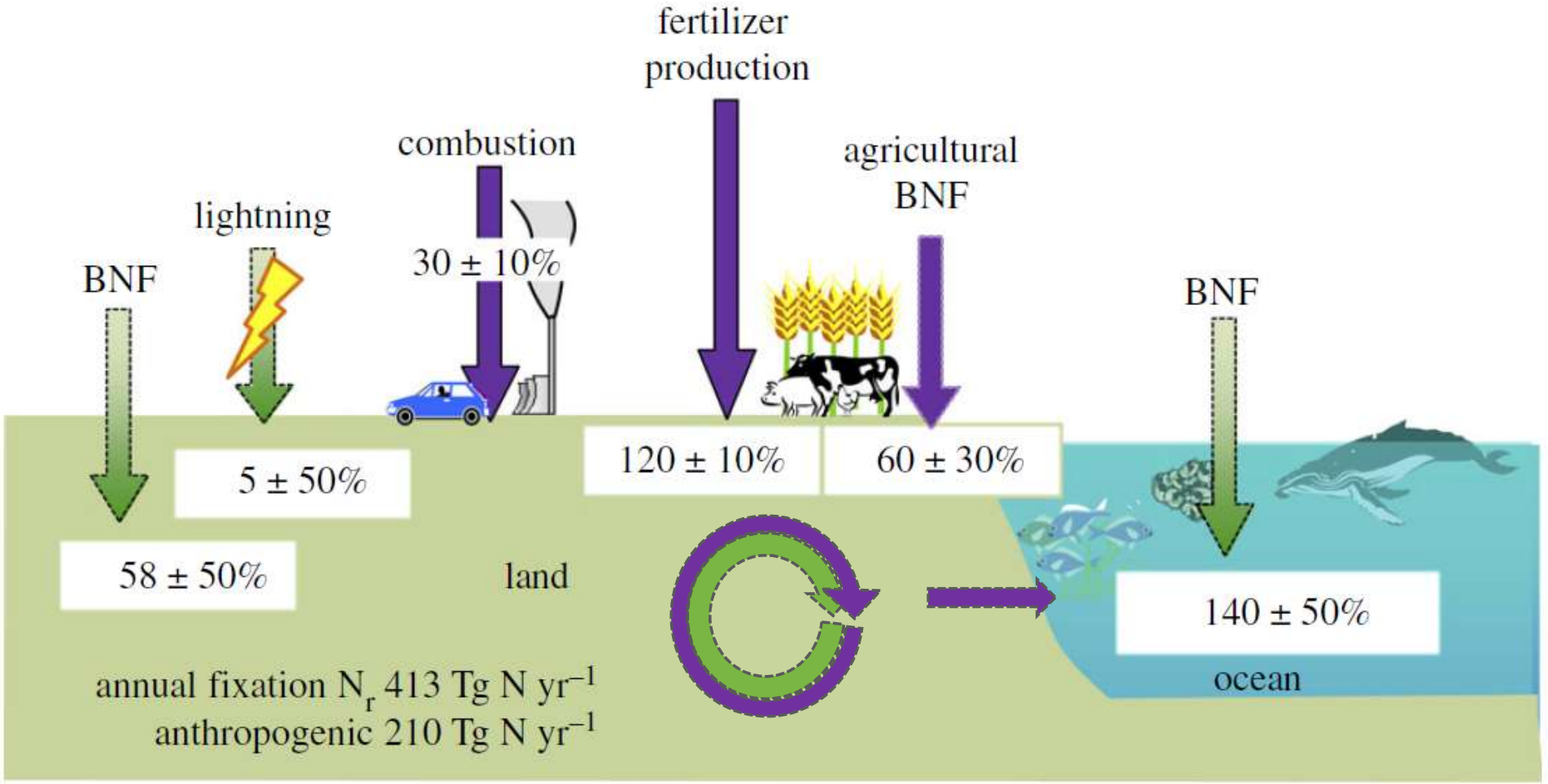

Food system
Land use
Animal produc
Feeding rations
Production systems
Production systems
Exports
Imports
Resource use: land, fertilizers, etc.
Resource use: feed, etc.
Crop products
Animal products
Environmental impacts:
• Energy (CED)
• GHGs
• N-Eutrophication
• P-Eutrophication
• Area use
• Deforestation pressure
• Soil erosion
• Toxicity
Food availability:
• Calories
• Protein
• Etc.
Commodities


Biophysical and environmental drivers
Natural resource capital
Ecosystem services
Climate change
Innovation, technology and infrastructure drivers
Innovation
Technology
Infrastructure
Political and economic drivers
Leadership
Globalization and trade
Conflicts and humanitarian crises
Food prices and volatility
Land tenure
Socio-cultural drivers
Culture
Religions & rituals
Social traditions
Women's empowerment
Demographic drivers
Population growth
Changing age distribution
Urbanization
Migration& forced displacement
Food supply chains
Production systems
Farmers, indigenous peoples, agribusiness, land and plantation owners, fisheries, financial entities
Storage and distribution
Transporters, agribusiness, distributors
Processing and packaging
Packing plants, food and beverage industry, small and medium enterprises
Retail and markets
Retailers, vendors, food outlet owners, traders, resauranters, wholesealers
Food environments
Food availability and physical access (proximity)
Economic access (affordability)
Promotion, advertising and information
Food quality and safety
Consumer behaviour
Choosing where and what food to acquire, prepare, cook, store and eat
Diets
Quantity
Quality
Diversity
Safety
Nutrition and health outcomes
Impacts
Social
Economic
Environmental
Political, programme and institutional actions
Sustainable Development Goals
AVAILABILITY
ACCESS
UTILIZATION

HLPE 2017

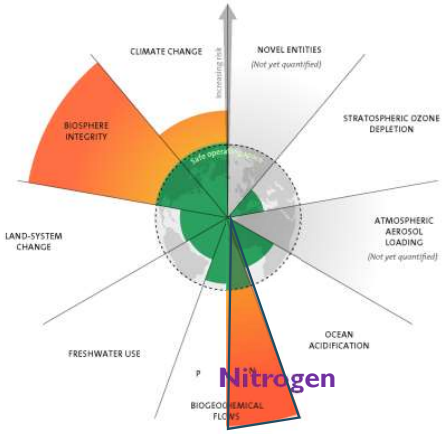


Galloway et al. 2021



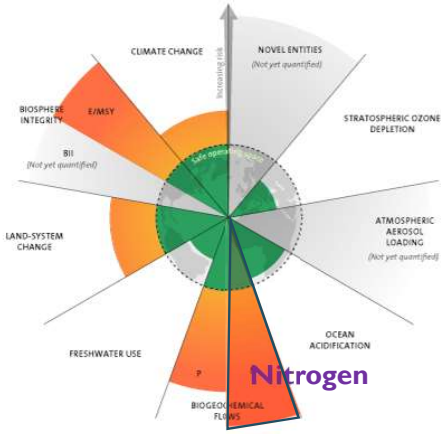
Fowler et al. 2013

2009



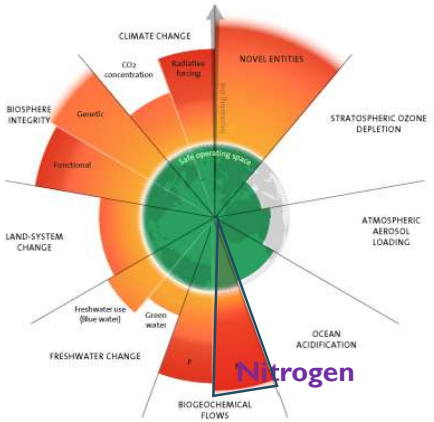
3 boundaries crossed

2015

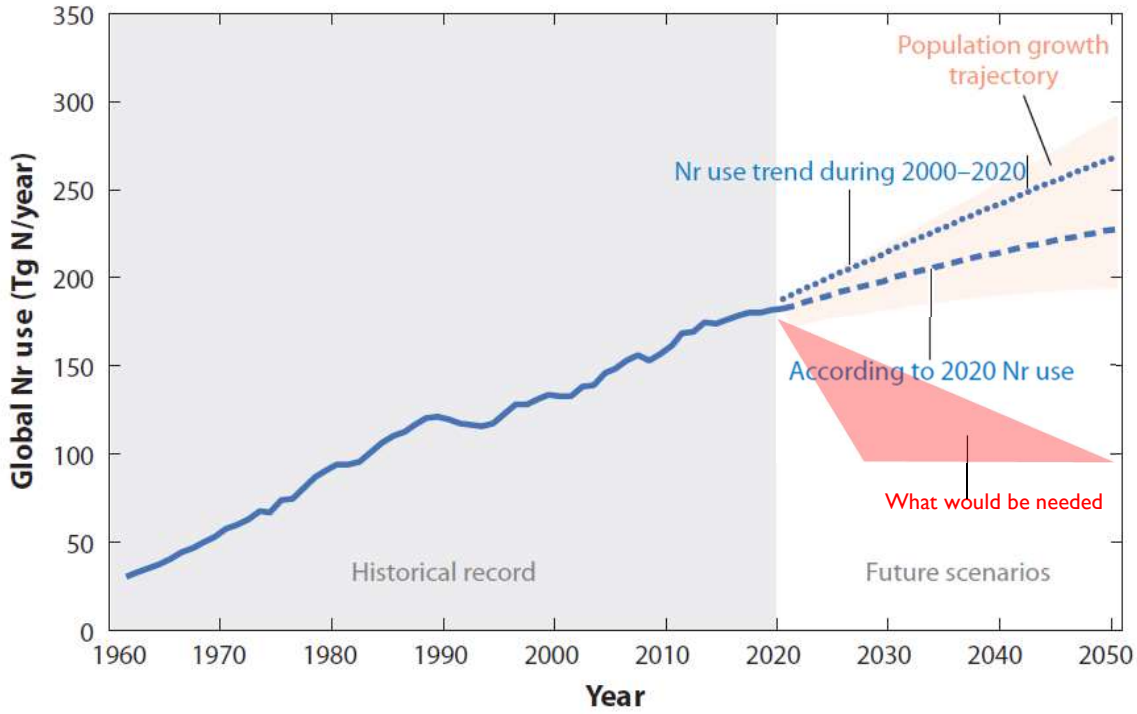


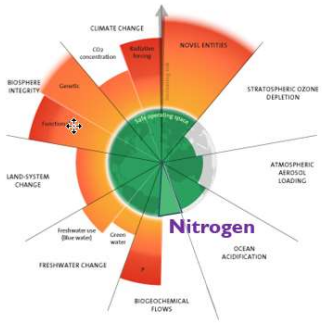
4 boundaries crossed

2023

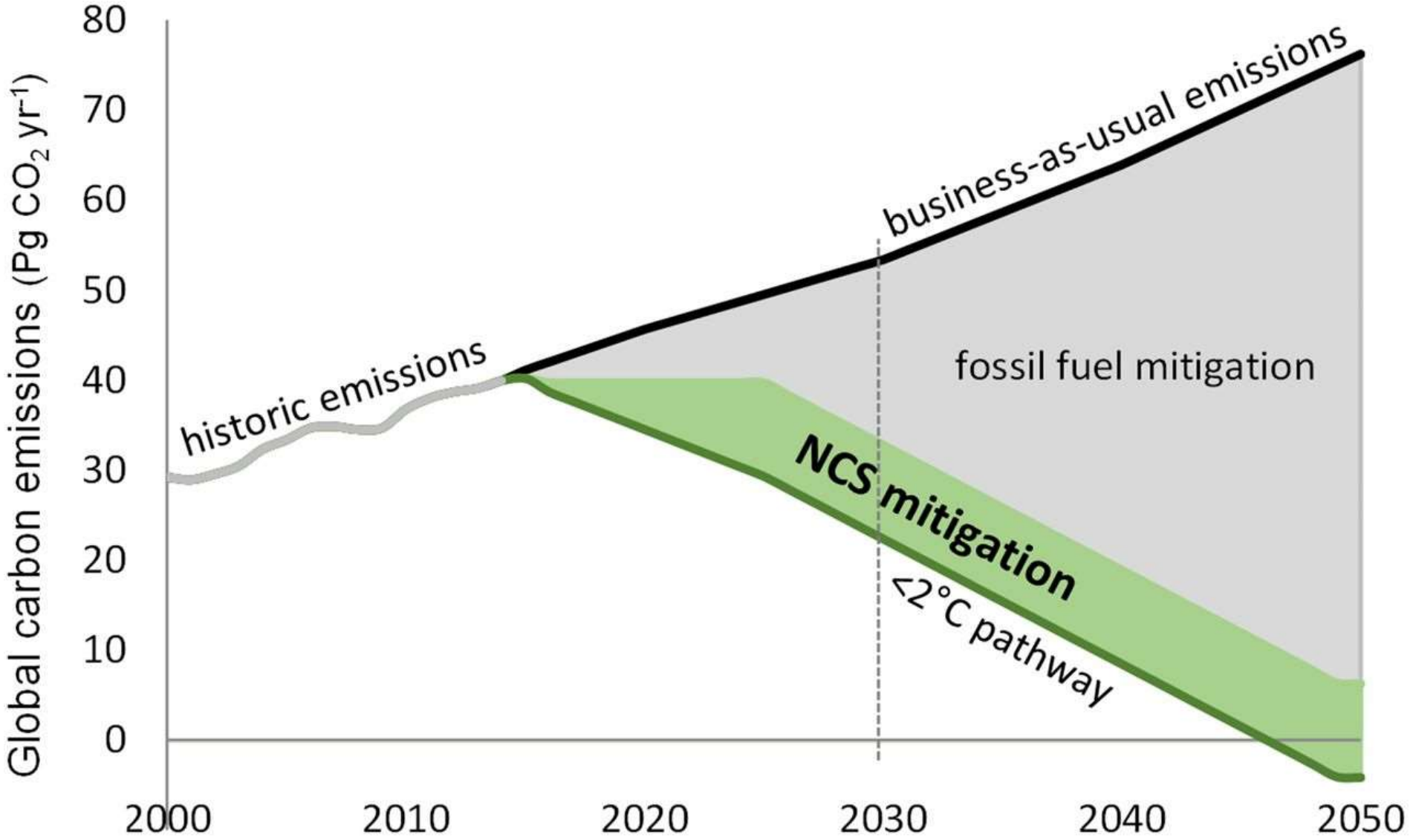


6 boundaries crossed

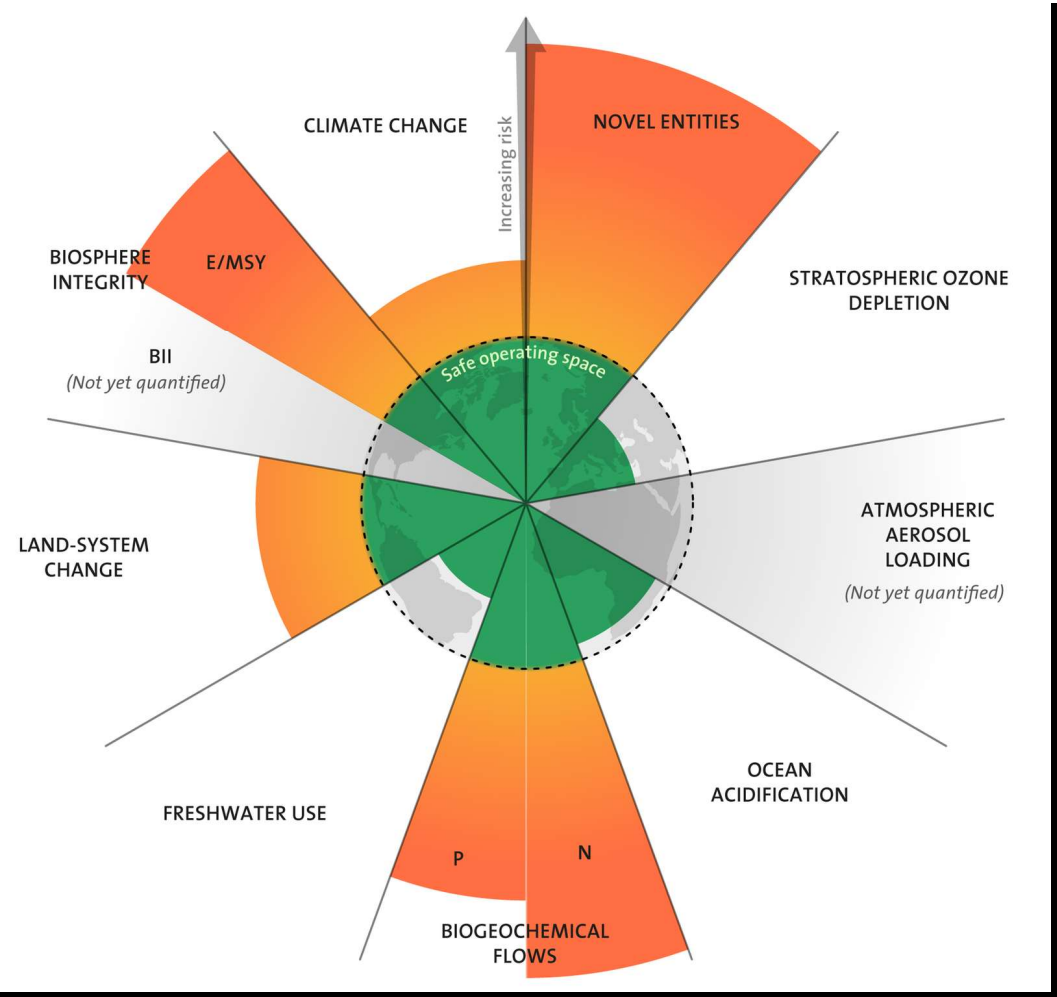




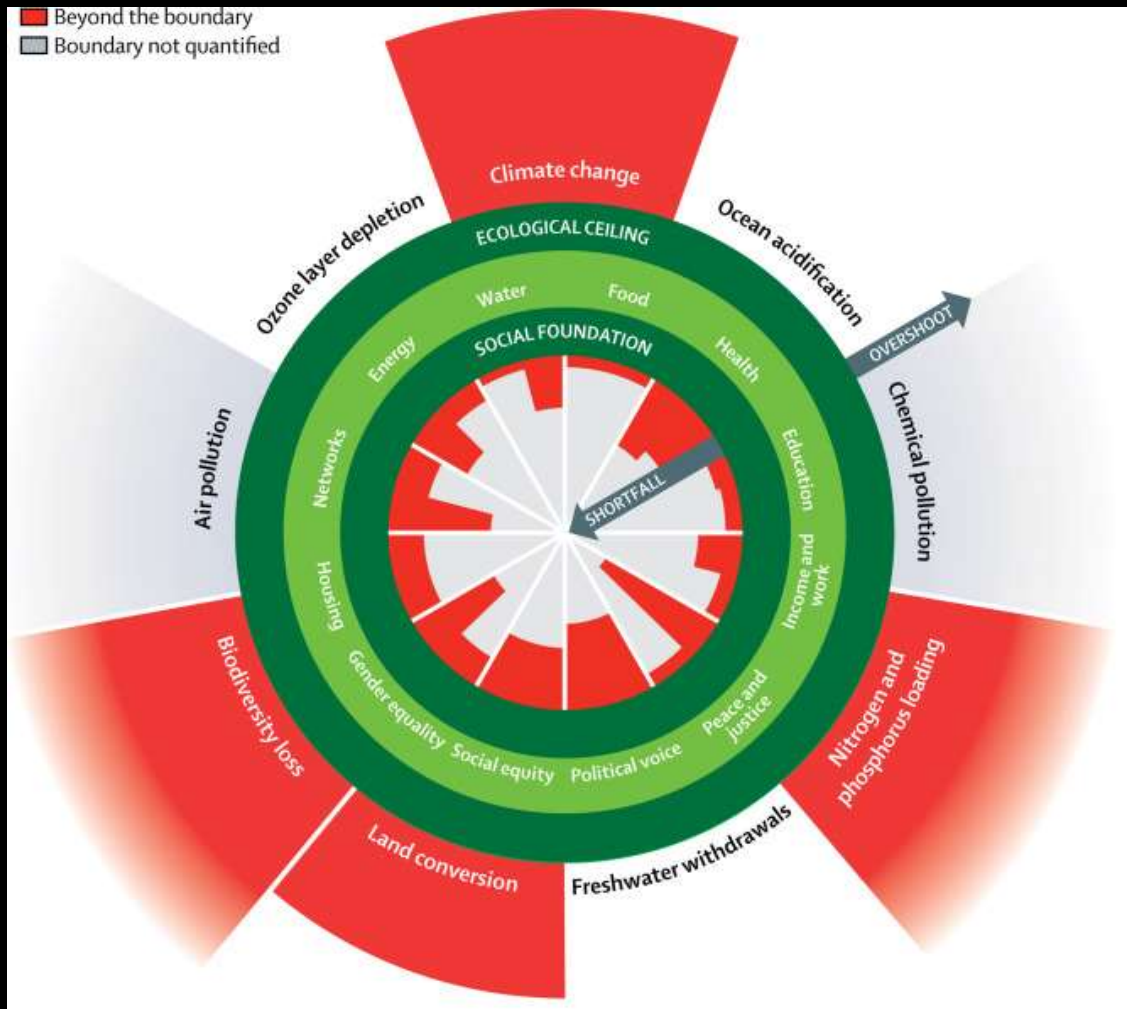
Galloway et al. 2021, SRC 2023, plus eigene Darstellung



