Compatibility of the ecosystem assessment framework and life cycle assessment

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Lay-out presentation

Introduce ecosystem services (ES) framework

- Definition
- Value of ES framework in livestock sector

Introduce life cycle assessment (LCA)

- Definition
- Value LCA in livestock sector

Definition of Ecosystem Services (ES)

« Benefits that humans derive from ecosystems » (MEA 2005)

« Direct and indirect contributions of ecosystems to human well-being» (de Groot et al. 2010)

« Contributions of structure and function of ecosystems, in combination with other human inputs, to human well-being » (Burkhard et al. 2012)

Categories of ecosystem services

Provisioning

Products from ecosystems

e.g. food, fibre, timber, water

Regulating

Benefits from bio-physical processes of ecosystems

e.g. climate regulation, flood prevention, water purification

Cultural

recreational, aesthetic and spiritual benefits provided by ecosystems

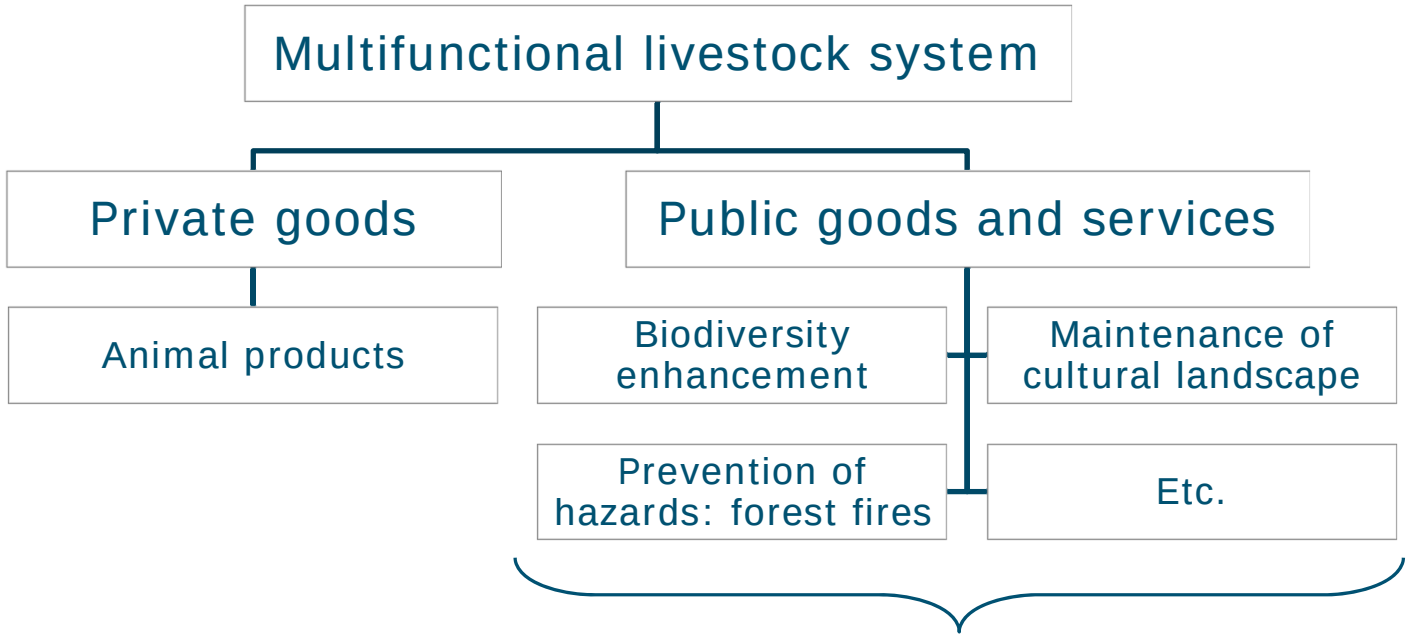
Supporting

Processes necessary for production and maintenance of all other ecosystem services

e.g. primary production, soil formation, nutrient cycling

Adapted from: MEA (2005)

Private and public goods



A public good's status may change over time!

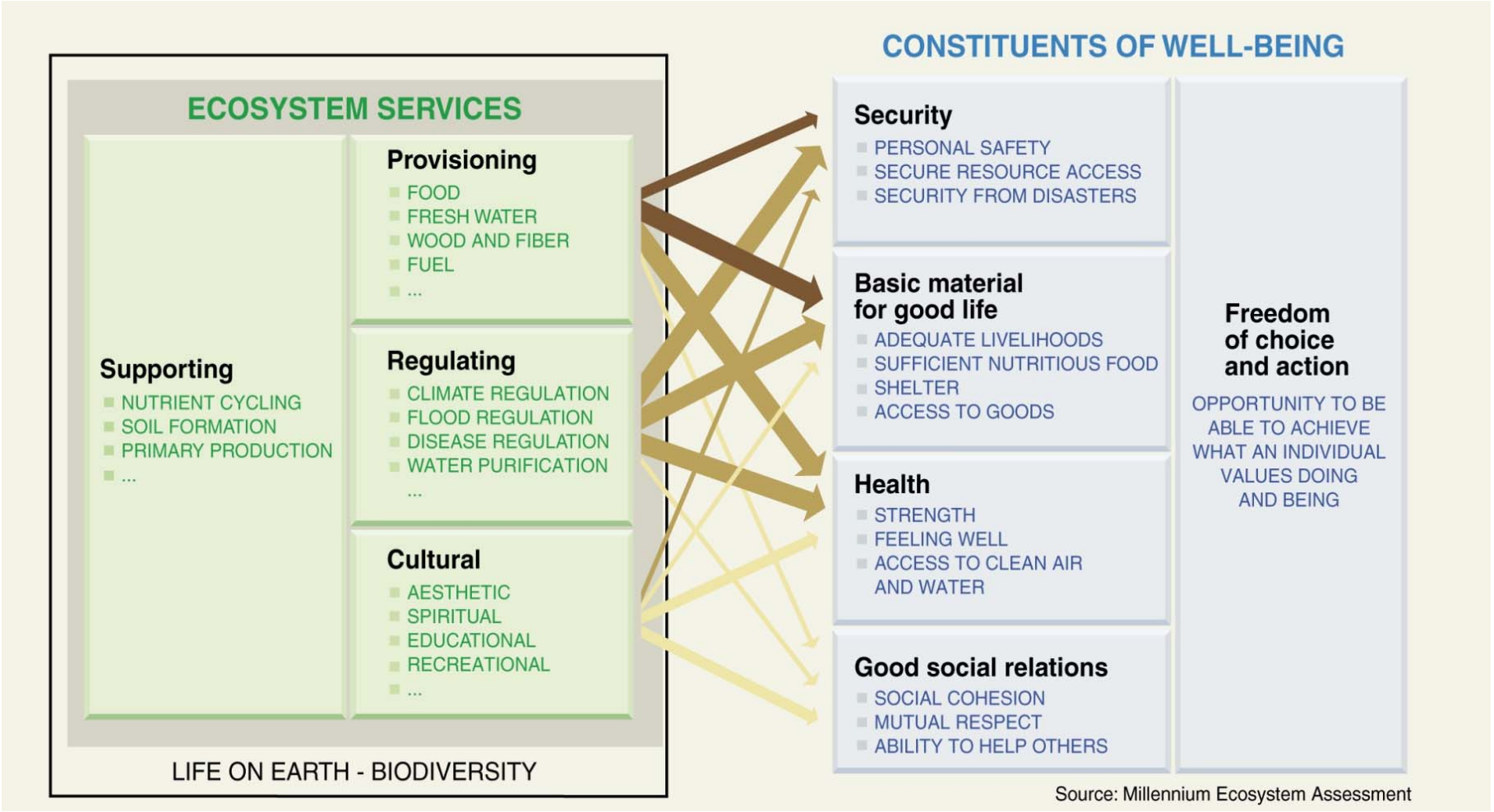
- Non-excludable
- Non-rival

...

- Non-marketable
- Inherently linked to grazing systems

IEEP (2009). Provision of Public Goods through Agriculture in the European Union

Linkages between ES and human well-being



Source: Millennium Ecosystem Assessment

ARROW'S COLOR
Potential for mediation by socioeconomic factors
Low
Medium
High

ARROW'S WIDTH
Intensity of linkages between ecosystem services and human well-being
Weak
Medium
Strong