Griscom et al. 2017

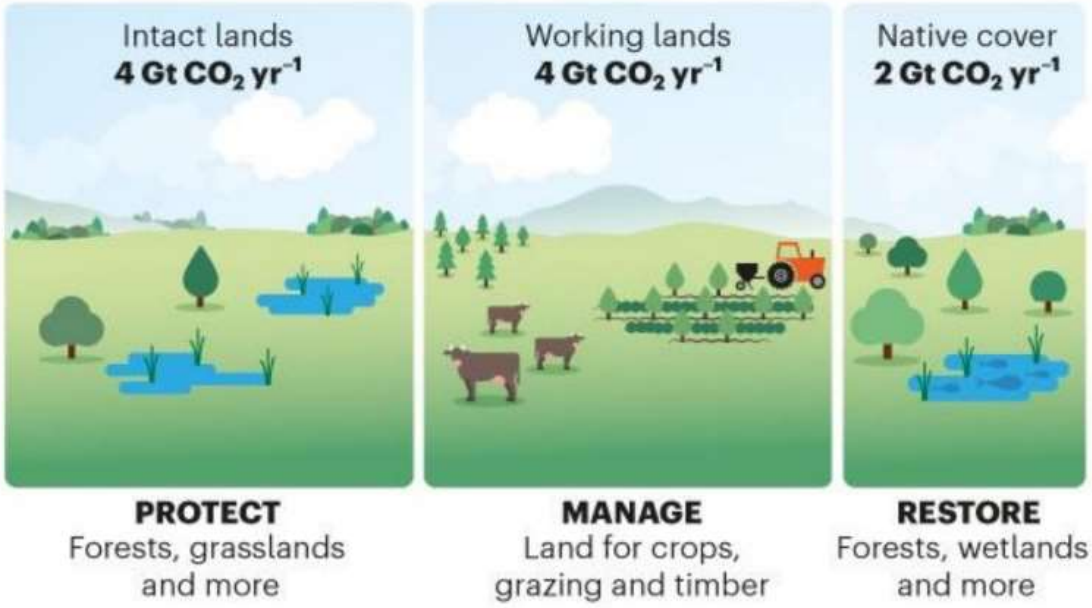


Stockholm Resilience Center 2022



Raworth 2017

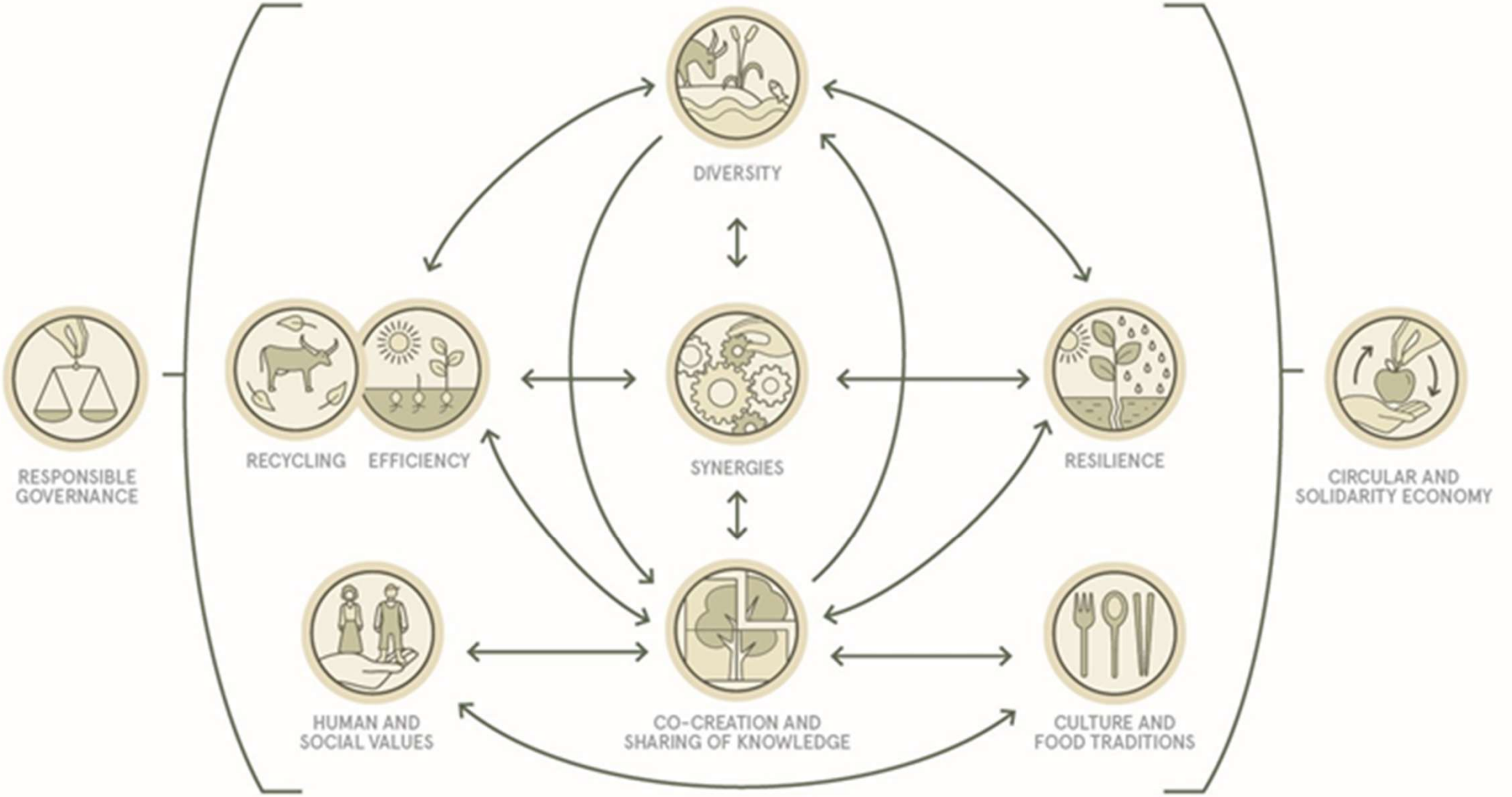
Nature based solutions – definition from the first lesson (from IUCN)



Girardin et al., Nature, 2021

Actions to **protect**, **sustainably manage and restore natural or modified ecosystems** that address societal challenges effectively and adaptively, simultaneously providing **human wellbeing and biodiversity benefits** (IUCN)

The 10 Elements of Agroecology according to the FAO



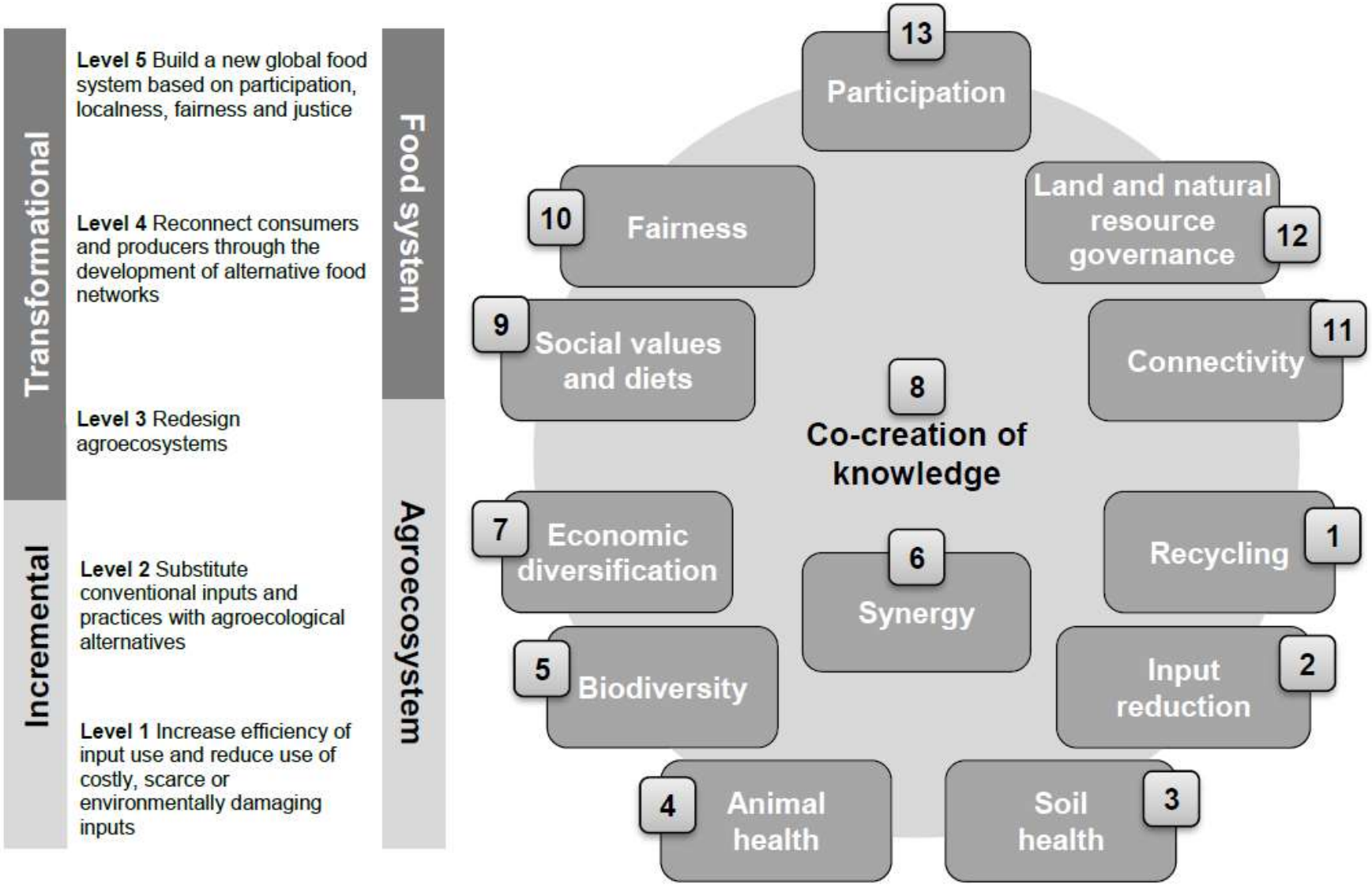
FAO 2018

The 13 Principles of Agroecology

and the

5 Gliessman levels

Figure 3 Five levels of transition towards SFSs and related principles of Agroecology



What is organic agriculture?

„We define Organic Agriculture as

a production system that

sustains the health of soils, ecosystems and people;
relies on ecological processes, biodiversity and cycles adapted to local conditions,
rather than the use of inputs with adverse effects; and
combines tradition, innovation and science
to benefit the shared environment and
promote fair relationships and a good quality of life for all involved.“

In practice, simplistic formulation:

- no mineral fertilizer
- no synthetic pesticides
- focus on good crop rotations and good soils
- biological plant protection

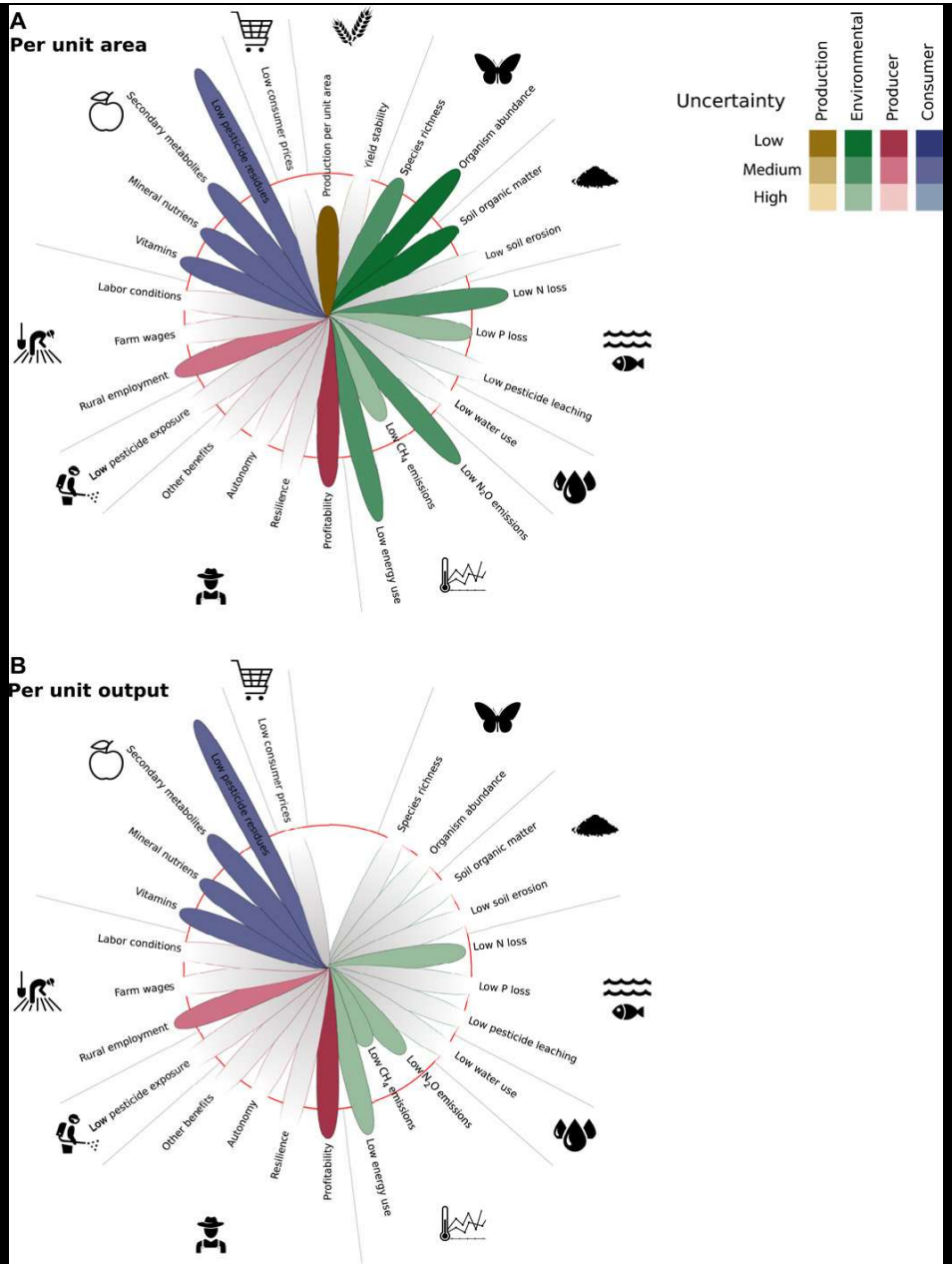
		Indicators for climate change adaptation																	
		Soil health		**Biodiversity**		**Plant protection**			**Productivity**									**Employ-ment**	**Health**
		Soil organic carbon	Soil fertility	Species richness/ abundance/ diversity	Stability of species richness/ abundance	Natural plant protection	Weed abundance	Pathogen abundance	Total biomass production	Stability in total production	Yield	Yield stability	Pollination services	Resource use efficiency	Eco-system services stability	Profitability	Stability of costs and profits	Rural employ-ment	Exposure to pesticides
Agroecological practices	Organic agriculture	✓	✓	✓	✓		×	✓			×	×						✓	✓
	Low-input systems			✓							×								
	Agroforestry		✓	✓					✓										
	No tillage	✓	✓								×								
	Reduced tillage	✓	✓																
	Cover crops	✓	✓																
	Biochar	✓																	
	Organic fertilizers	✓	✓						×										
	Crop rot./ diversity/ intercropping	✓	✓	✓		✓				✓		✓				✓	✓		
	Grassland diversity										✓								
	Practices enhancing biodiversity & complex landscapes					✓					✓		✓	✓	✓				

Muller et al. 2021

- **Environmental impacts**

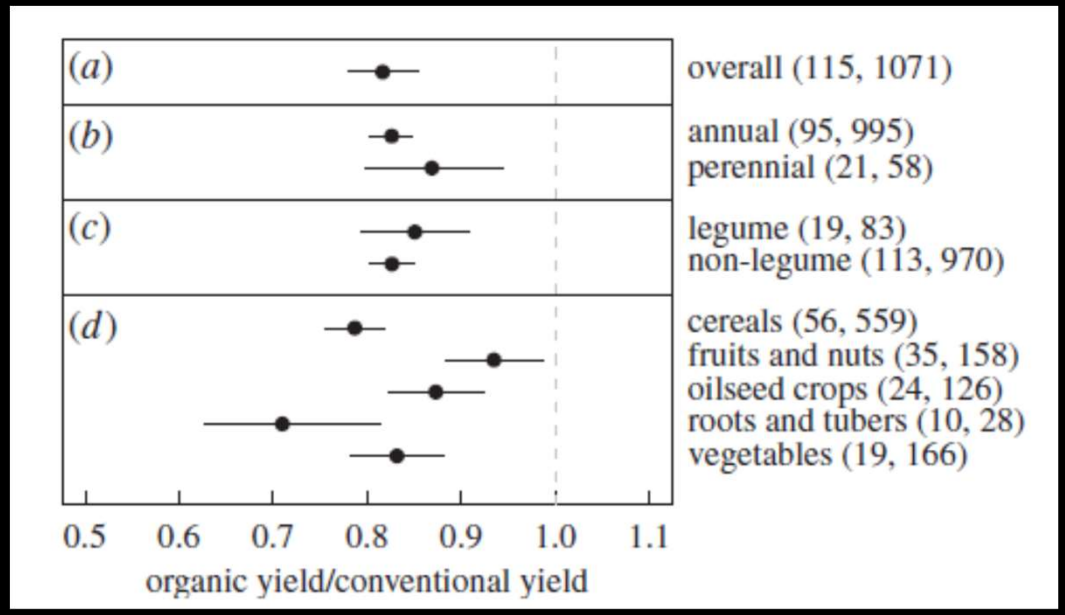
per hectare

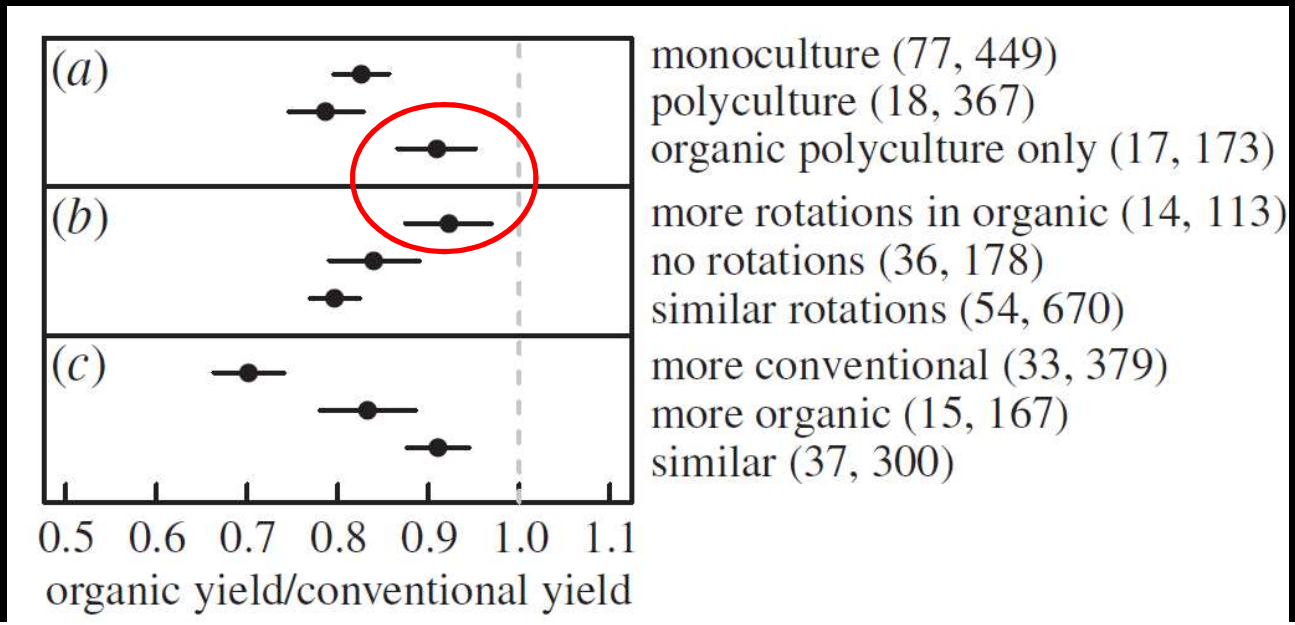
per kg product



Seufert und Ramankutty 2017

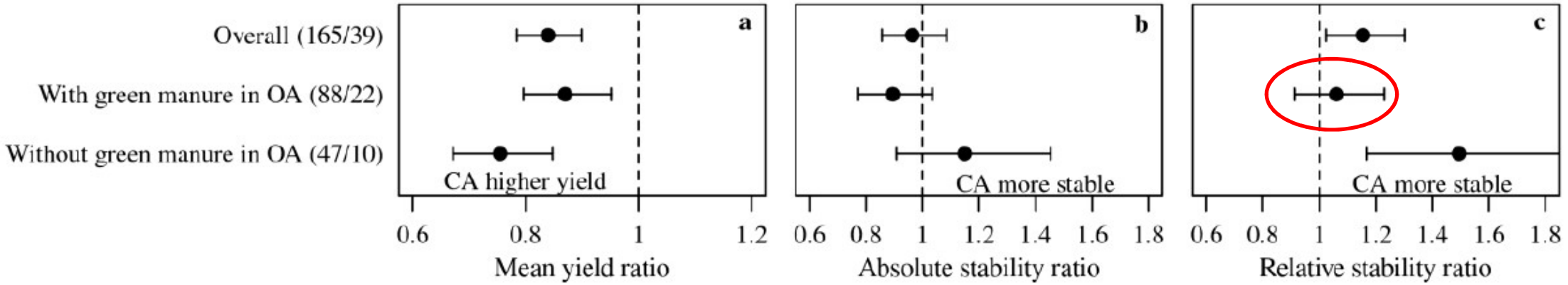
Yields





Ponisio et al. 2014

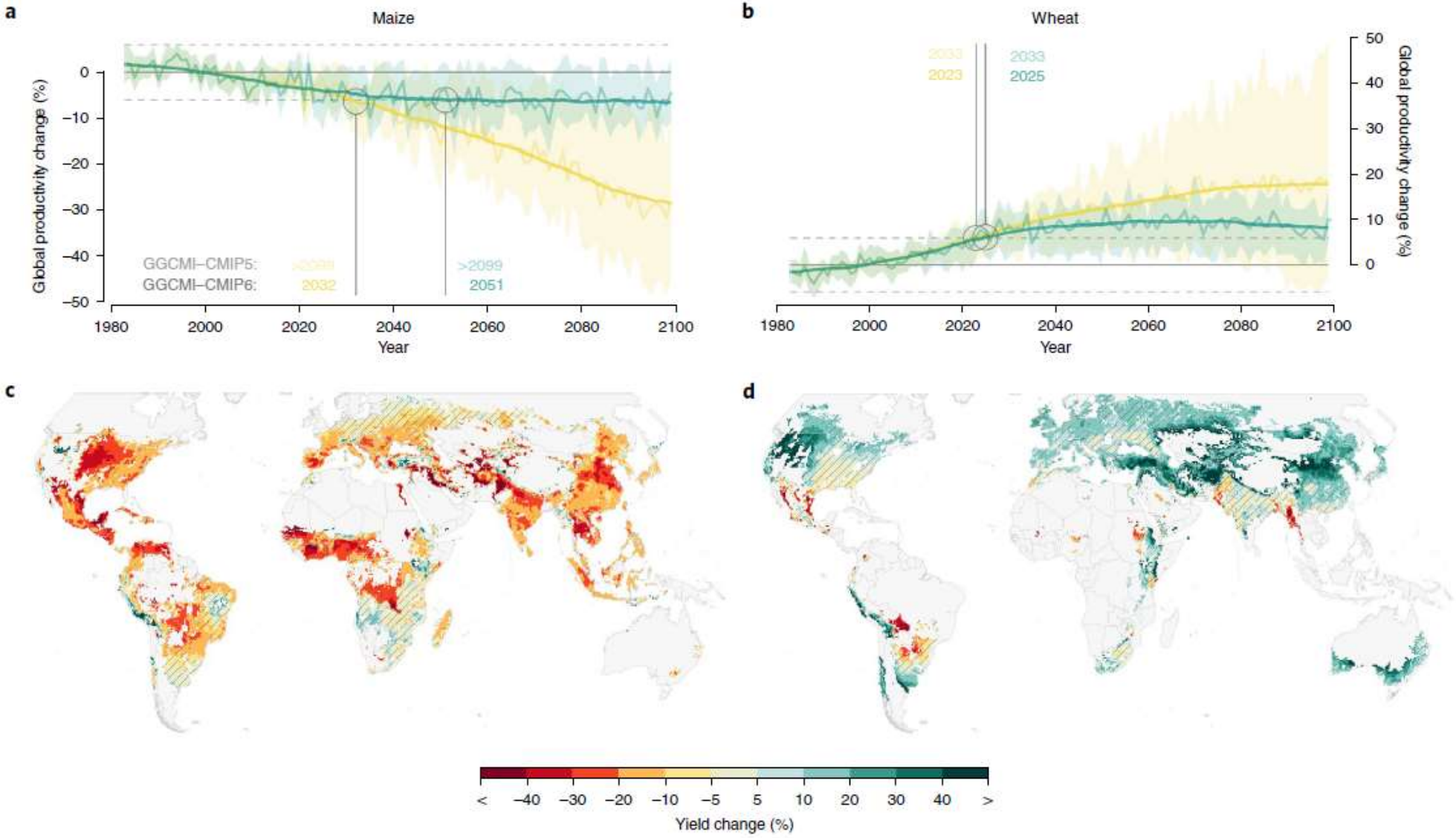
Yield stability



Lack of diversity in organic agriculture?