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Livestock systems

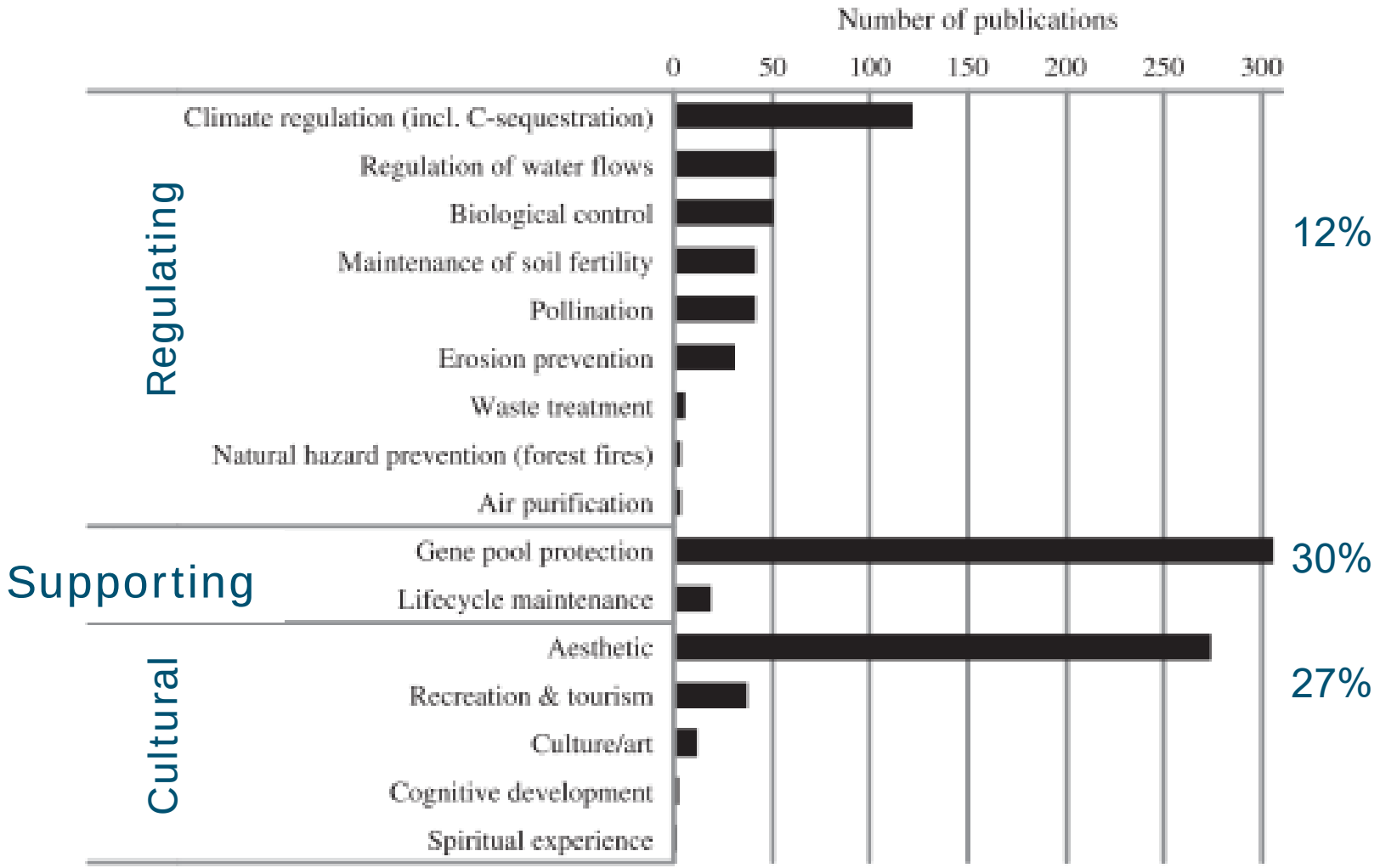
- Not only provide nutritious food
- Many other non-provisioning **benefits**

Which benefits have been studied / quantified?

Biophysically or economically

ES in pasture-based livestock systems

(n=563 since 1995)



Rodriguez Ortega et al. (2014) Animal

Assessing ecosystem services

- Concept originates from nature
- Concept focusses on **benefits**
- Livestock systems can have multiple benefits
- Do farmers or society acknowledge all benefits?
- Benefits appear at various scales: farm, region ....
- Sound assessment requires spatially explicit indicators (fragmentation)

Lay-out presentation: part-2

Introduce ecosystem services (ES) framework

- Definition
- Value of ES framework in livestock sector

Introduce life cycle assessment (LCA)

- Definition
- Value LCA in livestock sector

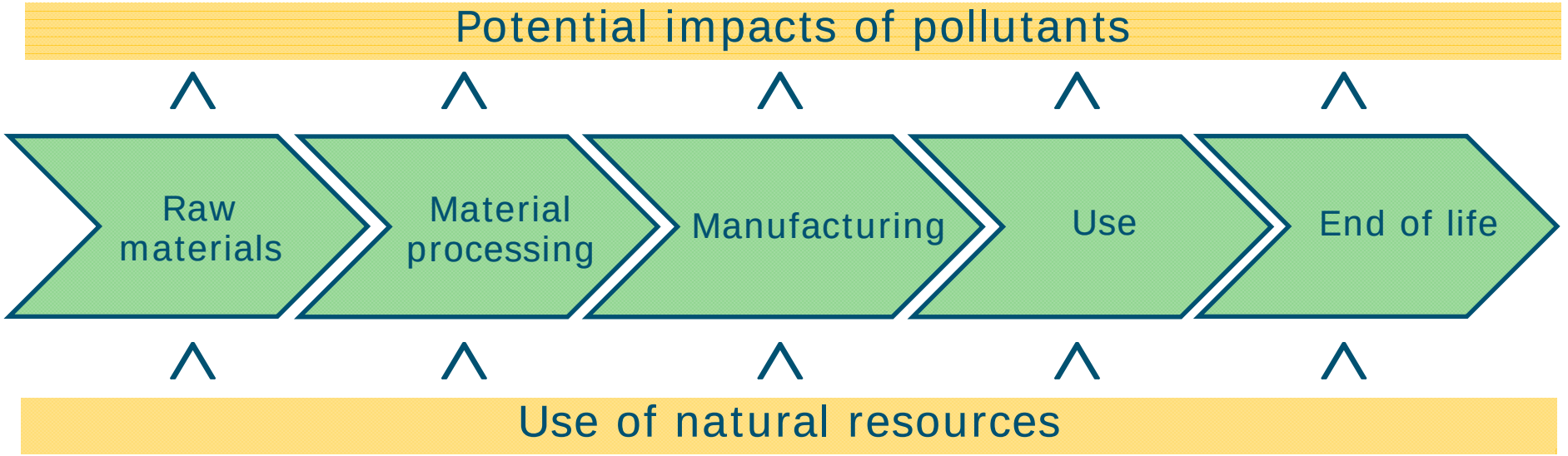
Life cycle assessment (LCA)

method to evaluate *use of resources* and *emission of pollutants* during the entire life cycle of a *product*

Aim

Reduce "**impact**" during product's life cycle

Illustration of LCA



Industry 1st LCA on Coca Cola in 1969

Livestock 1st LCA on milk in 1998

(Cederberg and Mattson, 2000)

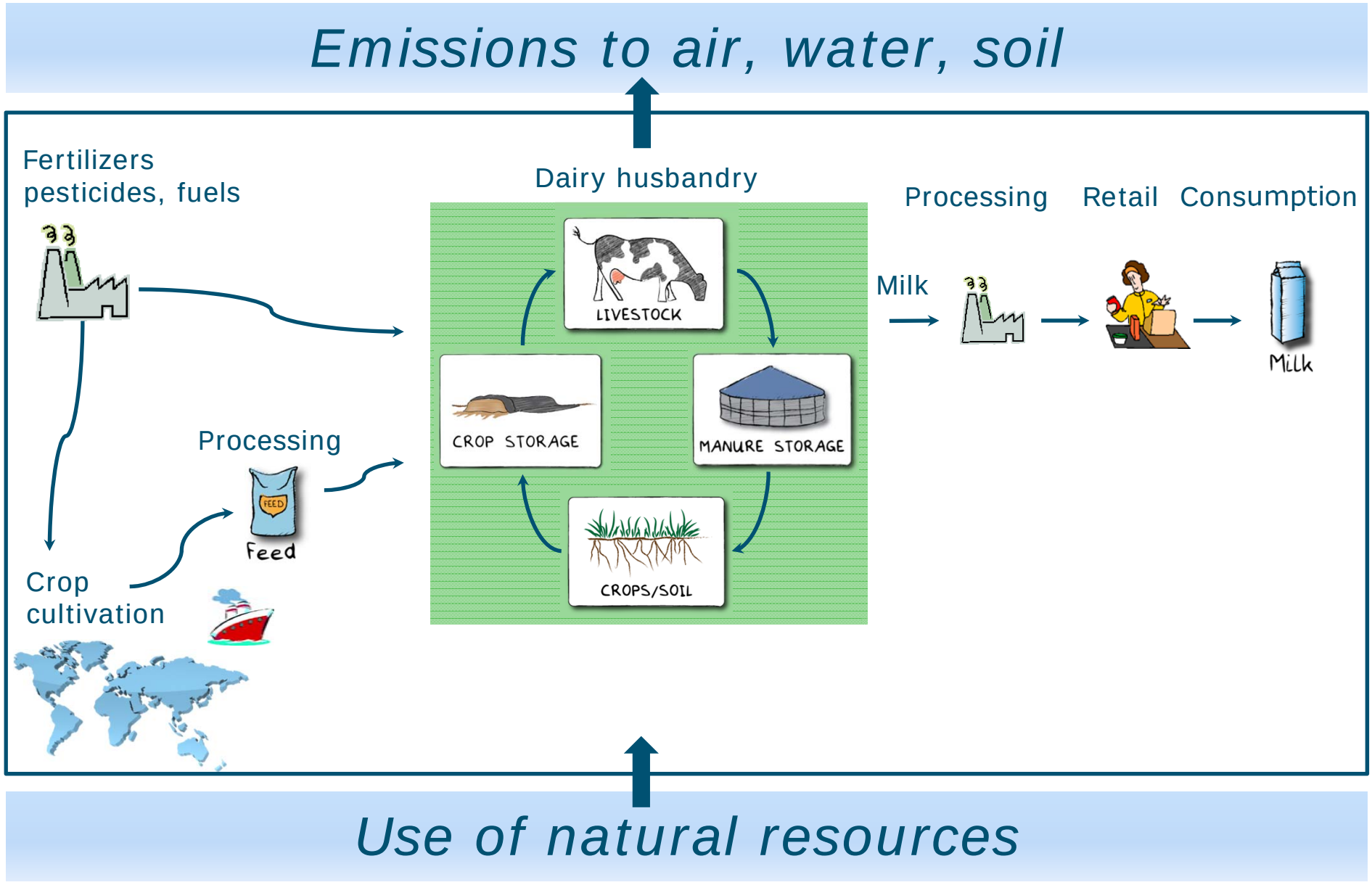
First LCAs

- Impact of food production & hotspots
- Use of fossil energy & land, global warming, eutrophication, acidification
- Metrics: impact/unit output