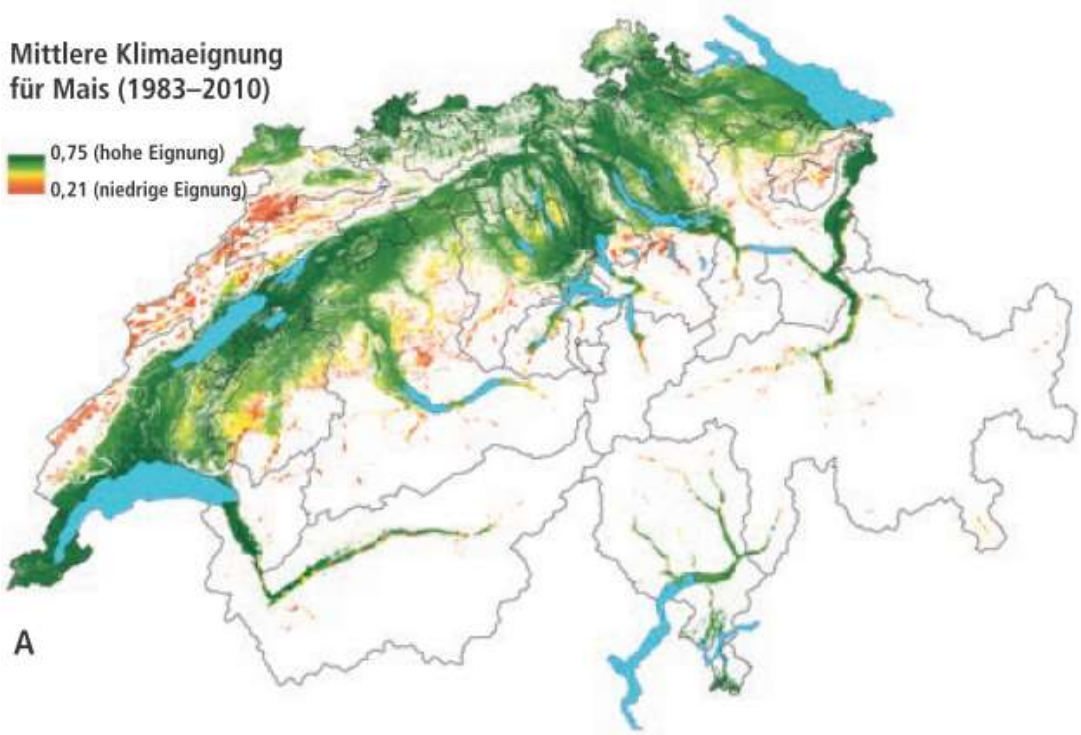
cf. e.g. large-scale organic operations in eastern Europe

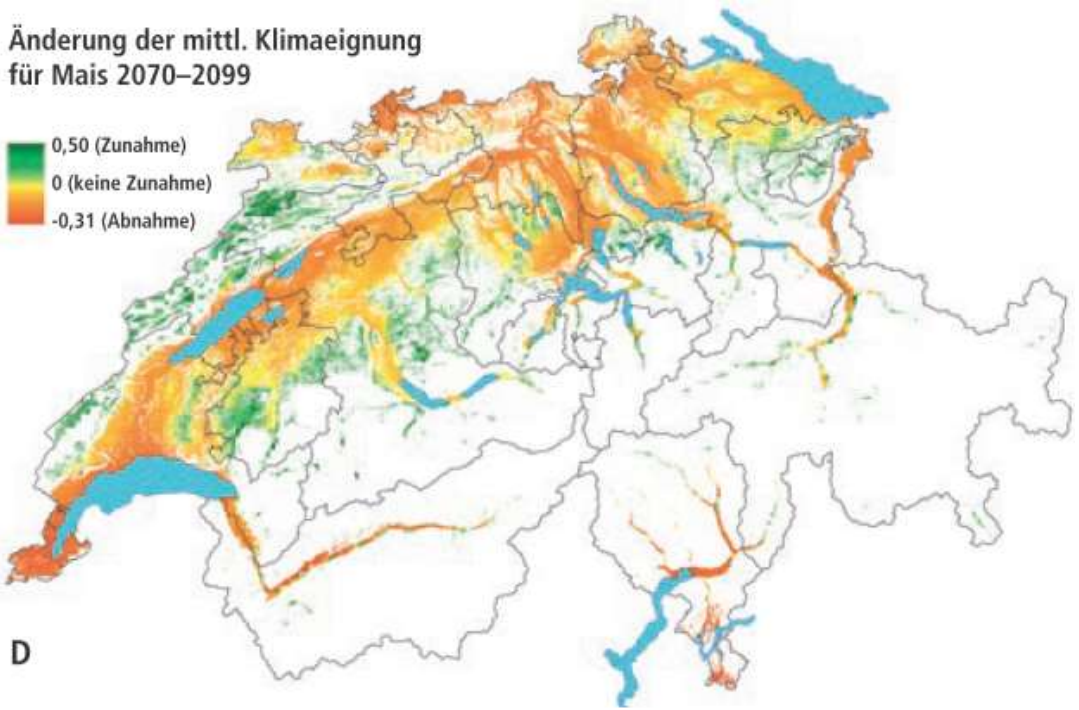
Knapp und van der Heijden 2018



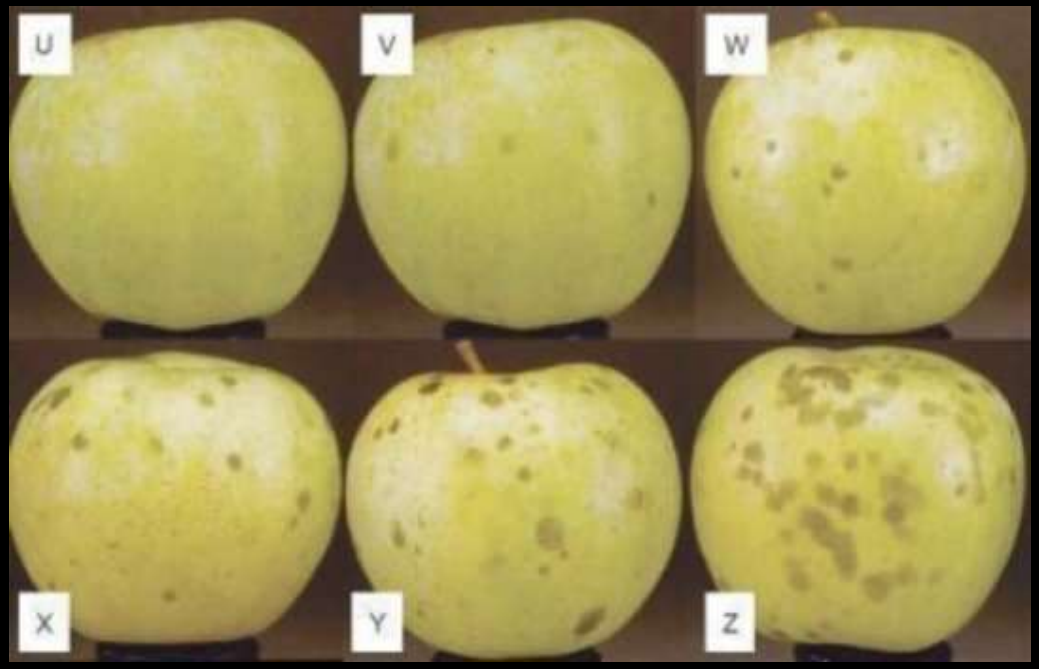
Jägermeyr et al. 2021

Eignung für Maisanbau unter dem Klimawandel

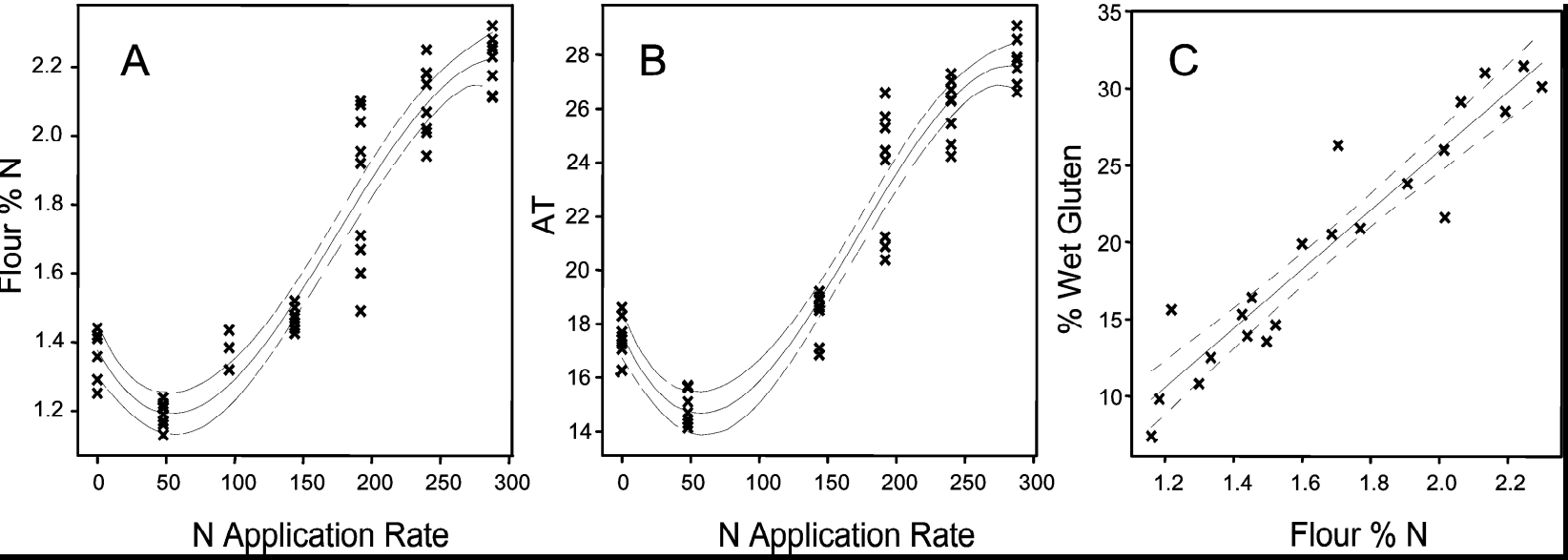


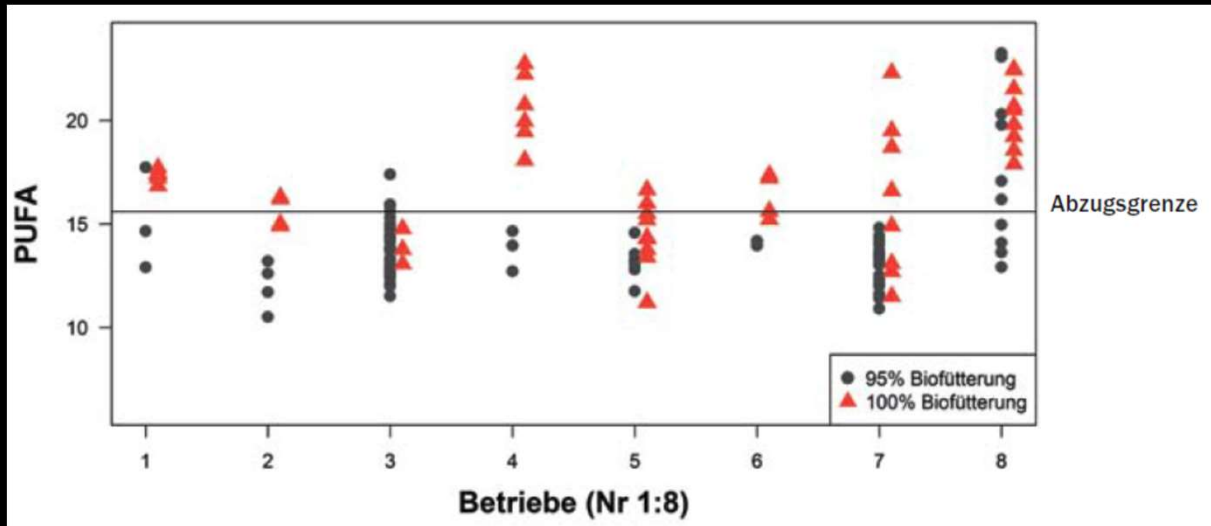


Holzkämper A., Fuhrer J. (2015): Wie sich der Klimawandel auf den Maisanbau in der Schweiz auswirkt. Agrarforschung Schweiz 6 (10): 440-447



ScienceDaily 2007; Photo: Chengyan Yue / jp.123rf.com

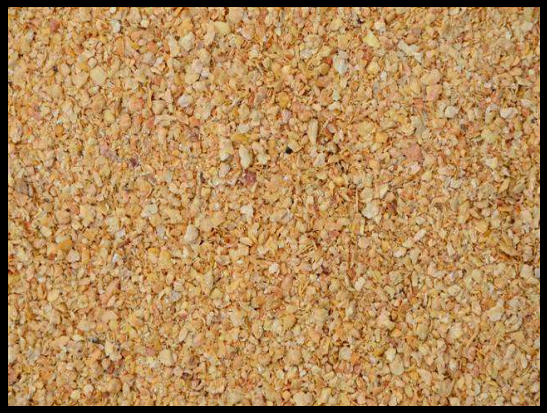




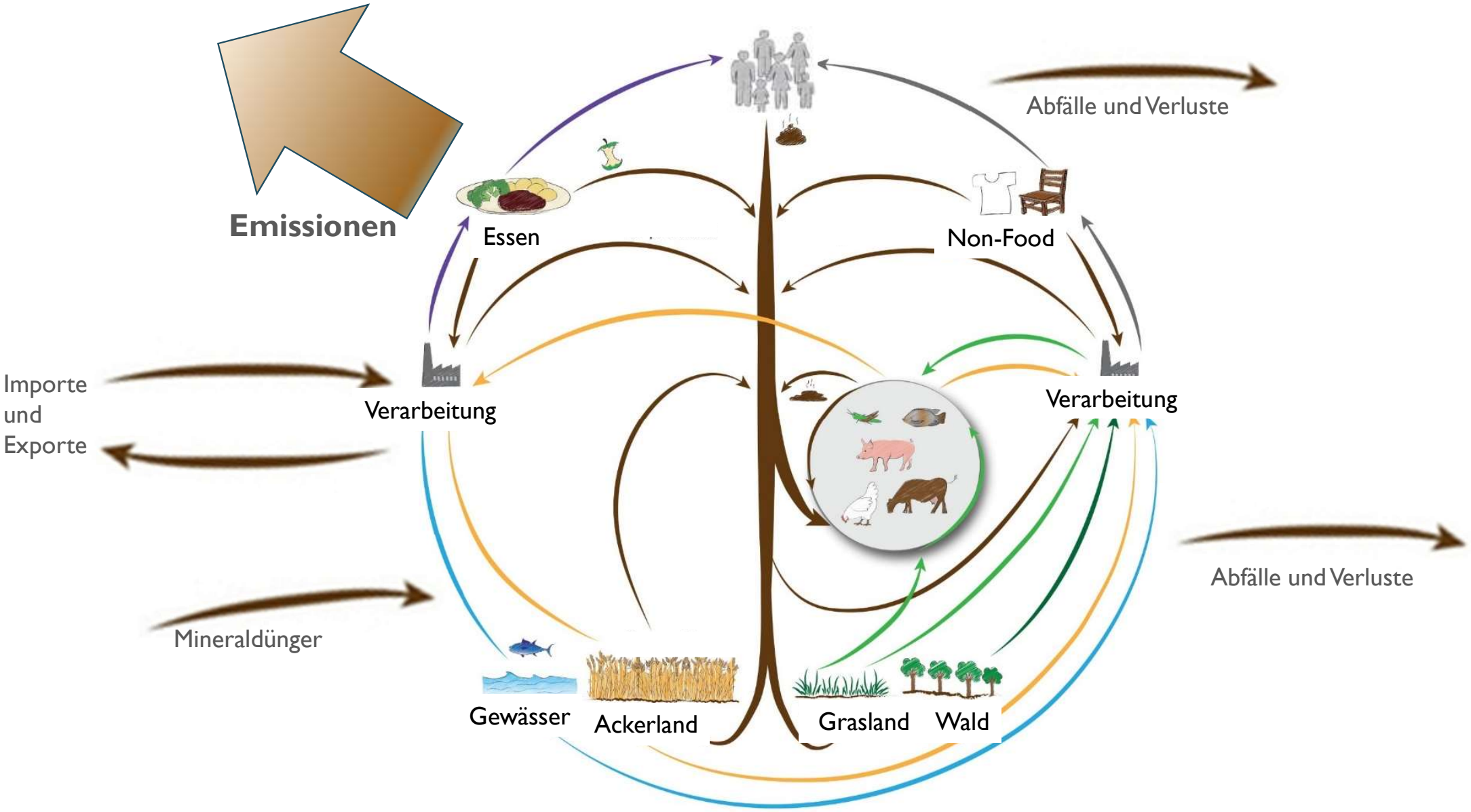
Vergleich der PUFA-Zahl-Messungen zwischen 100 Prozent Biofütterung und 95 Prozent Biofütterung auf acht Versuchsbetrieben mit unterschiedlichen Futterrationen. *Grafik: FiBL*

Godfrey et al. 2010; Früh 2016

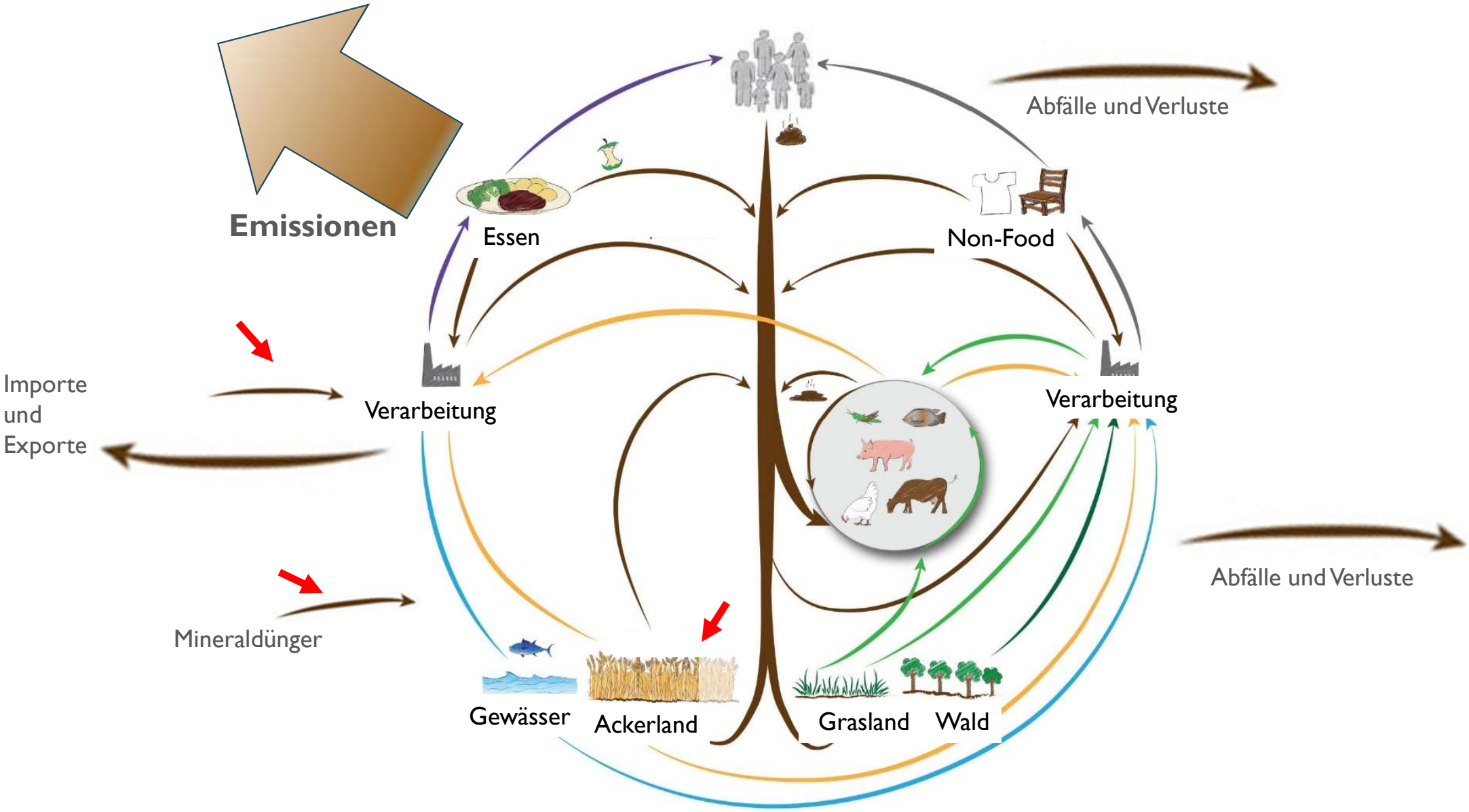
Todays and future business as usual food systems



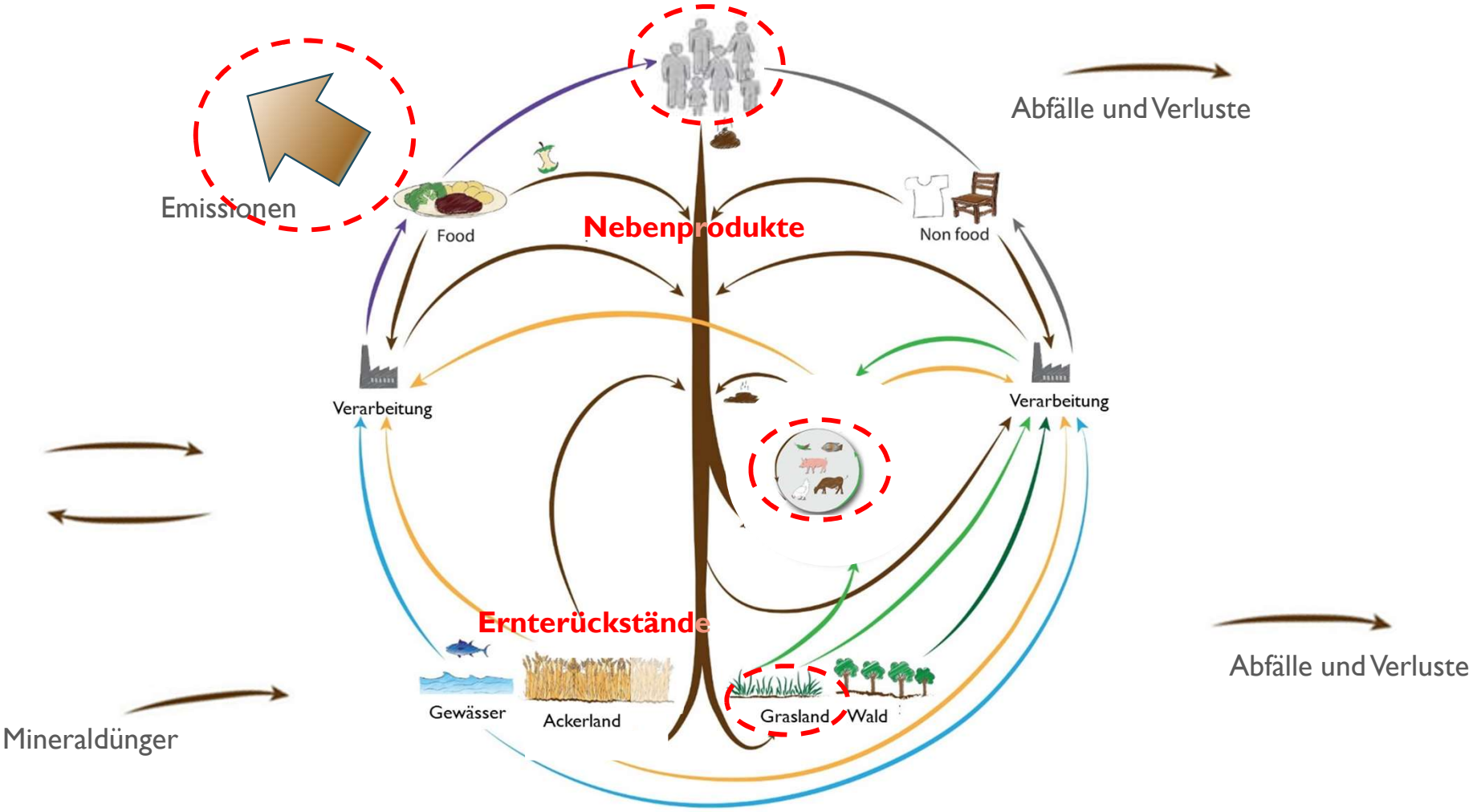
- 3000 kcal per capita and day (global)
  - 35-40% protein from animal sources
- 30% food waste and losses
- High shares of feed from croplands
  - EU: 60% of croplands is used for feed production



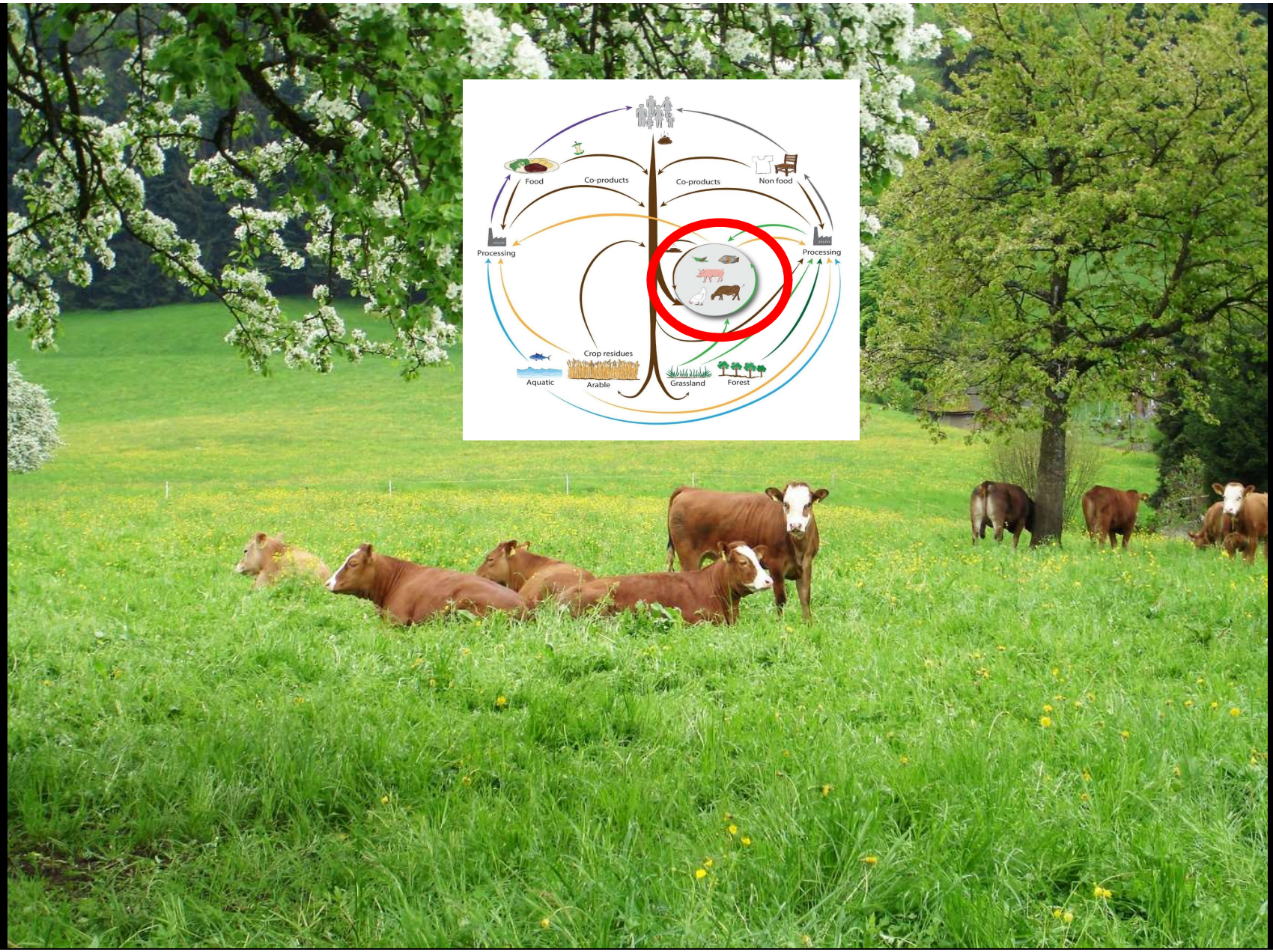
Muscat et al. 2021



Muscat et al. 2021

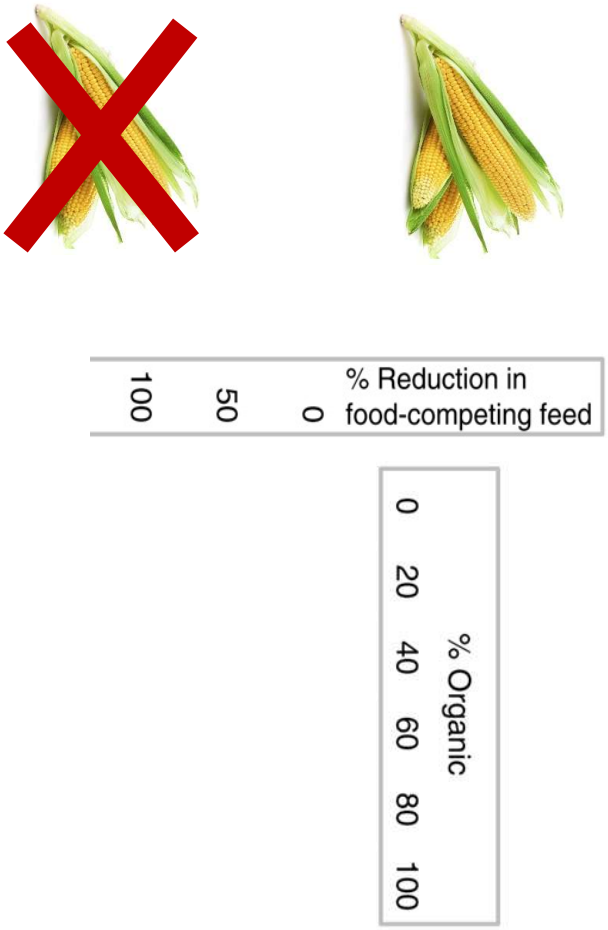


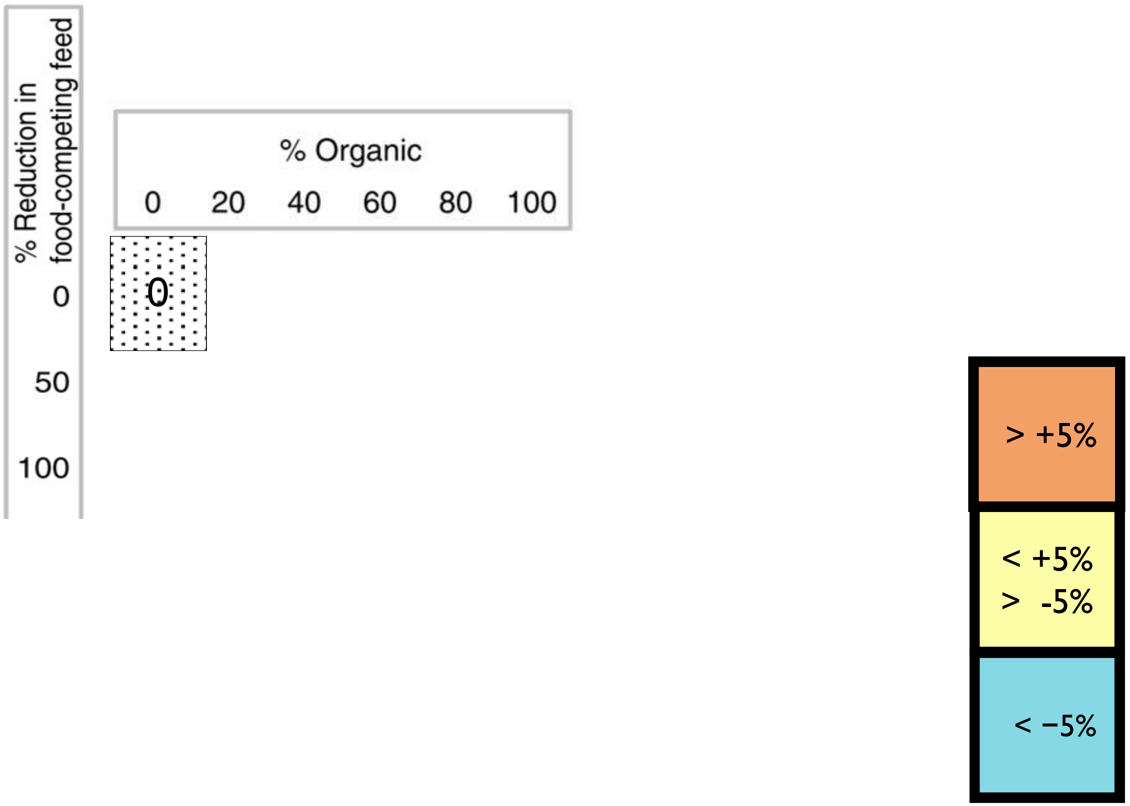
Muscat et al. 2021



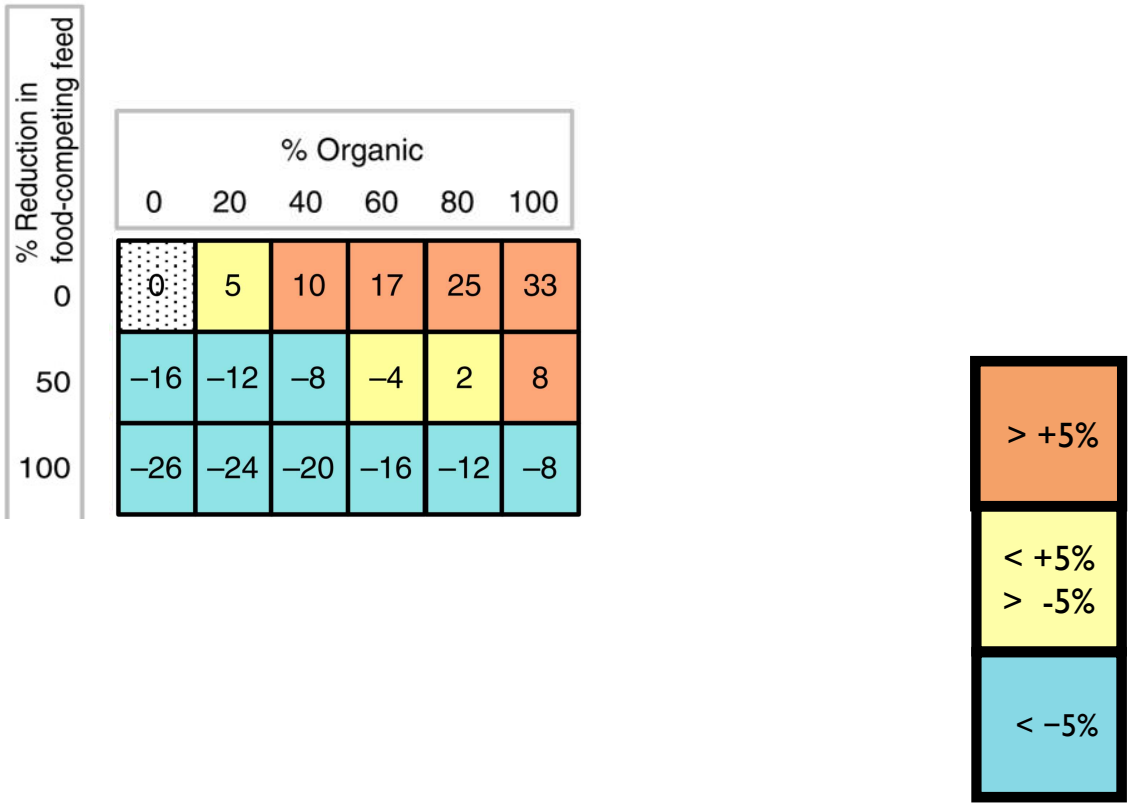
Biohoif Wigger Obernau

Muller et al. 2017; Courtesy: R. Zürcher

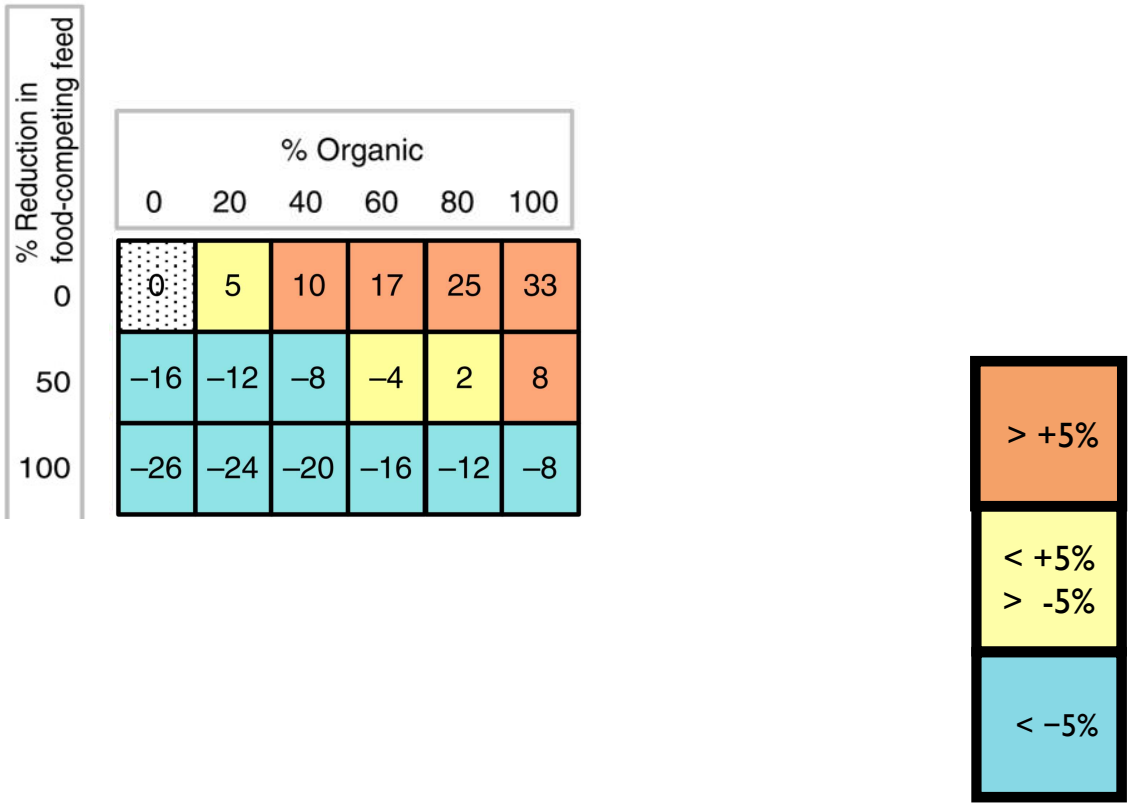




Muller et al. 2017; Courtesy: R. Zürcher



Muller et al. 2017; Courtesy: R. Zürcher



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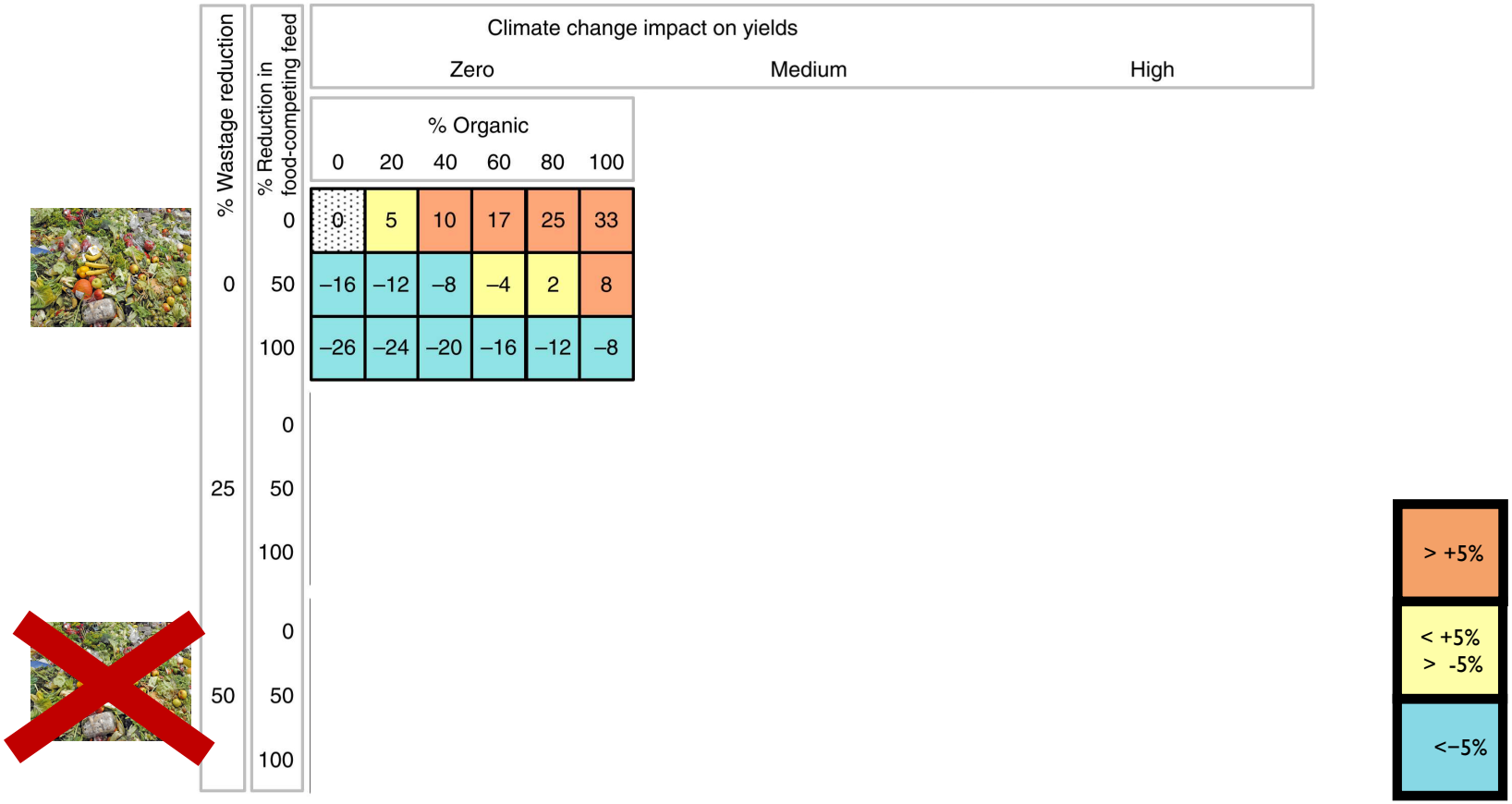
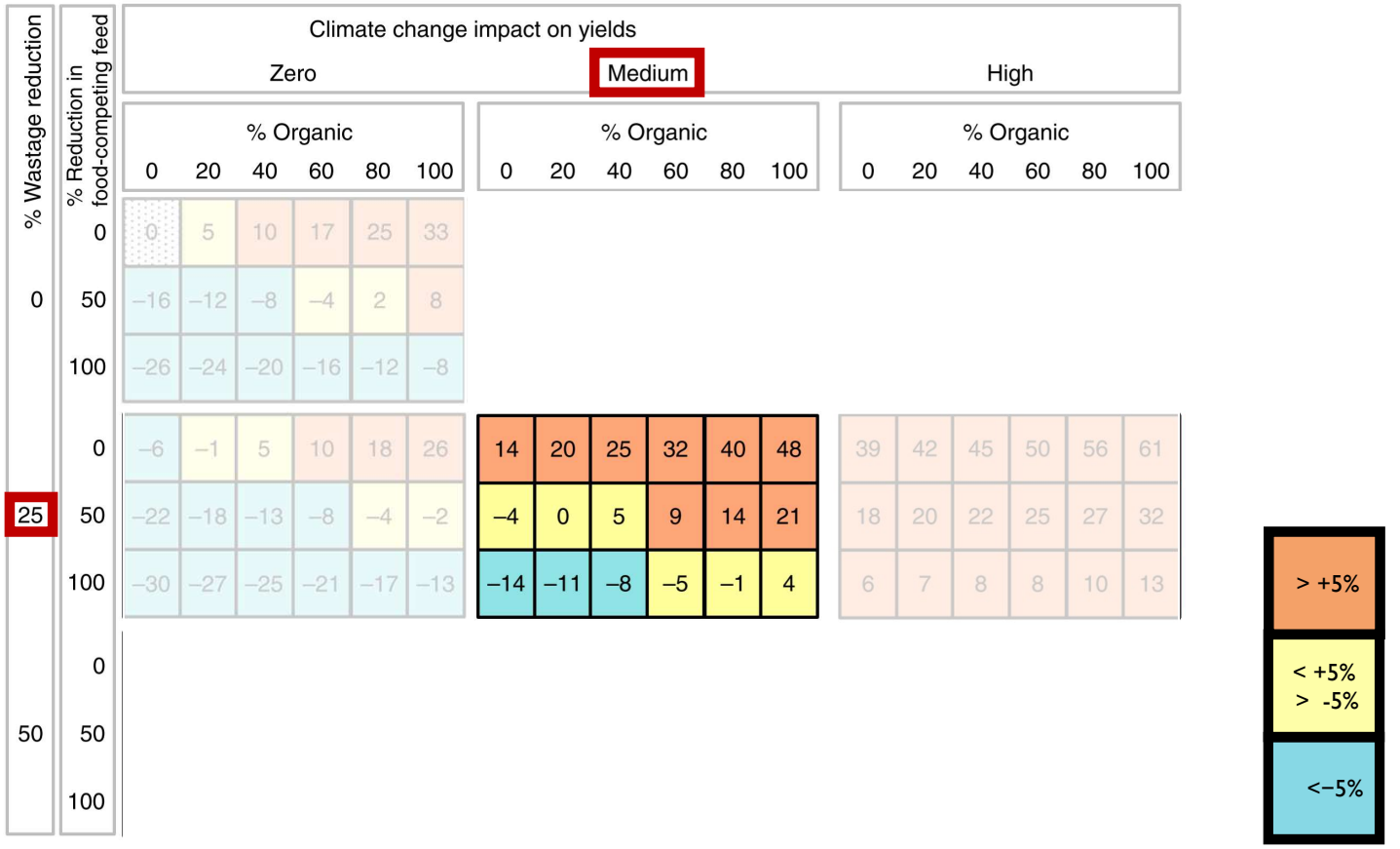
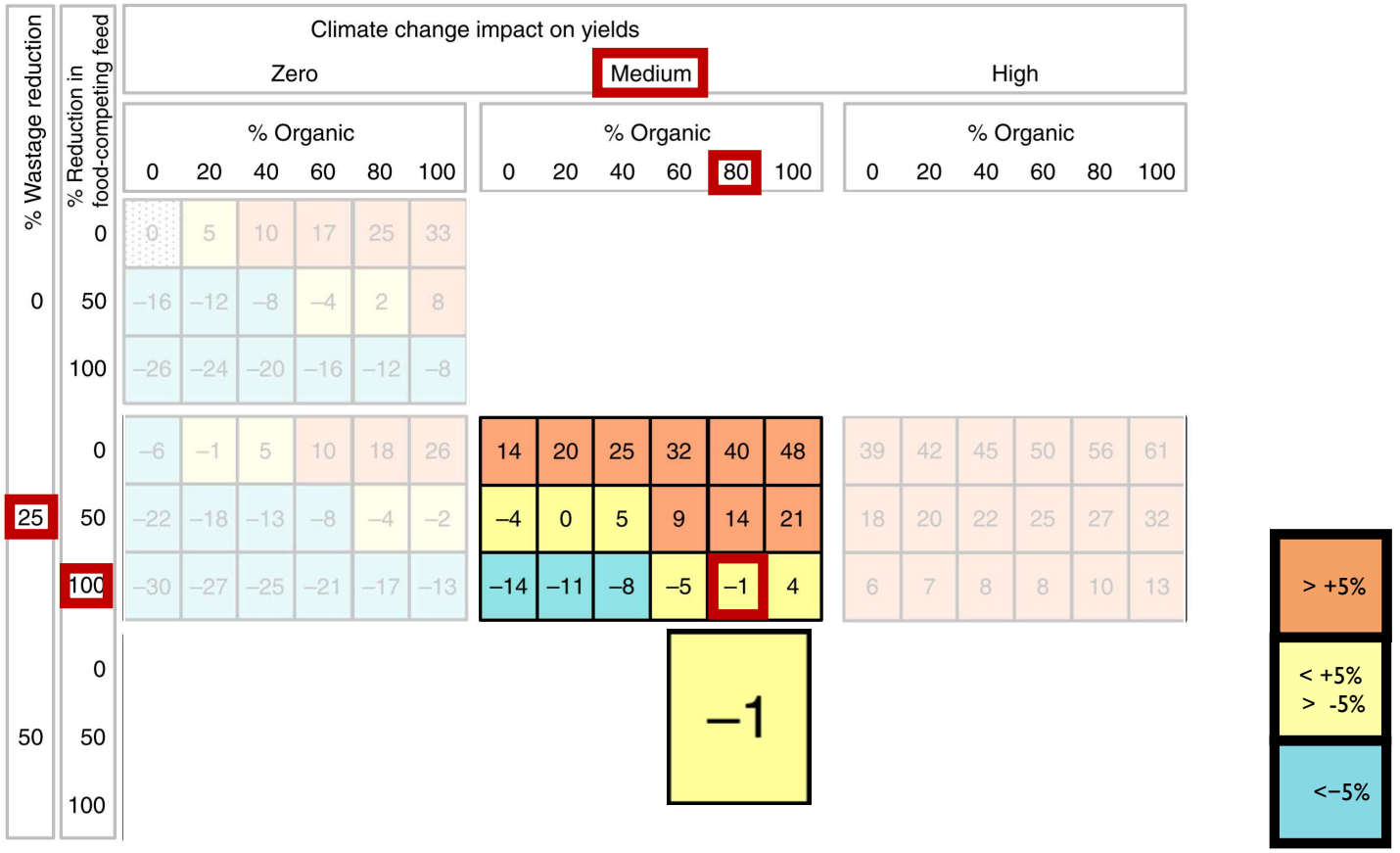