impact: e.g. global warming (CO_2-e)
unit: e.g. kg milk, eggs, carcass meat

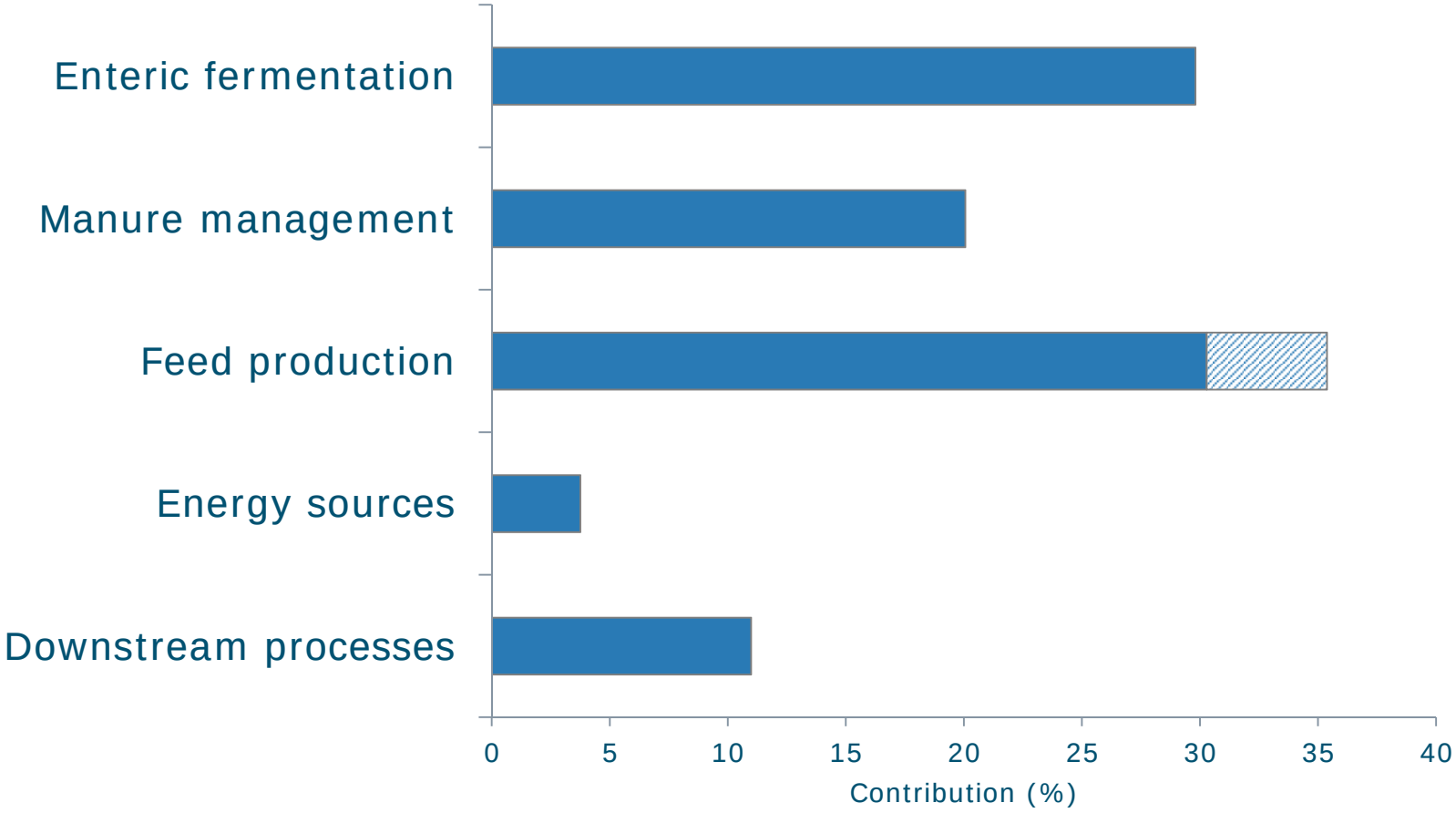
Focus: (food) provisioning function

LCA of milk


Emissions to air, water, soil
Fertilizers
pesticides, fuels
Dairy husbandry
Processing
Retail
Consumption
LIVESTOCK
CROP STORAGE
MANURE STORAGE
CROPS/SOIL
Milk
Milk
Processing
FEED
Feed
Crop
cultivation
Use of natural resources

Example GHG hotspots

Global warming potential: 1.15 kg CO_2/kg FPCM



Van Middelaar (2014) PhD Thesis

Comparison of beef production systems

Pasture-based

Concentrate-based

Global warming	>
Energy & land use	>
Eutrophication	≈
Acidification	≈

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De Vries, Van Middelaar, De Boer (2015)

Competition between humans and animals

human edible energy return on human edible energy investment

System	Ratio (Calorie / Calorie)
Concentrates-based beef	4.2
Pasture-based beef	69.1

Ruminants on marginal land show no feed-food competition

Moreover grazing systems ....

Provide non-provisioning services, e.g.

- Biodiversity preservation
- Conservation of the landscape (aesthetic value)
- Climate regulation (incl. C-sequestration)
- Maintenance of soil fertility
- Water purification
- National hazards prevention (fire)

Question

(How) can we incorporate these issues in an LCA?