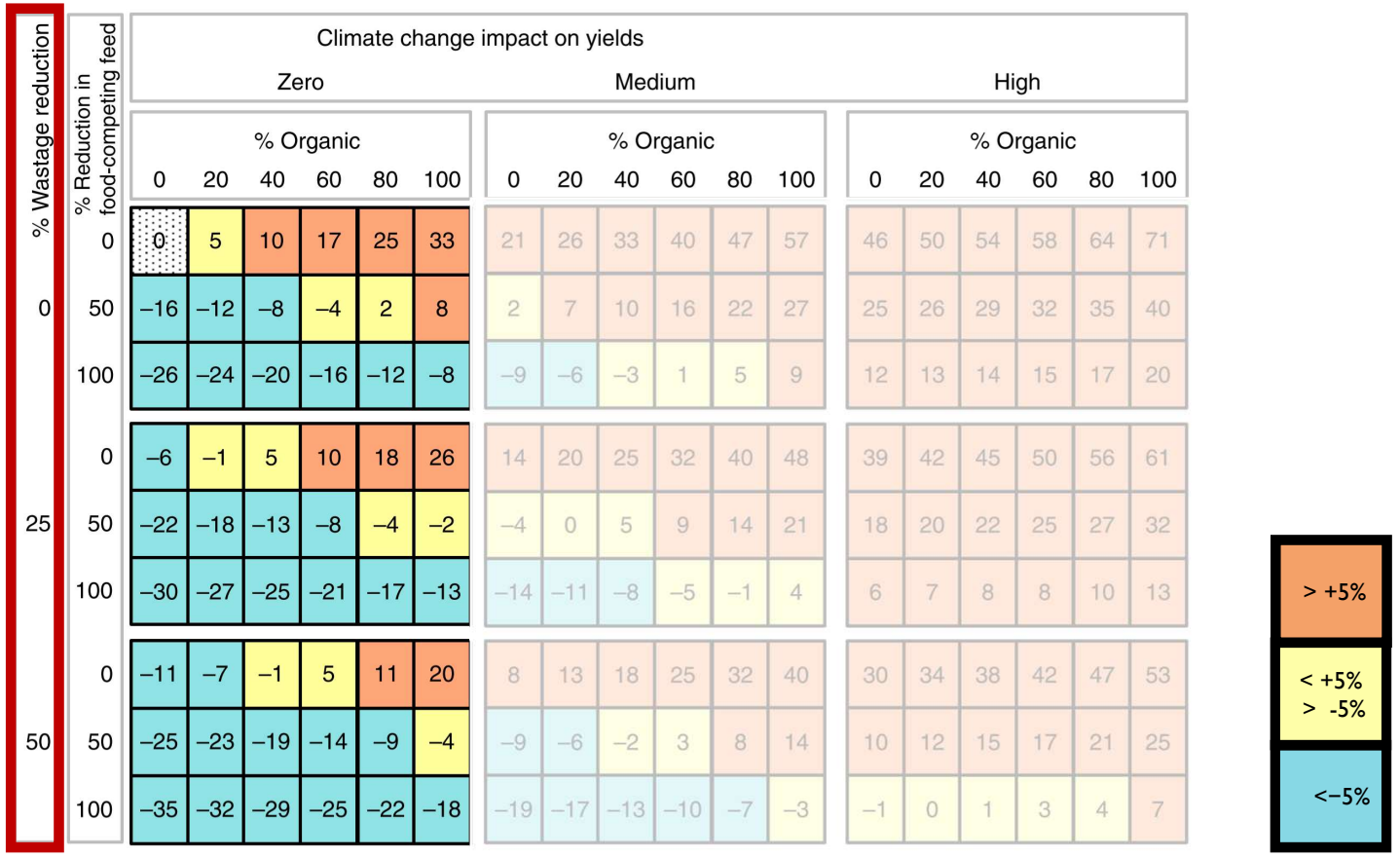
Muller et al. 2017; Courtesy: R. Zürcher



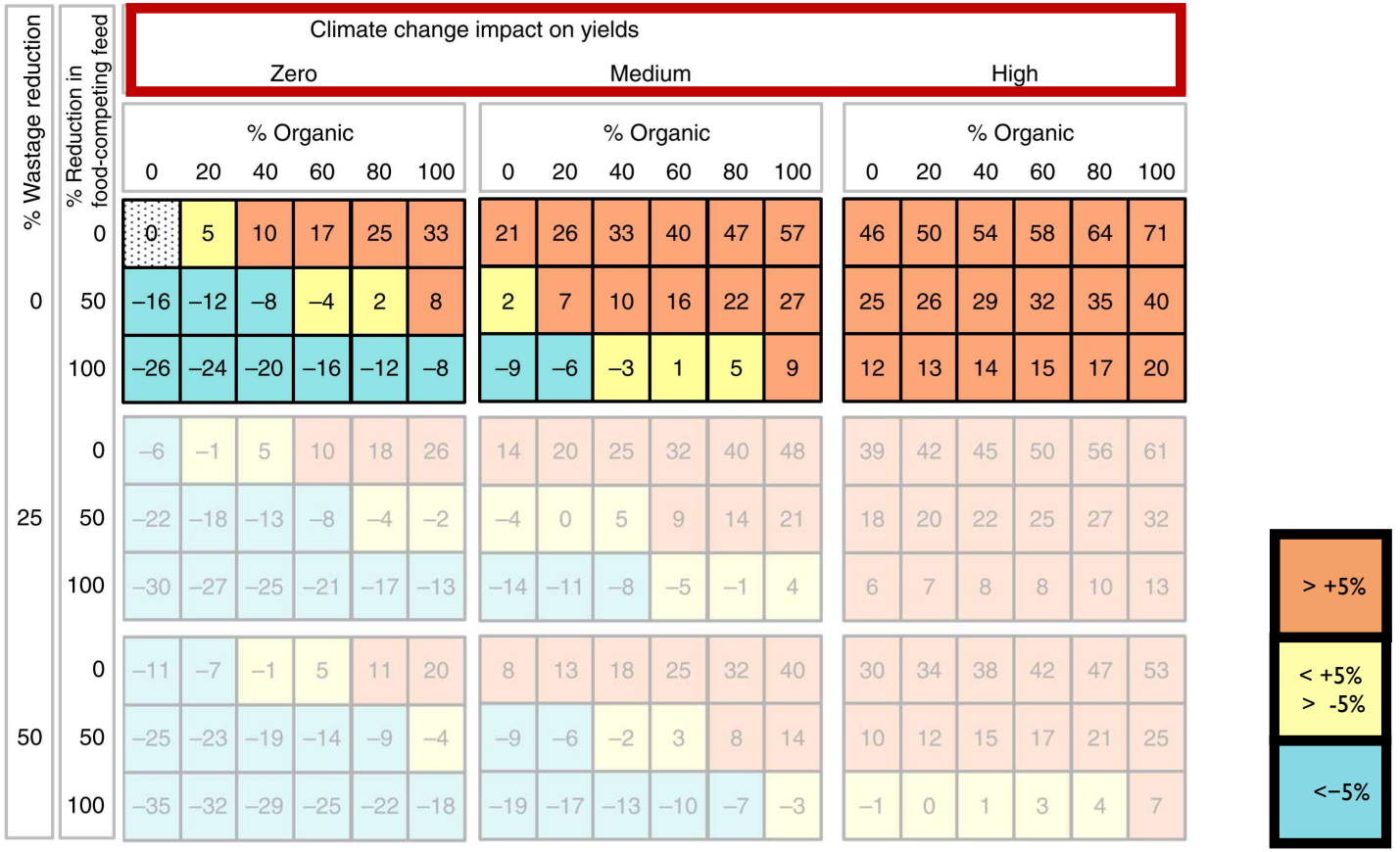
Muller et al. 2017; Courtesy: R. Zürcher



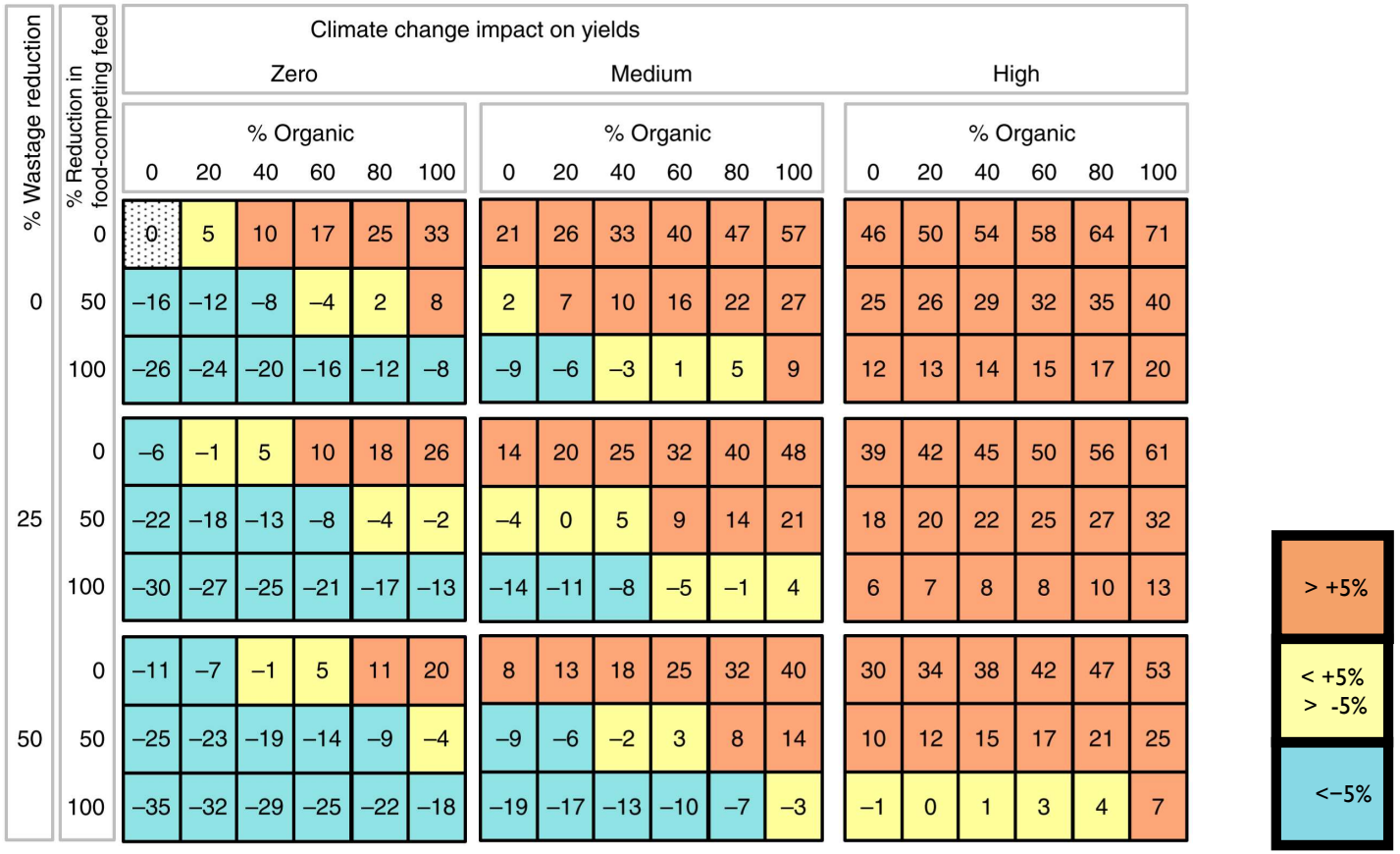
Muller et al. 2017; Courtesy: R. Zürcher



Muller et al. 2017; Courtesy: R. Zürcher



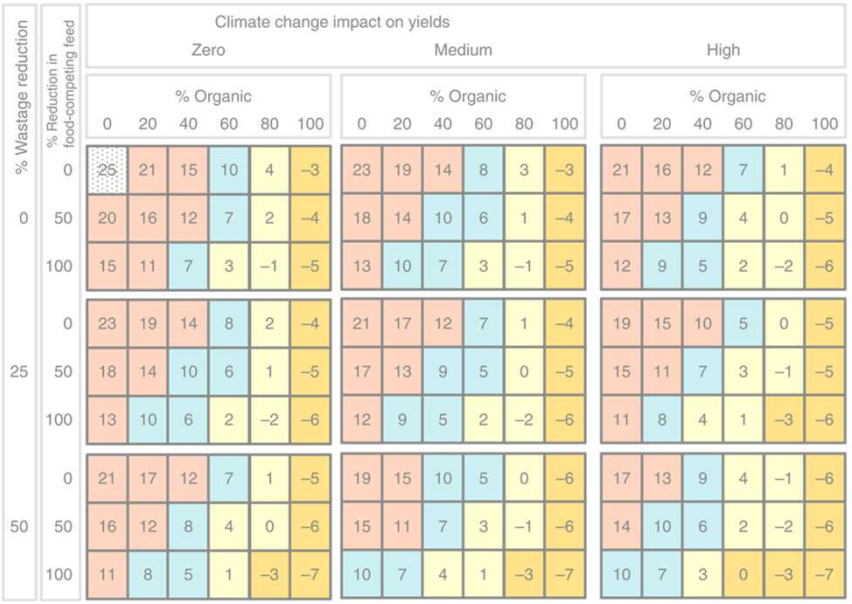
Muller et al. 2017; Courtesy: R. Zürcher



Muller et al. 2017; Courtesy: R. Zürcher

Nutrient supply in organic agriculture

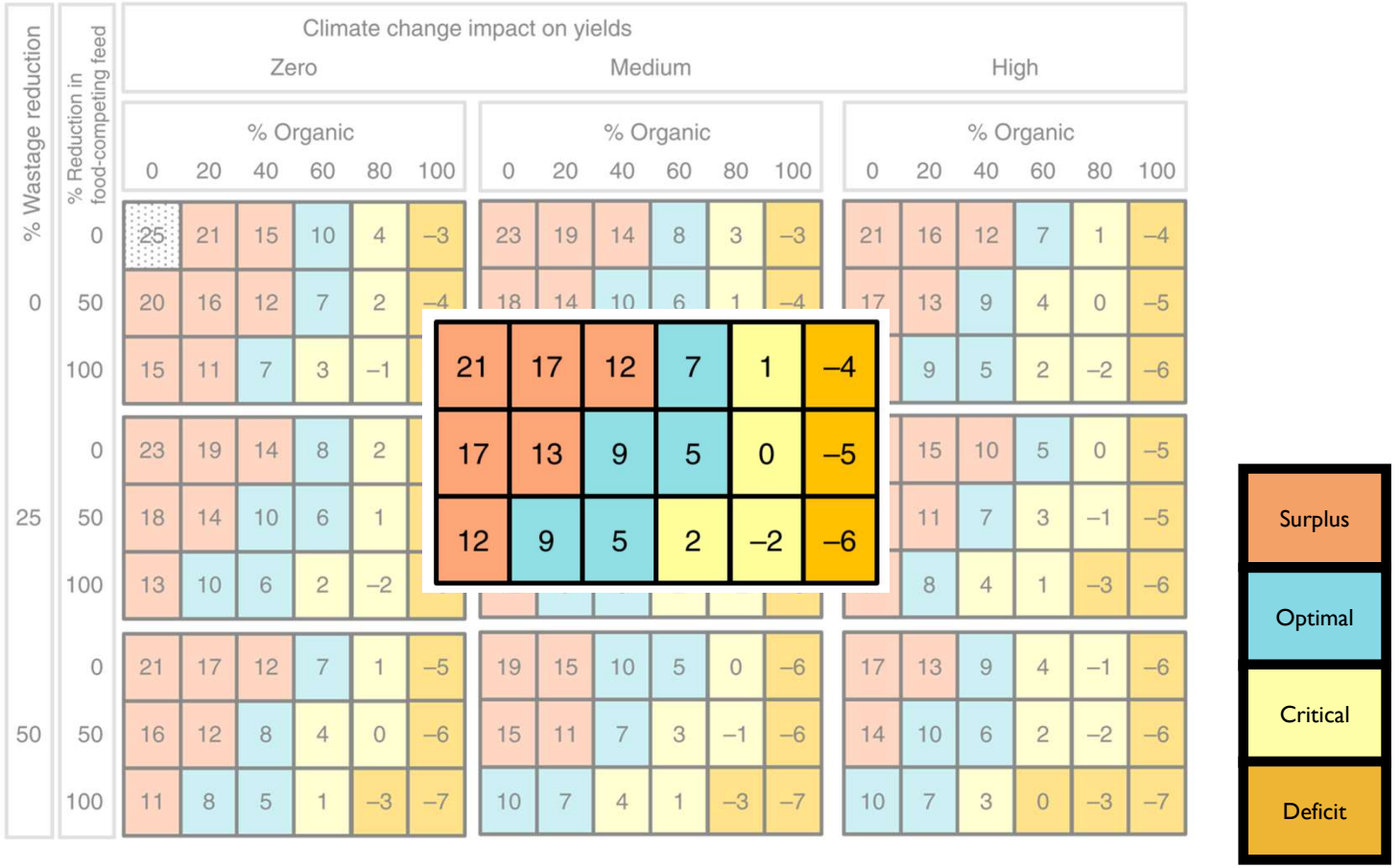
- Not only the products, but also the fertilizer is produced on the fields.
- Challenge to provide sufficient nutrients, especially N and P



> 10kg/ha	Surplus
between 10 and 5kg/ha	Optimal
between +5 and -5 kg/ha	Critical
<-5kg/ha	Deficit