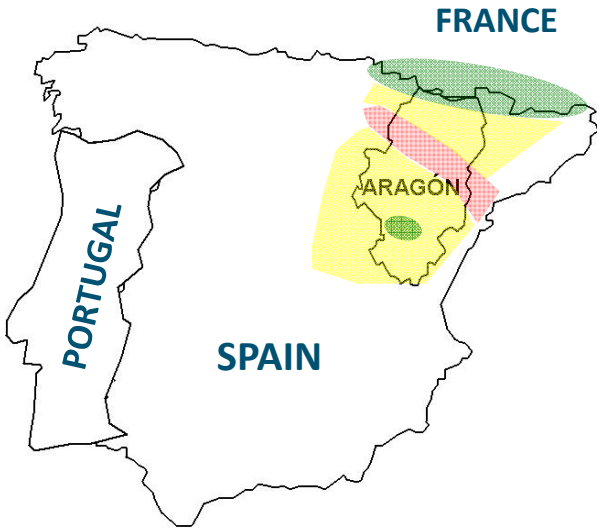
Let’s discuss using examples

An LCA metric (mid-point)

$$\frac{\text{potential impact}}{\text{unit of main output of system}}$$

Non-provisioning services as an output

Comparison of three systems



1. Grazing or pastoral system:

- Pyrenees
- 1 lambing per ewe per year
- Free ranging

2. Mixed sheep-cereal crop system:

- Mid-altitude Mediterranean ranges and plateaus
- 1.5 lambings per ewe per year
- Grazing daily with shepherd

3. Industrial system or zero grazing:

- Low altitude semi-arid conditions.
- 1.7 lambings per ewe per year
- Indoors all year round

Ripoll-Bosch, De Boer, Bernues, Vellinga (2013)



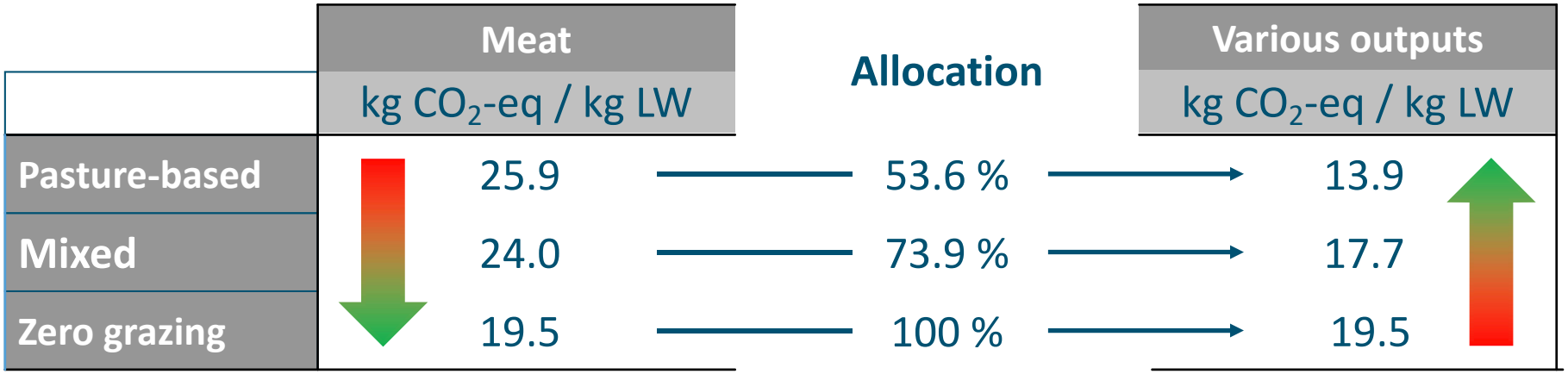
meat production

non-provisioning services
e.g. biodiversity & landscape conservation, wildfires prevention

Ripoll-Bosch, De Boer, Bernues, Vellinga (2013)

- Economic allocation to various outputs (subsidies)
- Use system expansion
- Use farm income as a functional unit

Non-provisioning services as an output



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Ripoll-Bosch, De Boer, Bernues, Vellinga (2013)

Non-provisioning services as an output

- Acknowledging multi-functionality of livestock systems affects the conclusion
- Non-provisioning services have an environmental cost, also if not provided by livestock

- Requires “sound” economic values for non-provisioning services
- Does not allow handling negative “negative impacts” of services

Non-provisioning services as an impact

Link services with **land occupation** & **transformation**

- focus on land occupation -

Example of biodiversity

Biodiversity impact of land occupation

1. Quantify land area
2. Categorize land area in classes
   - agricultural use: e.g. grassland, grains, beans etc.
   - practices: e.g. intensive or extensive grazing