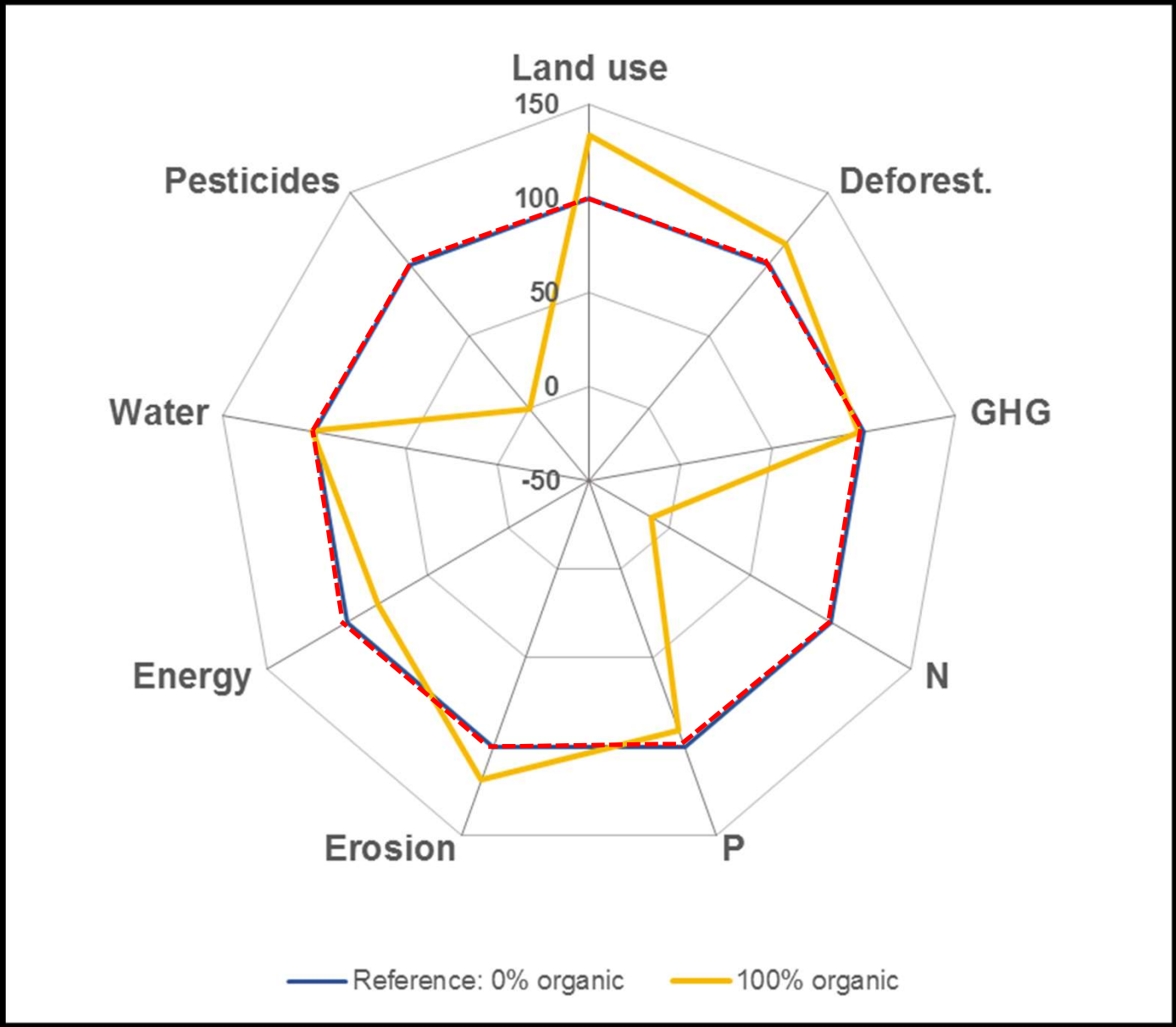
Muller et al. 2017; Courtesy: R. Zürcher

Muller et al. 2017; Courtesy: R. Zürcher



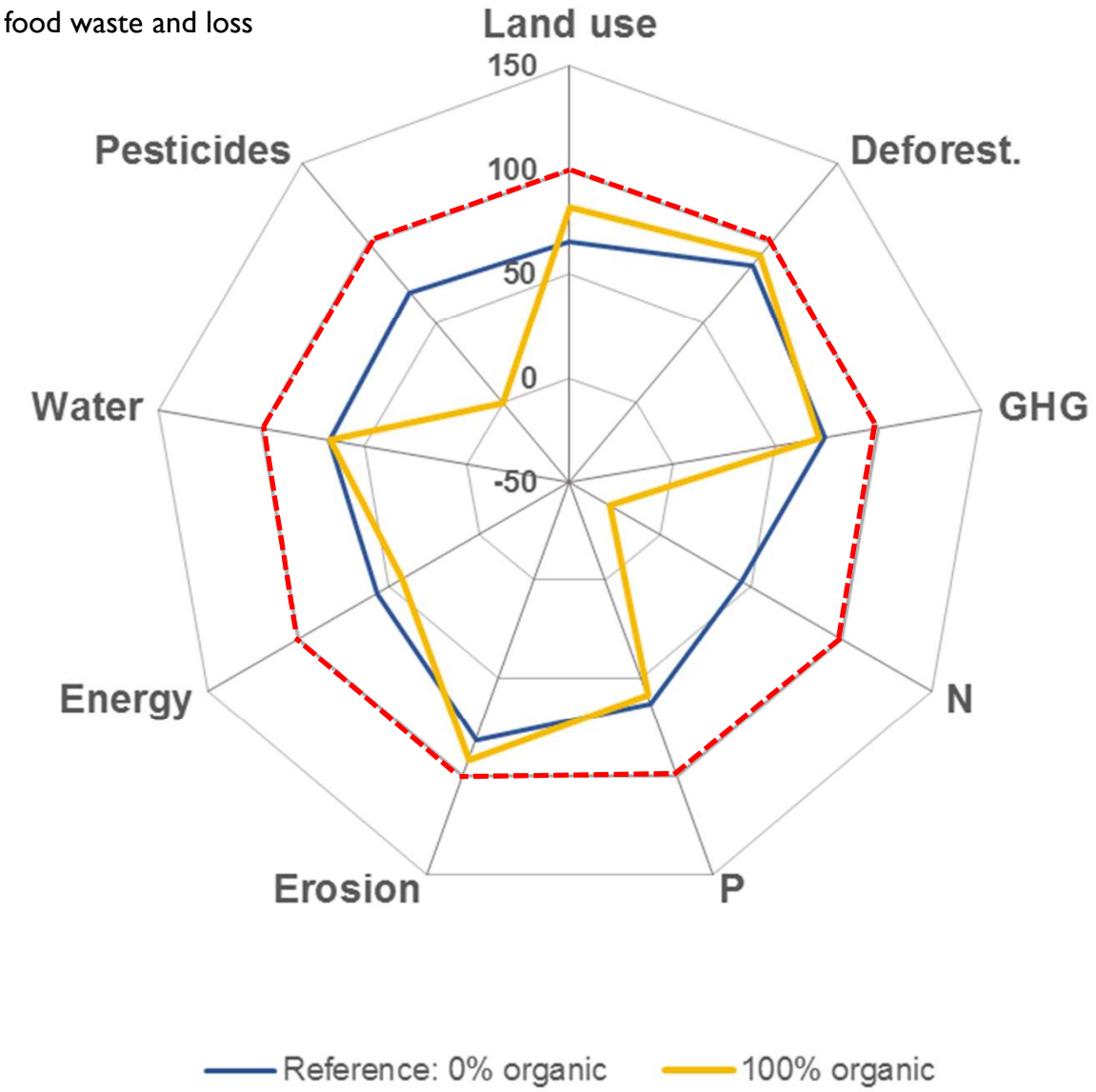
Muller et al. 2017; Courtesy: R. Zürcher

Other environmental impacts besides land use and nitrogen supply



Muller et al. 2017

100% food competing feed reduction
50% less food waste and loss



Muller et al. 2017

% Wastage reduction	% Reduction in food-competing feed	Climate change impact on yields: Zero						Medium						High					
		% Organic: 0	20	40	60	80	100	0	20	40	60	80	100	0	20	40	60	80	100
0	0	0	5	10	17	25	33	21	26	33	40	47	57	46	50	54	58	64	71
	50	−16	−12	−8	−4	2	8	2	7	10	16	22	27	25	26	29	32	35	40
	100	−26	−24	−20	−16	−12	−8	−9	−6	−3	1	5	9	12	13	14	15	17	20
25	0	−6	−1	5	10	18	26	14	20	25	32	40	48	39	42	45	50	56	61
	50	−22	−18	−13	−8	−4	−2	−4	0	5	9	14	21	18	20	22	25	27	32
	100	−30	−27	−25	−21	−17	−13	−14	−11	−8	−5	−1	4	6	7	8	8	10	13
50	0	−11	−7	−1	5	11	20	8	13	18	25	32	40	30	34	38	42	47	53
	50	−25	−23	−19	−14	−9	−4	−9	−6	−2	3	8	14	10	12	15	17	21	25
	100	−35	−32	−29	−25	−22	−18	−19	−17				−3	−1	0	1	3	4	7

3

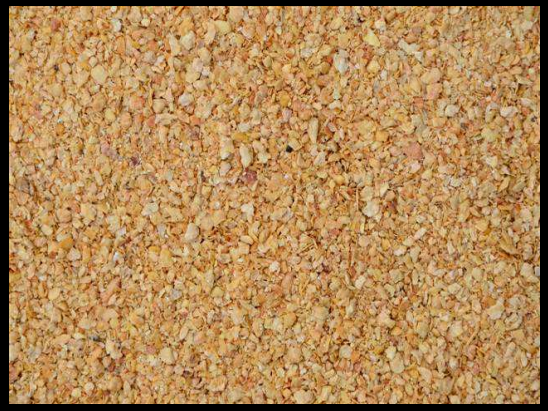
% Wastage reduction	% Reduction in food-competing feed	Climate change impact on yields: Zero						Medium						High					
		% Organic: 0	20	40	60	80	100	0	20	40	60	80	100	0	20	40	60	80	100
0	0	25	21	15	10	4	−3	23	19	14	8	3	−3	21	16	12	7	1	−4
	50	20	16	12	7	2	−4	18	14	10	6	1	−4	17	13	9	4	0	−5
	100	15	11	7	3	−1	−5	13	10	7	3	−1	−5	12	9	5	2	−2	−6
25	0	23	19	14	8	2	−4	21	17	12	7	1	−4	19	15	10	5	0	−5
	50	18	14	10	6	1	−5	17	13	9	5	0	−5	15	11	7	3	−1	−5
	100	13	10	6	2	−2	−6	12	9	5	2	−2	−6	11	8	4	1	−3	−6
50	0	21	17	12	7	1	−5	19	15	10	5	0	−6	17	13	9	4	−1	−6
	50	16	12	8	4	0	−6	15	11	7	3	−1	−6	14	10	6	2	−2	−6
	100	11	8	5	1	−3	−7	10	7				−7	10	7	3	0	−3	−7

3

Muller et al. 2017; Courtesy: R. Zürcher

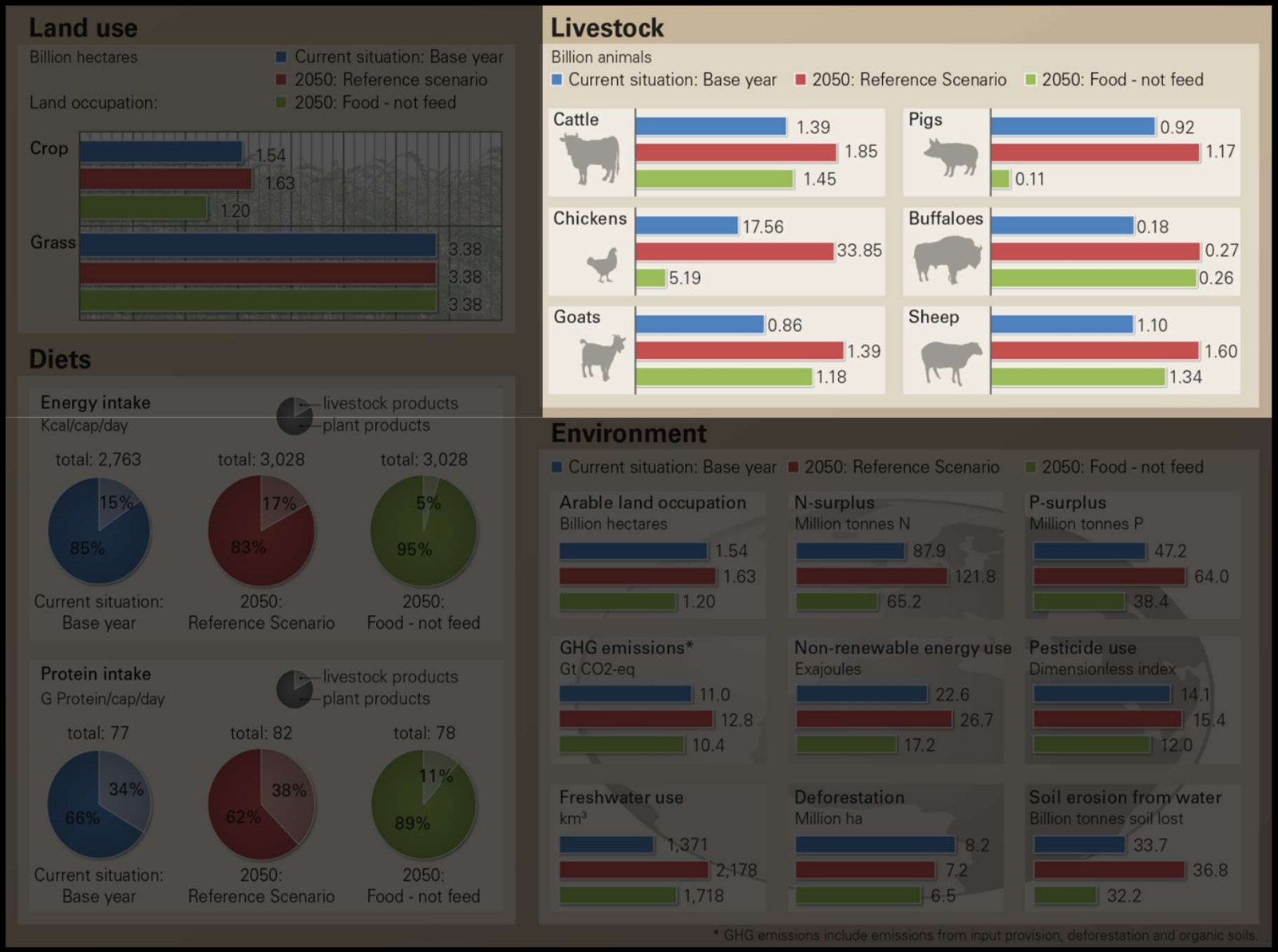
We know what to do for
being able to build on
NBS/agroecology
for sustainable food systems:

Size of the food system

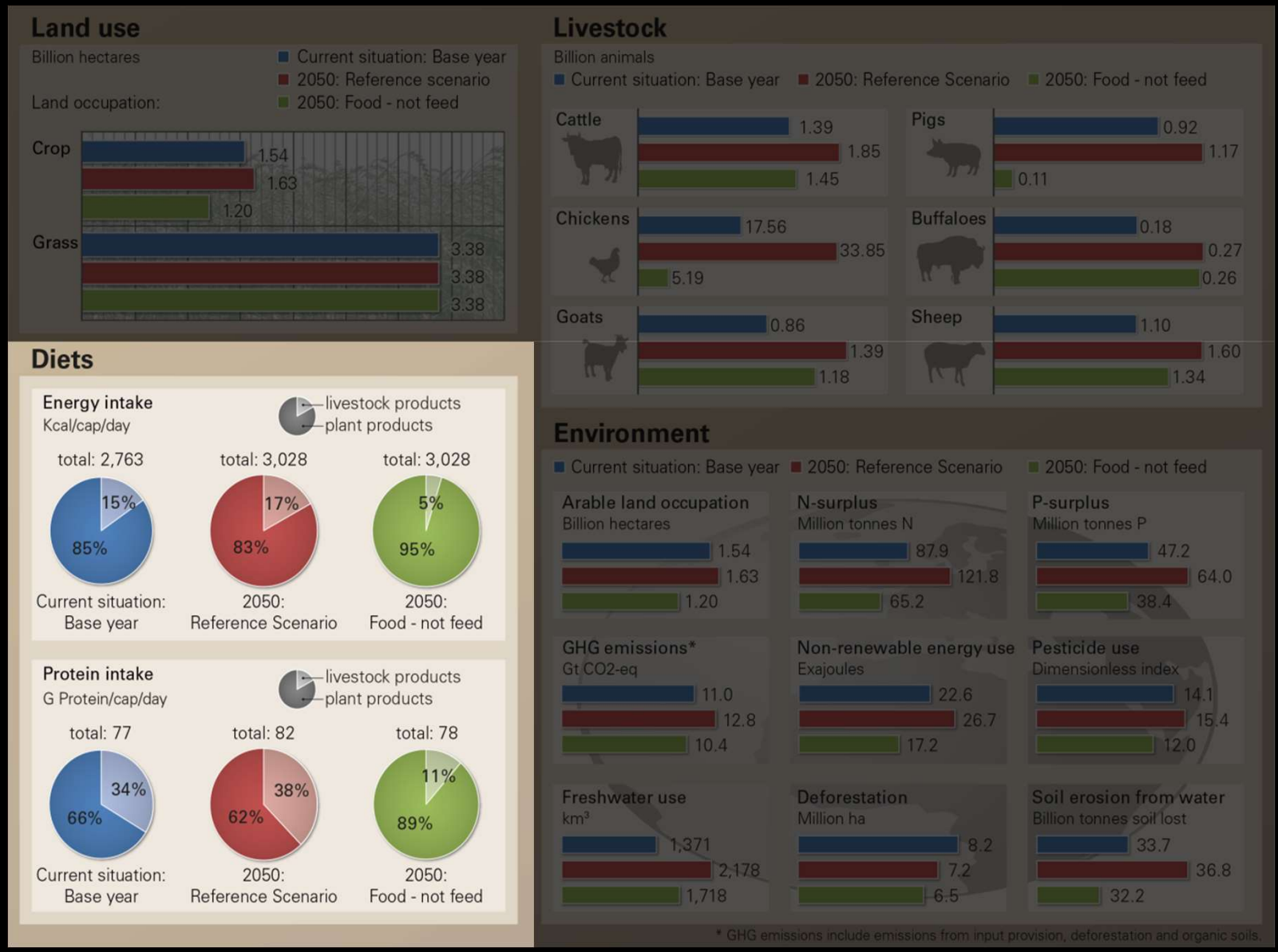


- less waste and losses
- less feed from cropland
- less animals
- (less fossil energy)

- less nitrogen
- less pesticides

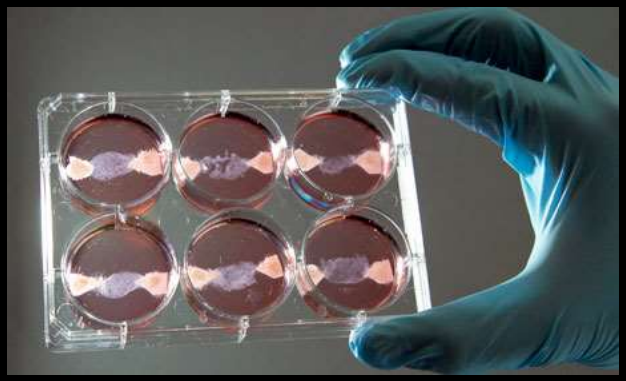


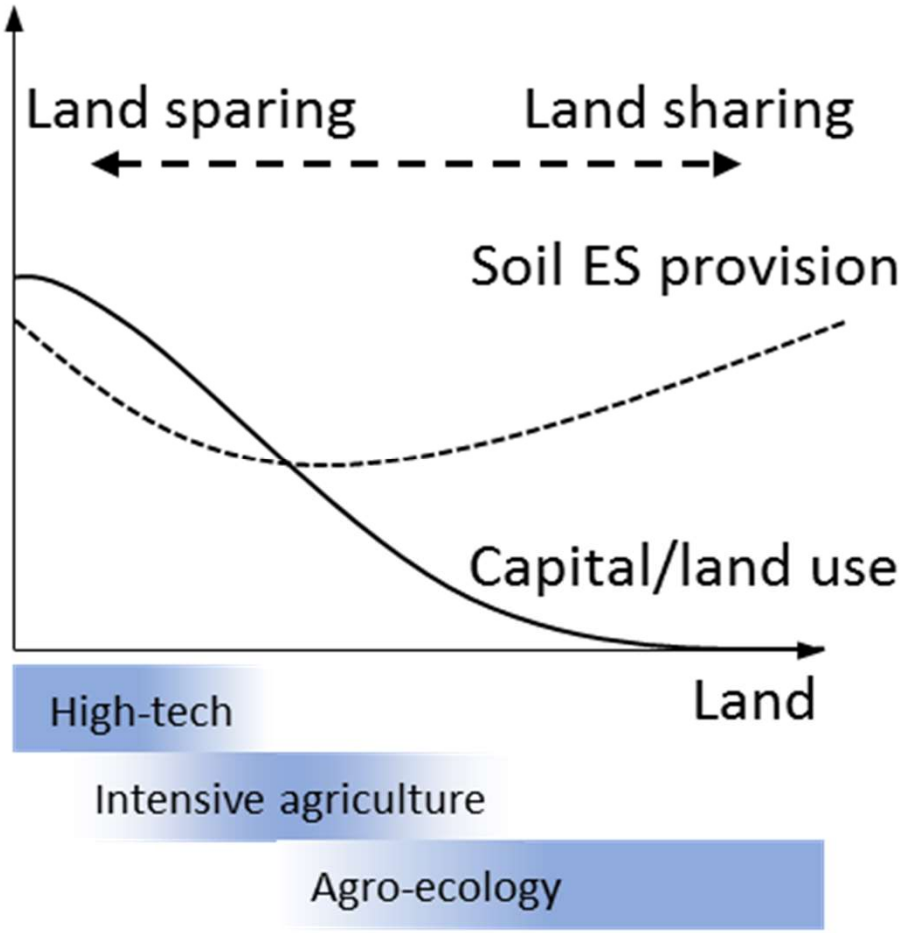
Schader et al. 2015



Schader et al. 2015

NBS vs. Other, technical approaches? What is a «farm»?





Muller et al, 2017b

Conclusions

- Business as usual is no option for future food systems – but changing to agroecology on the production side without any other changes is neither.

- Making the food system smaller is the key leverage point for achieving sustainable food systems building on agroecology;
  - making food systems smaller provides the room to produce less intensively with lower yields without compromising food security;
  - we know how to achieve this technically.

- Sustainable agriculture cannot be addressed without talking about consumption;
  - we need to adopt a food systems perspective to utilize the sustainability potential of NBS/agroecology.

- Avoid ideological approaches – non-NBS may also play their role.

- Assure that incentive schemes really fit to the complexity of the systems on which NBS are based and to which NBS refer to.