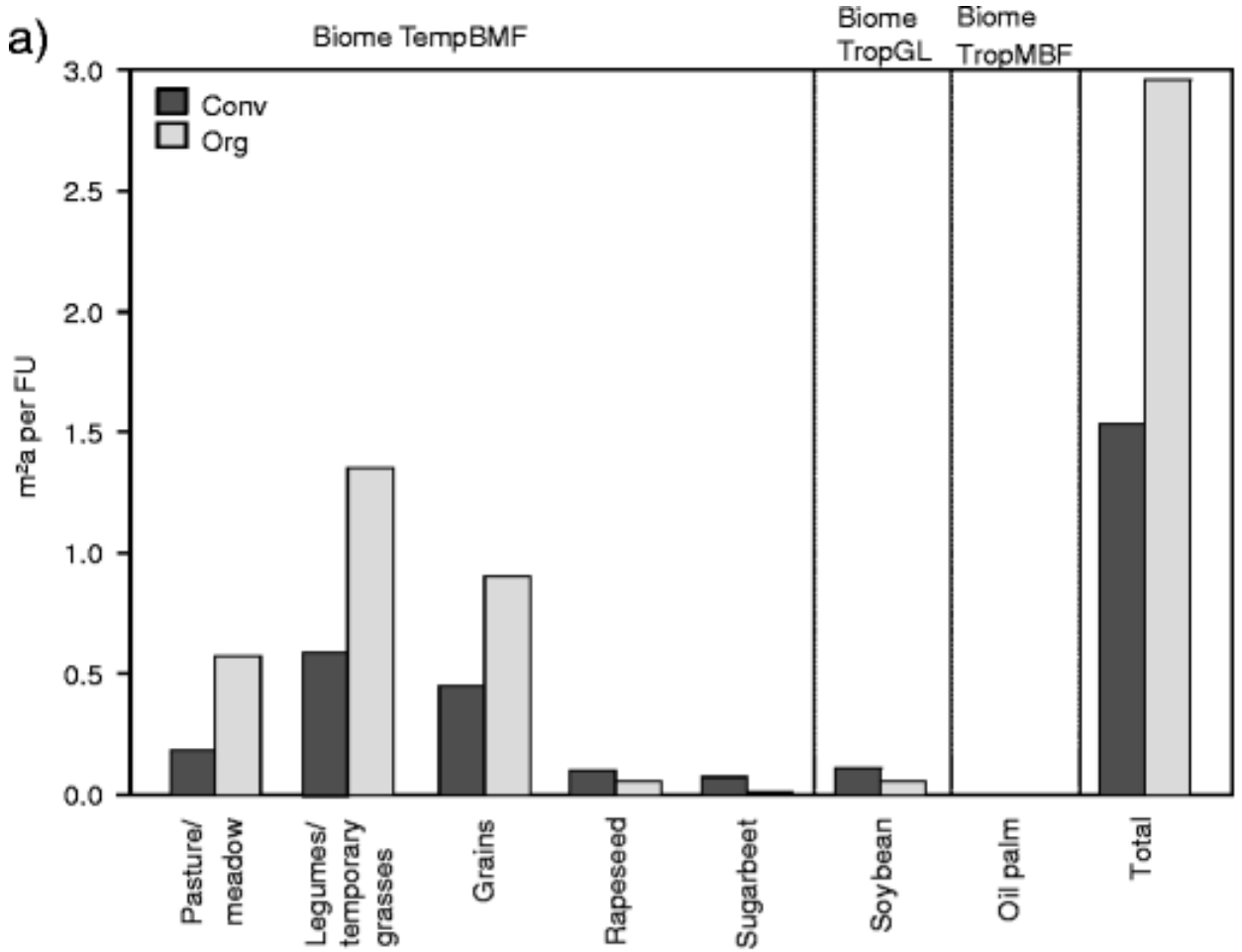
3. Link each class to (single) biodiversity impact

   Based on variety of organisms present in an ecosystem
   - loss in species richness (original habitat)