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FiBL

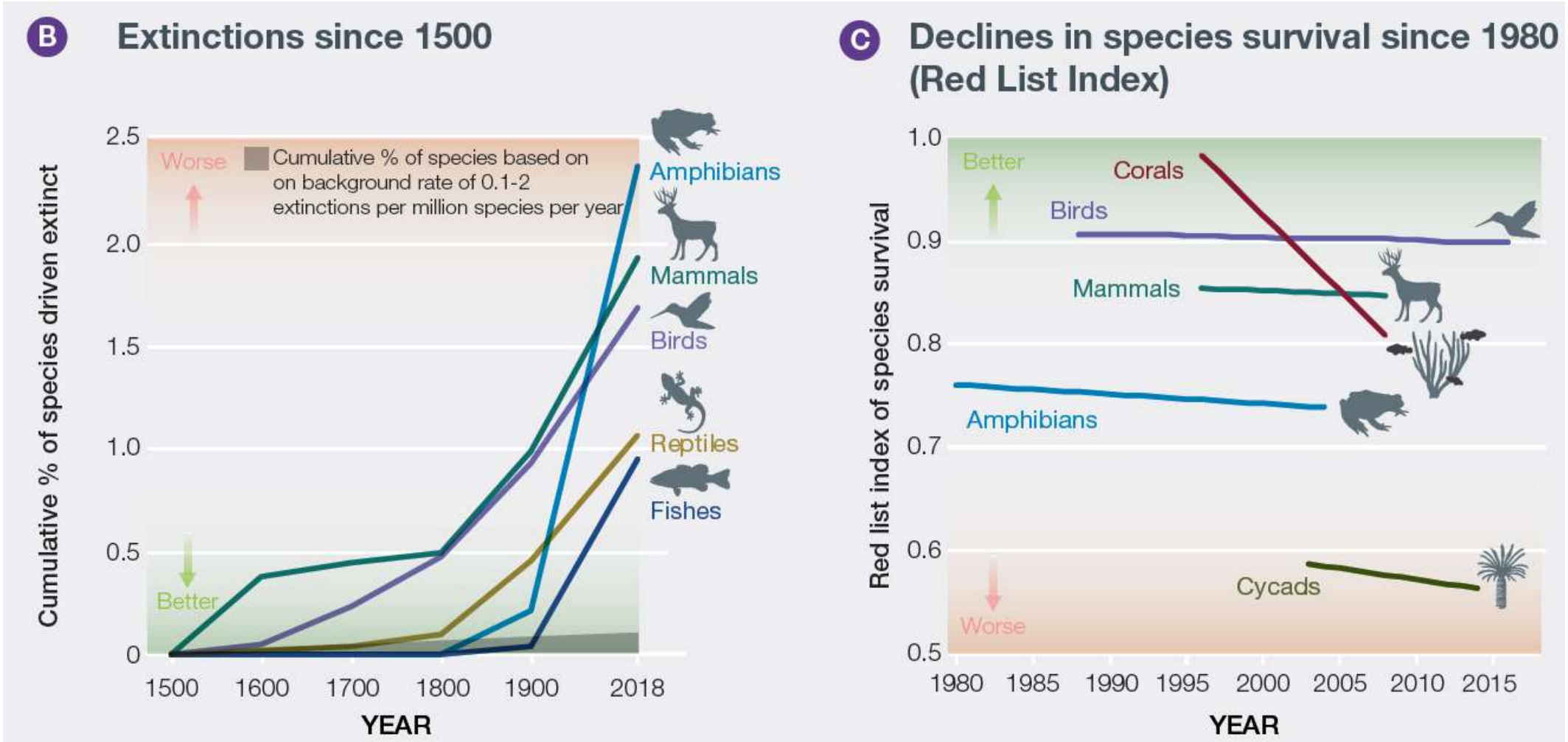
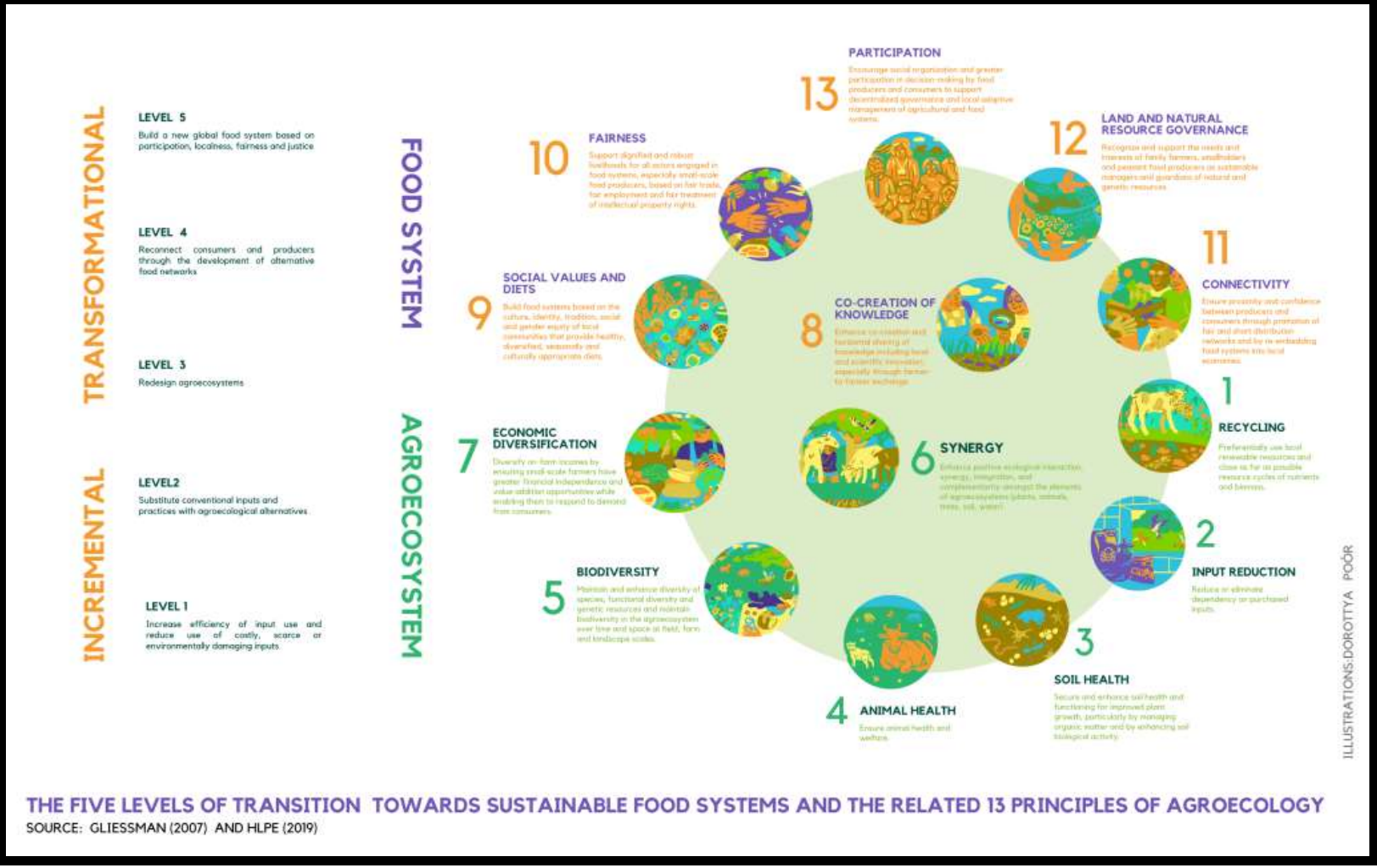


Figure SPM 3 **A substantial proportion of assessed species are threatened with extinction and overall trends are deteriorating, with extinction rates increasing sharply in the past century.**

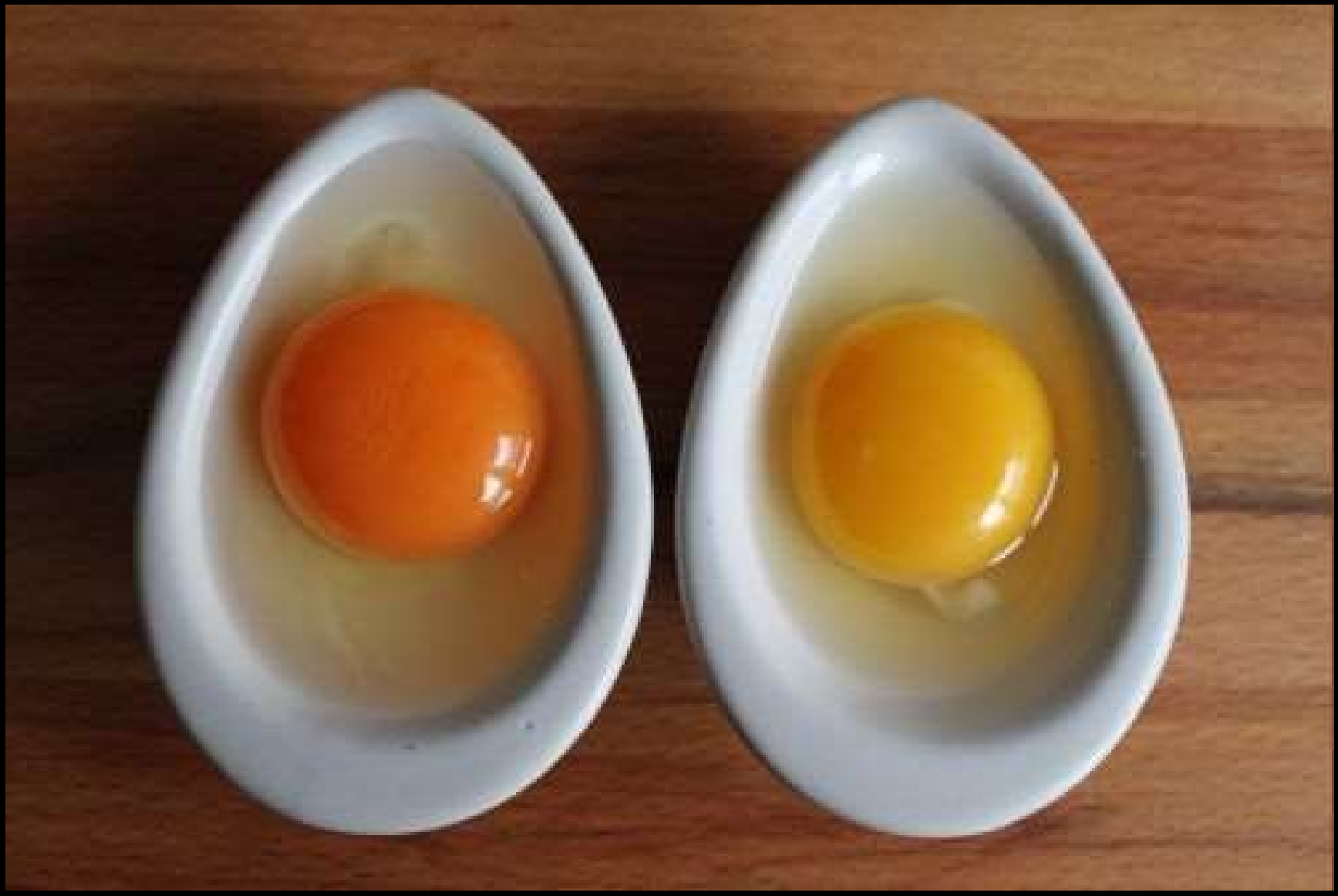
The 13 Principles of Agroecology according to Wezel et al. 2020 and the 5 Gliessman levels



THE FIVE LEVELS OF TRANSITION TOWARDS SUSTAINABLE FOOD SYSTEMS AND THE RELATED 13 PRINCIPLES OF AGROECOLOGY

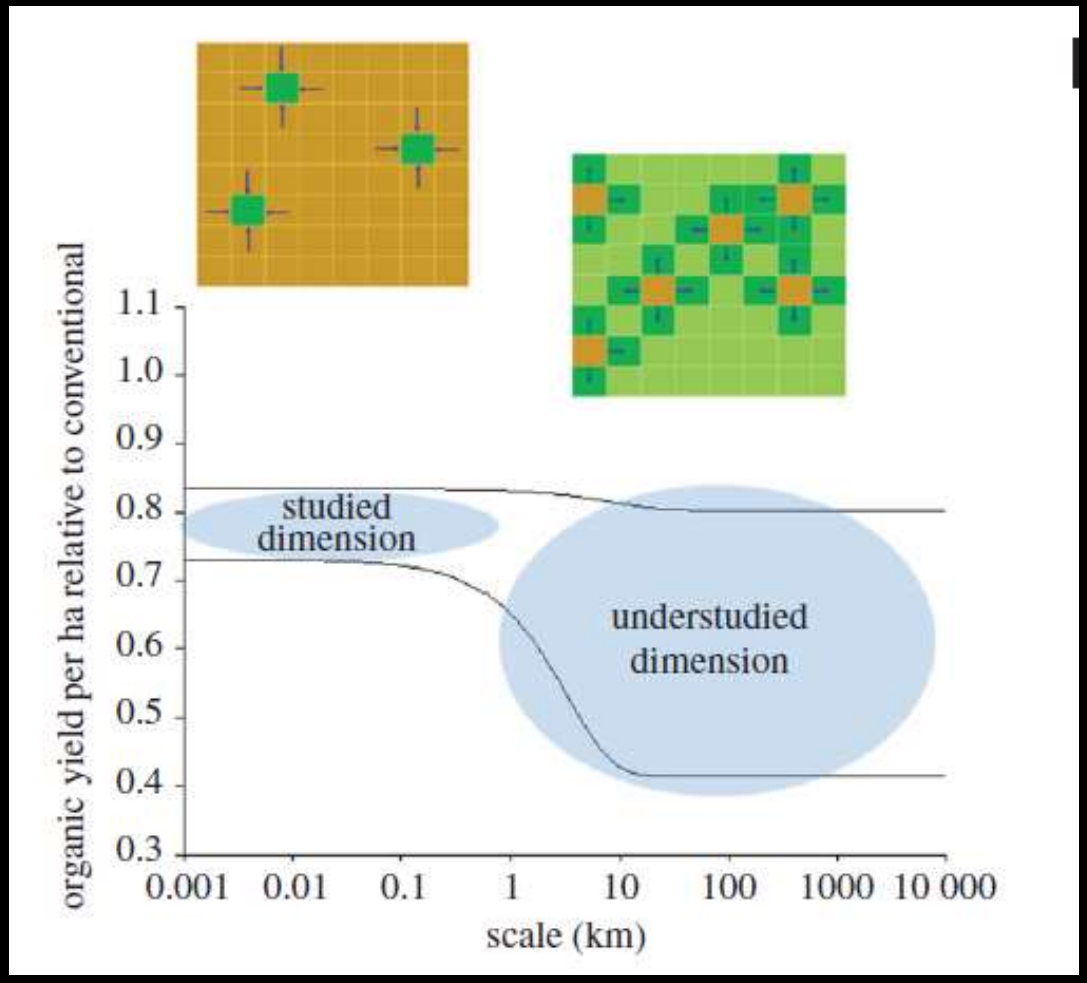
SOURCE: GLIESSMAN (2007) AND HLPE (2019)

https://www.agroecology-europe.org/the-13-principles-of-agroecology/



tik III

- Feld- versus Landschaftsskala



Leifeld 2016

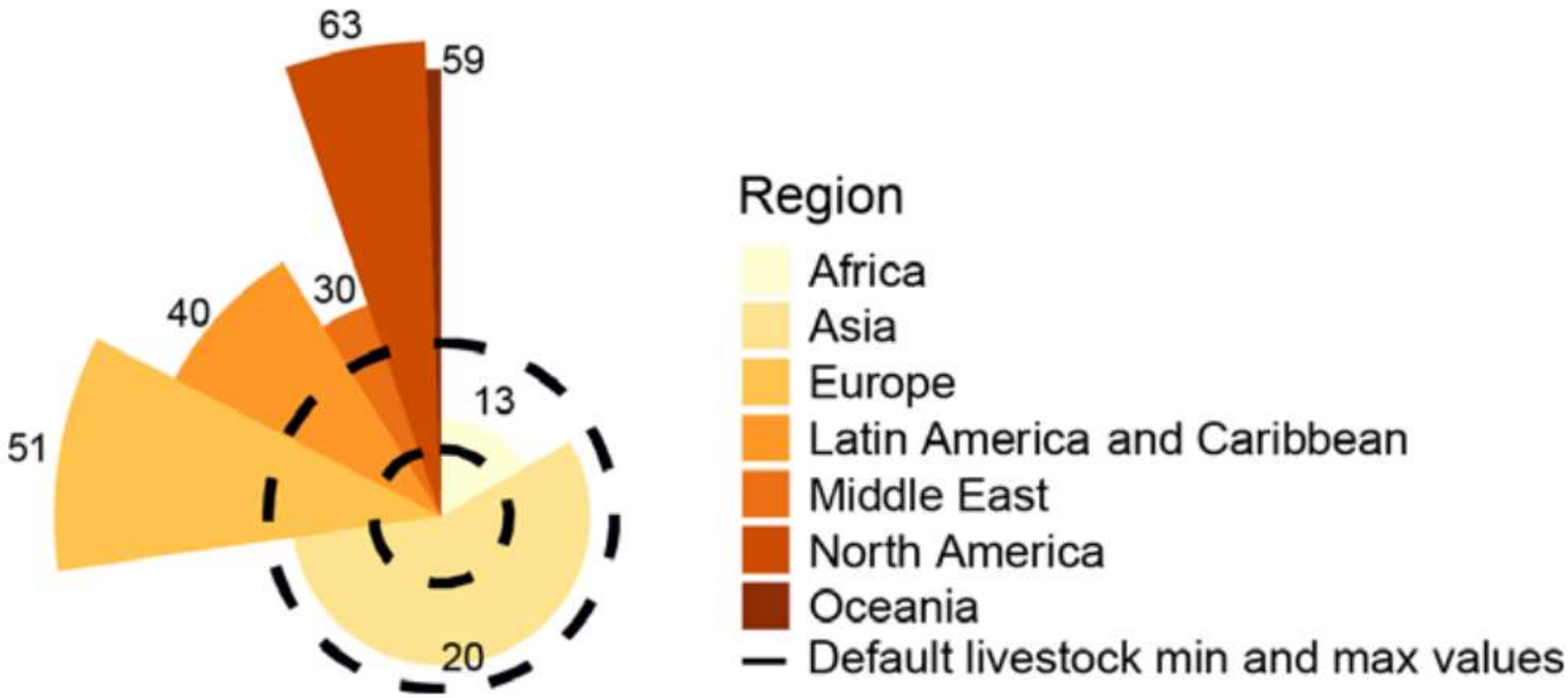
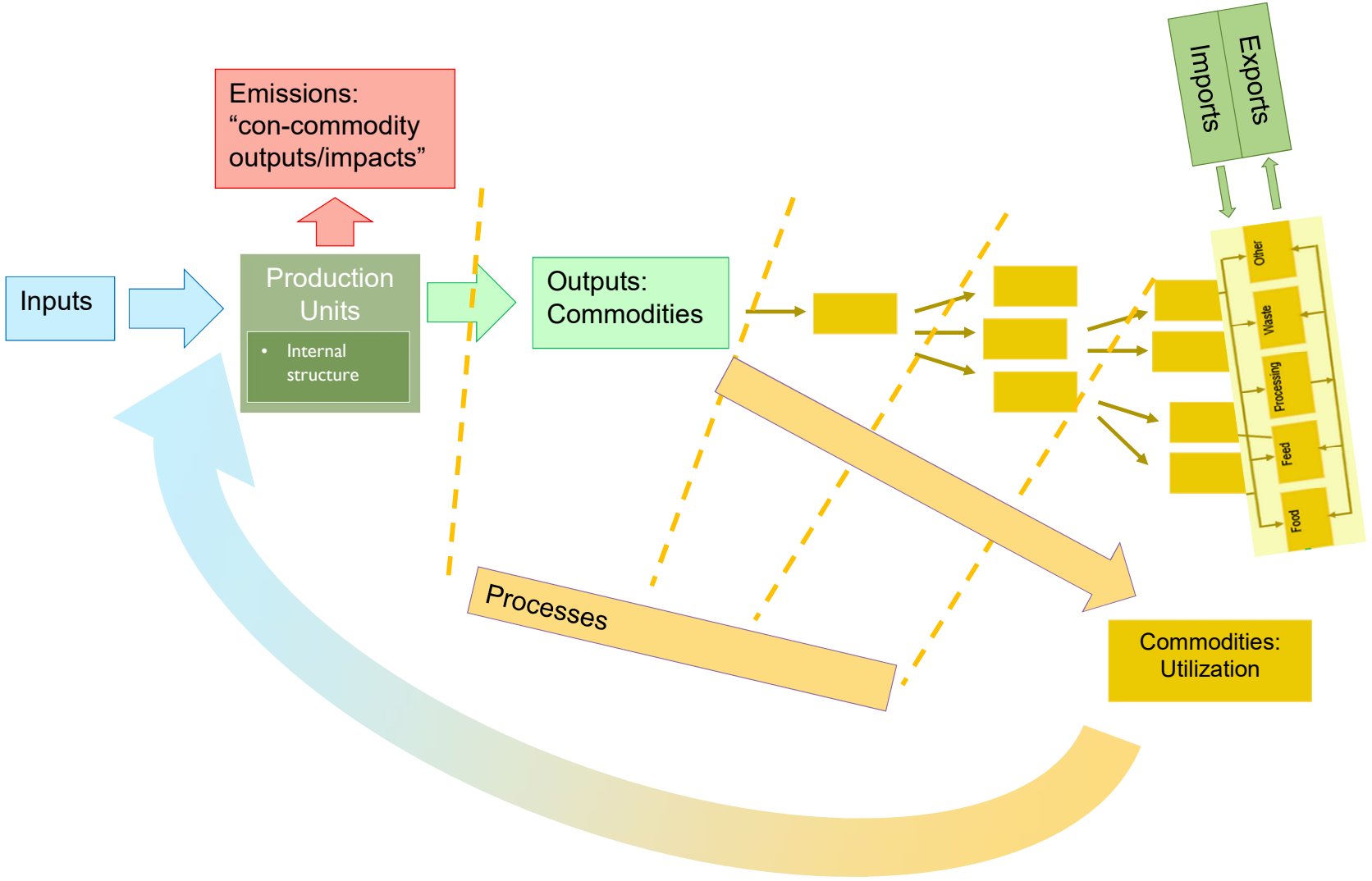
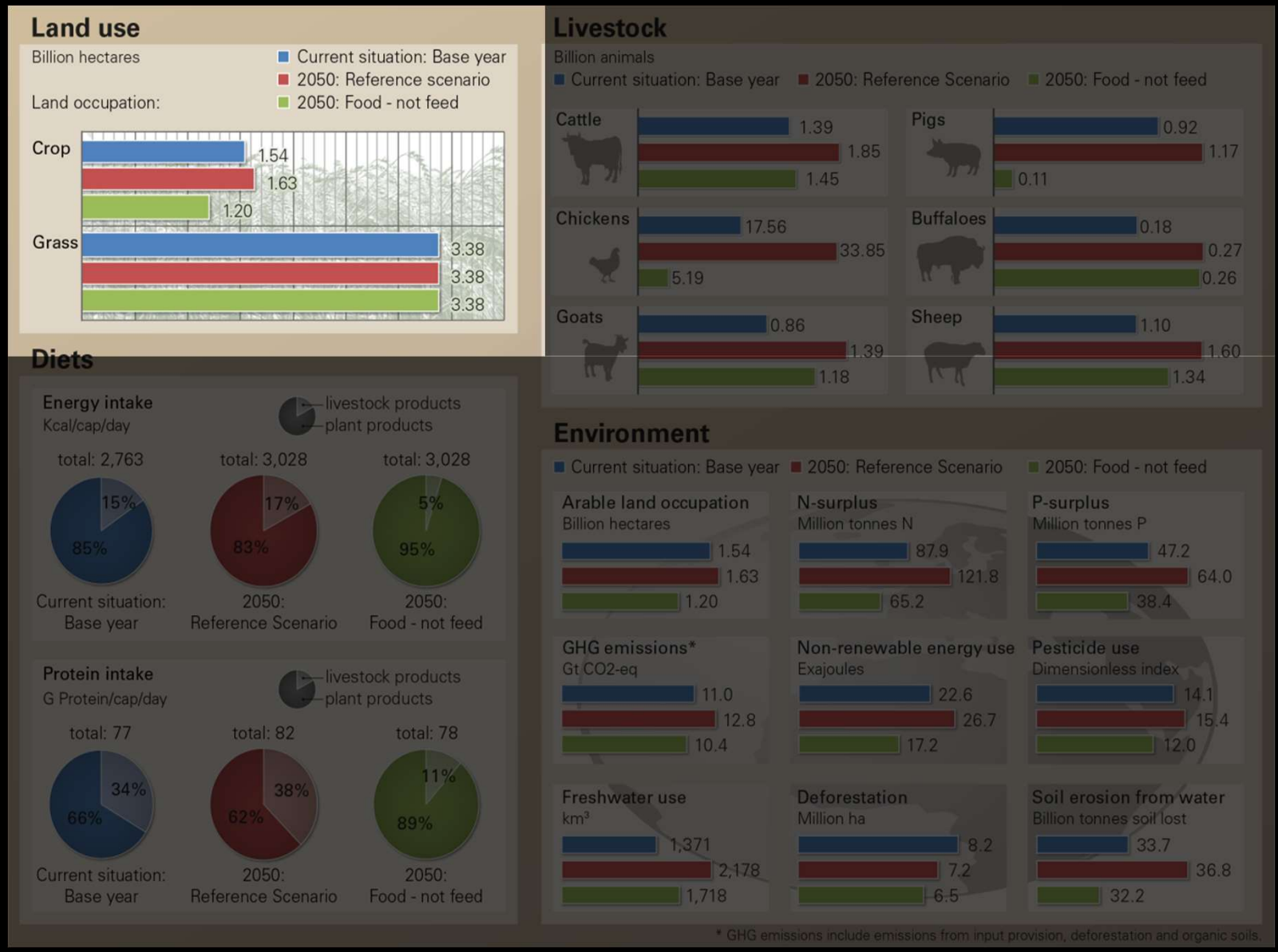
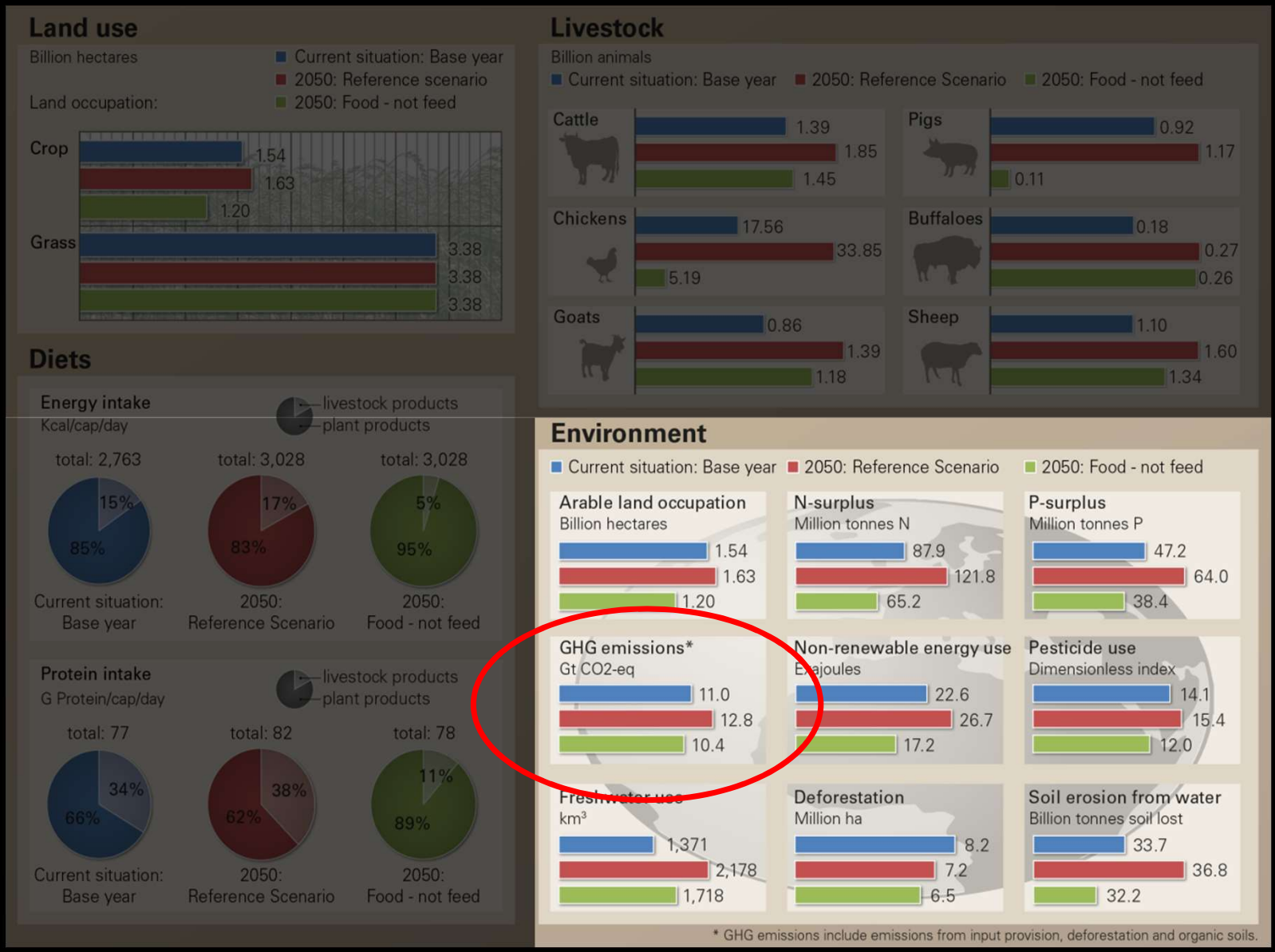


FIGURE 4 Current protein supply per person per day per region, based on (FAOSTAT, 2017) compared with the minimum global average value of low-cost livestock of Schader et al. (2015) of 9 g protein per person per day, and the maximum value of low-cost livestock based on Röös et al. (2017a) of 23 g protein per person per day


Emissions:
“con-commodity
outputs/impacts”
Inputs
Production
Units
• Internal
structure
Outputs:
Commodities
Imports
Exports
Other
Waste
Processing
Feed
Food
Processes
Commodities:
Utilization

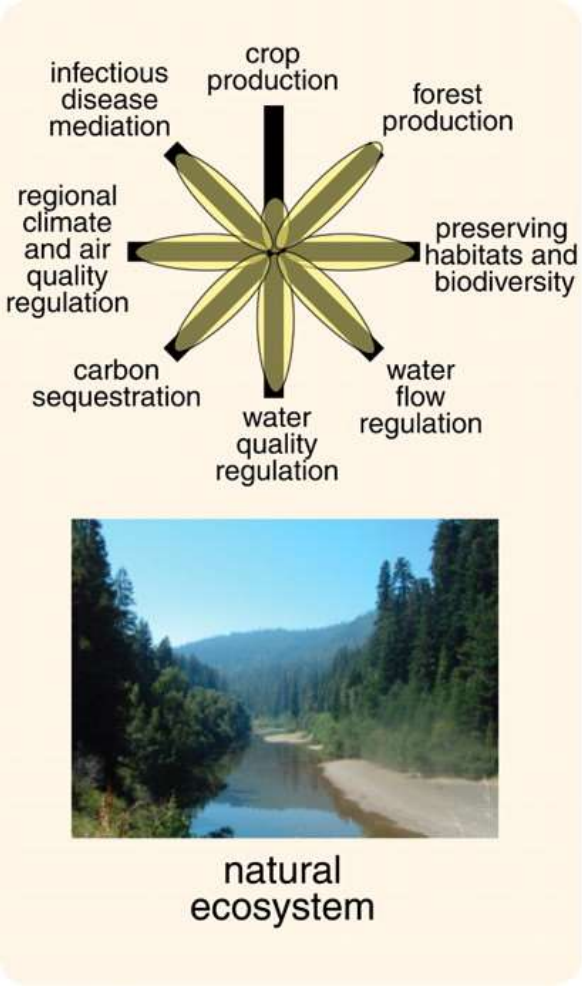


Schader et al. 2015

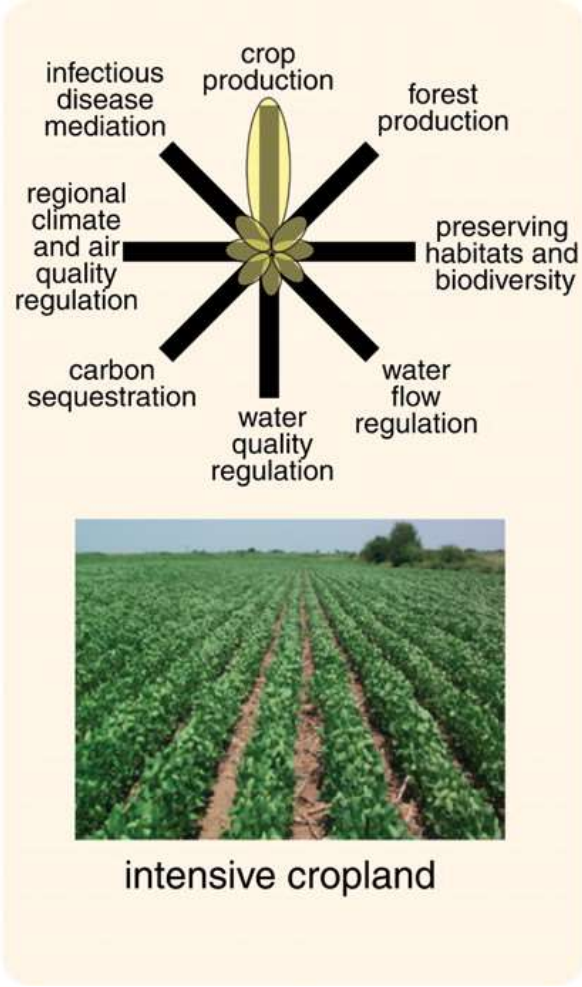


Schader et al. 2015

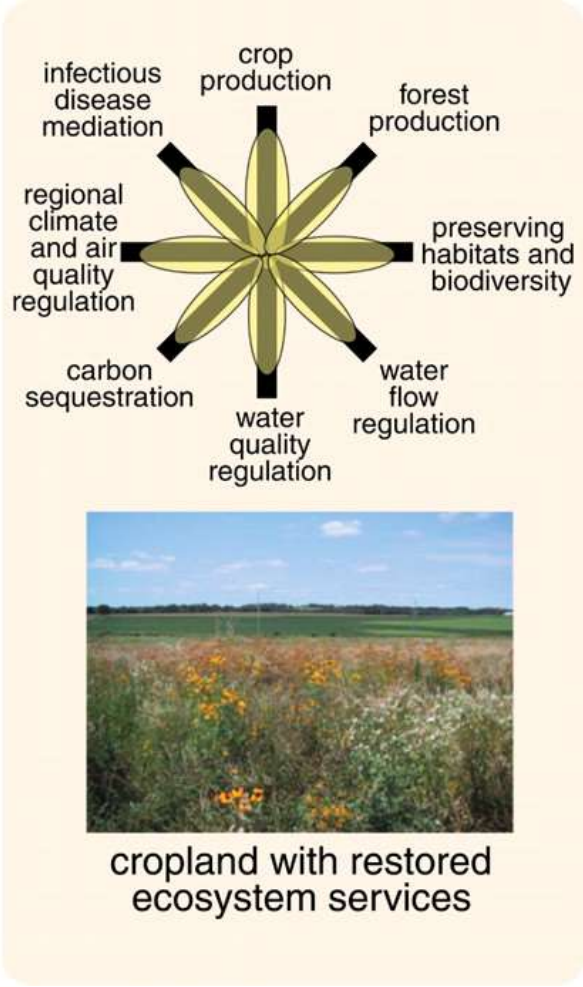
Impacts on/services from landscapes – «share vs. spare»



natural ecosystem

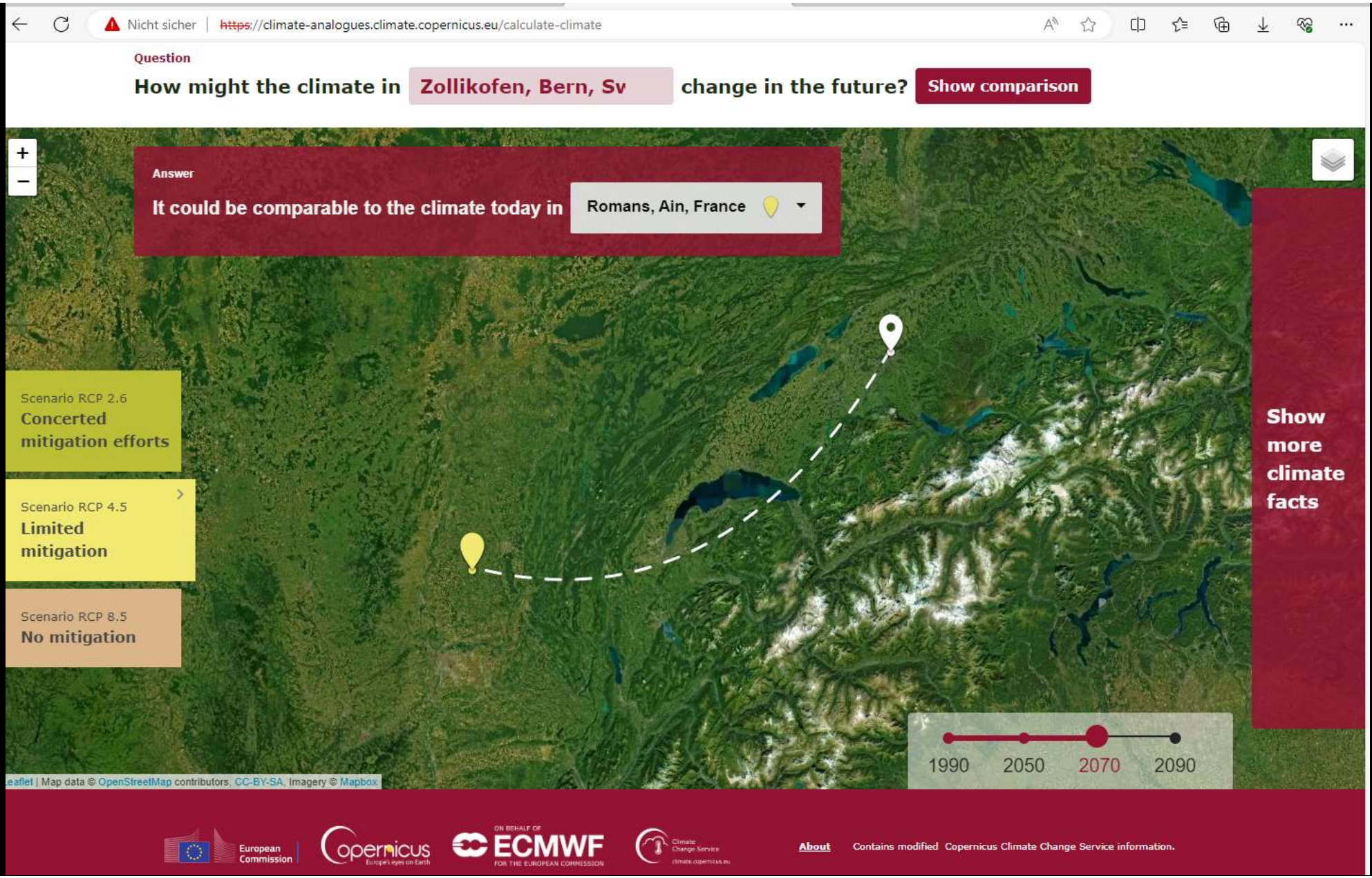


intensive cropland



cropland with restored ecosystem services

Foley et al. 2005



Optimal cropland distribution

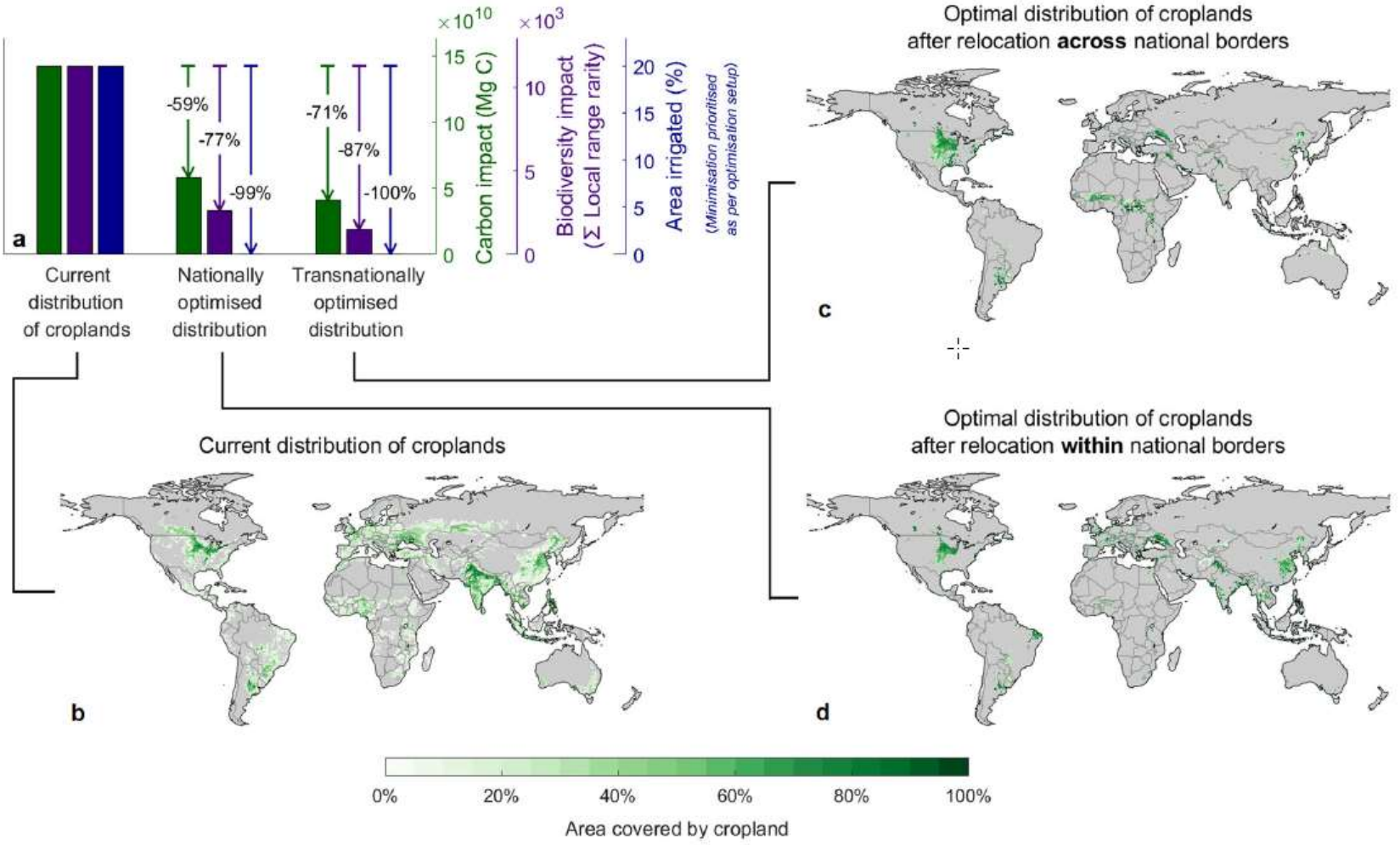
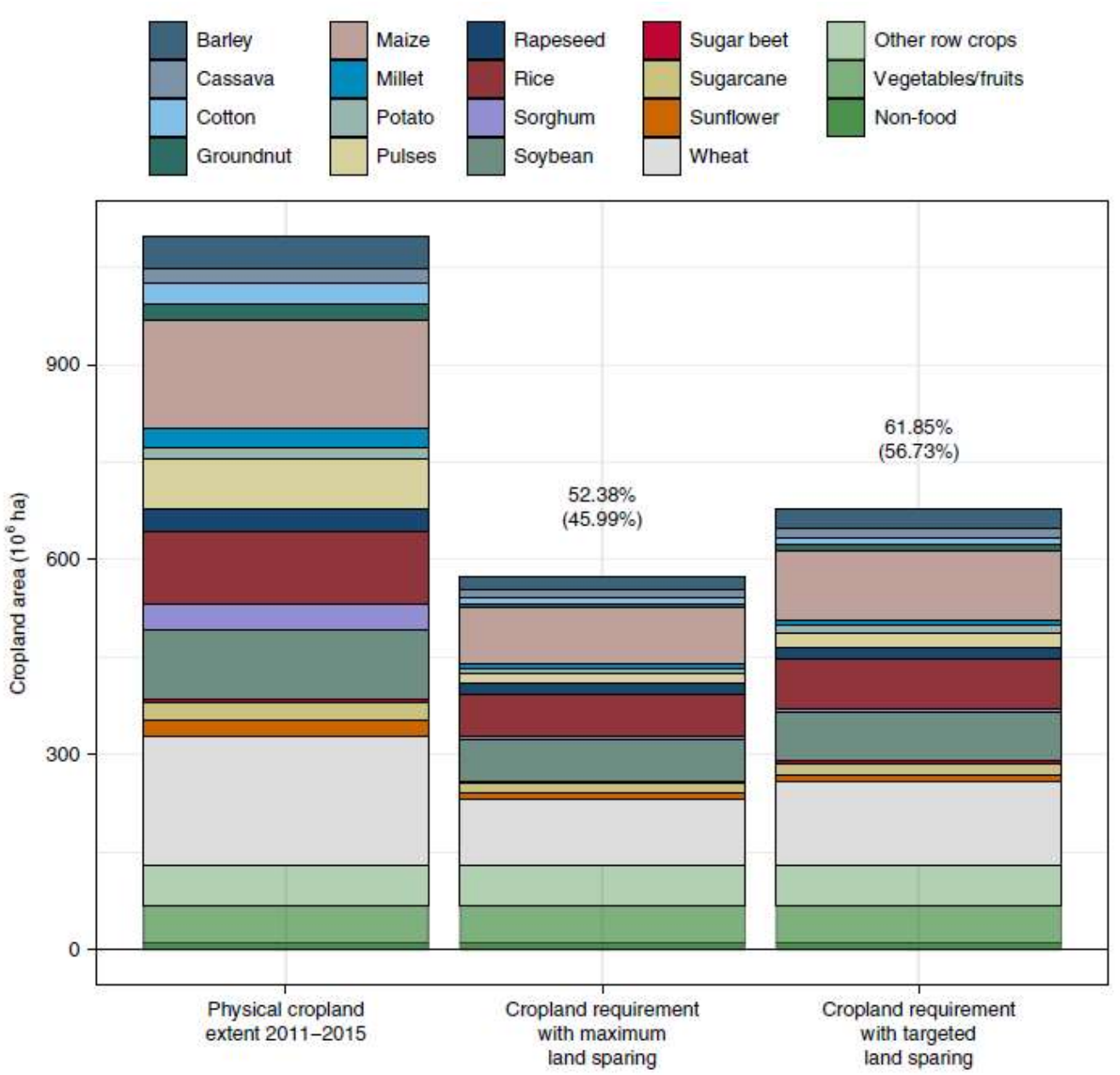


Fig. 1 Current and environmentally optimal distributions of global croplands. The estimated reduction potentials in **a** are based on an optimal trade-off between carbon and biodiversity impacts (see the "Methods" section). Potential yield data used here are based on current climatic conditions and assume high-input crop management and rainfed water supply, so that relocated areas are, by design of the approach, not irrigated. The global production levels of individual crops for optimally distributed areas are identical to current levels; in the scenario of national relocation, this is additionally the case for national production levels. For visualisation purposes, in **b–d**, the 25 crops were grouped together; maps of the optimal distribution of individual crops for across- and within-border relocation are shown in Supplementary Movie 1.

Beyer et al. 2022

Optimal cropland distribution



Folberth et al. 2020