4. Multiply area with “impact”: loss in species richness

Case: organic vs conventional production of Swedish milk

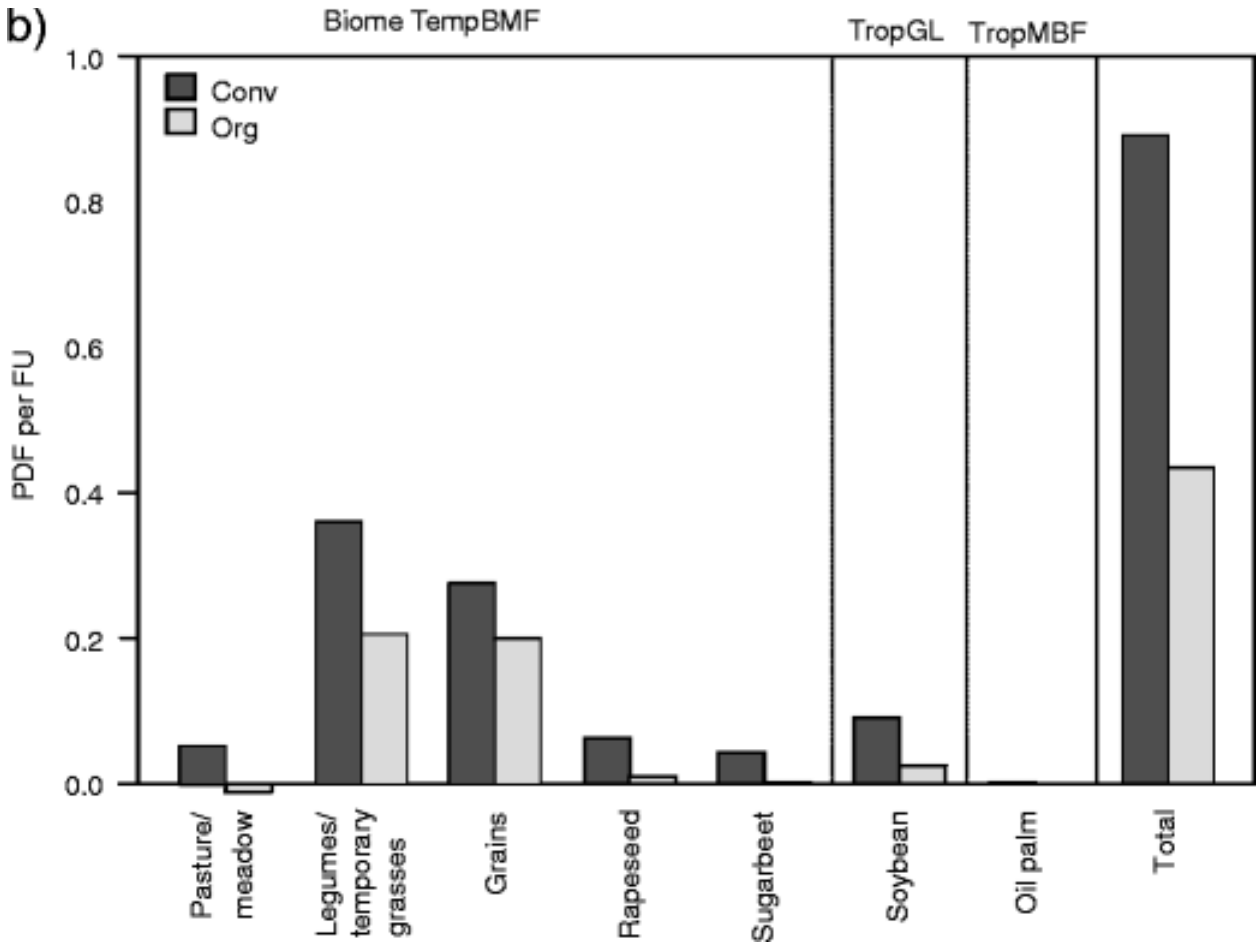
Identify land occupation and classes



Mueller et al. (2014)

Case: organic vs conventional production of Swedish milk

Link land area & classes to biodiversity impact



Mueller et al. (2014)

Non-provisioning services as an impact

- Allows summing of positive and negative impacts of biodiversity (or other non-provisioning service) along the chain
- Demonstrates strengths and weaknesses of systems

- Complex nature of e.g. biodiversity impact can not be captured easily in a ‘single’ indicator
- Current global land classifications do not capture agricultural practices (e.g. intensity of grazing)

Summary

- LCA designed for **industrial** processes:
  - product-based approach
  - focus on environmental **costs** of food production
- At first, multi-functionality of agriculture not addressed
- Approaches to incorporate ES differ: output or impact
- No single best method
- Combination of indicators required to demonstrate benefits and costs of complex livestock systems

Thank you for your attention

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PhD course

Awarded the WIAS education prize for best PhD course in 2015

Environmental impact assessment of livestock systems

13-17 February 2017

Animal Production Systems, Wageningen University, the Netherlands

Imke de Boer, Wageningen University

Pierre Gerber, FAO

Martin Persson, Chalmers University

Oene Oenema, Wageningen University

and others

INFO: www.aps.wur.nl Or contact: Corina.vanMiddelaar@wur.nl

C.4.U6 Richness and evenness are components of biodiversity.

Biodiversity

is variety of organisms present in an ecosystem

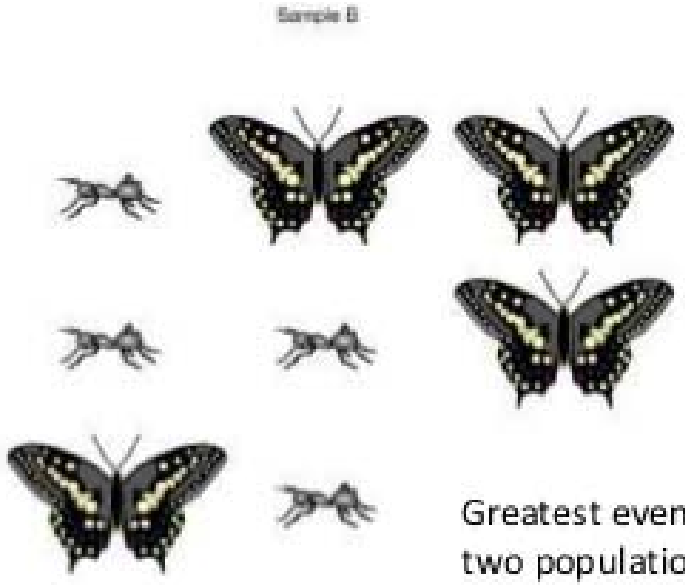
Richness

The number of different species present.

Evenness

If a habitat has similar abundance for each species present, the habitat is said to have eveness.

More species therefore highest richness



Greatest eveness as the two populations have similar abundance.

http://www.nature.com/nature/journal/v405/n6783/images/405212aa.2.jpg

Mitigation strategies

Measures

relate **productivity of food systems** to

environmental impact

To define a measure we need

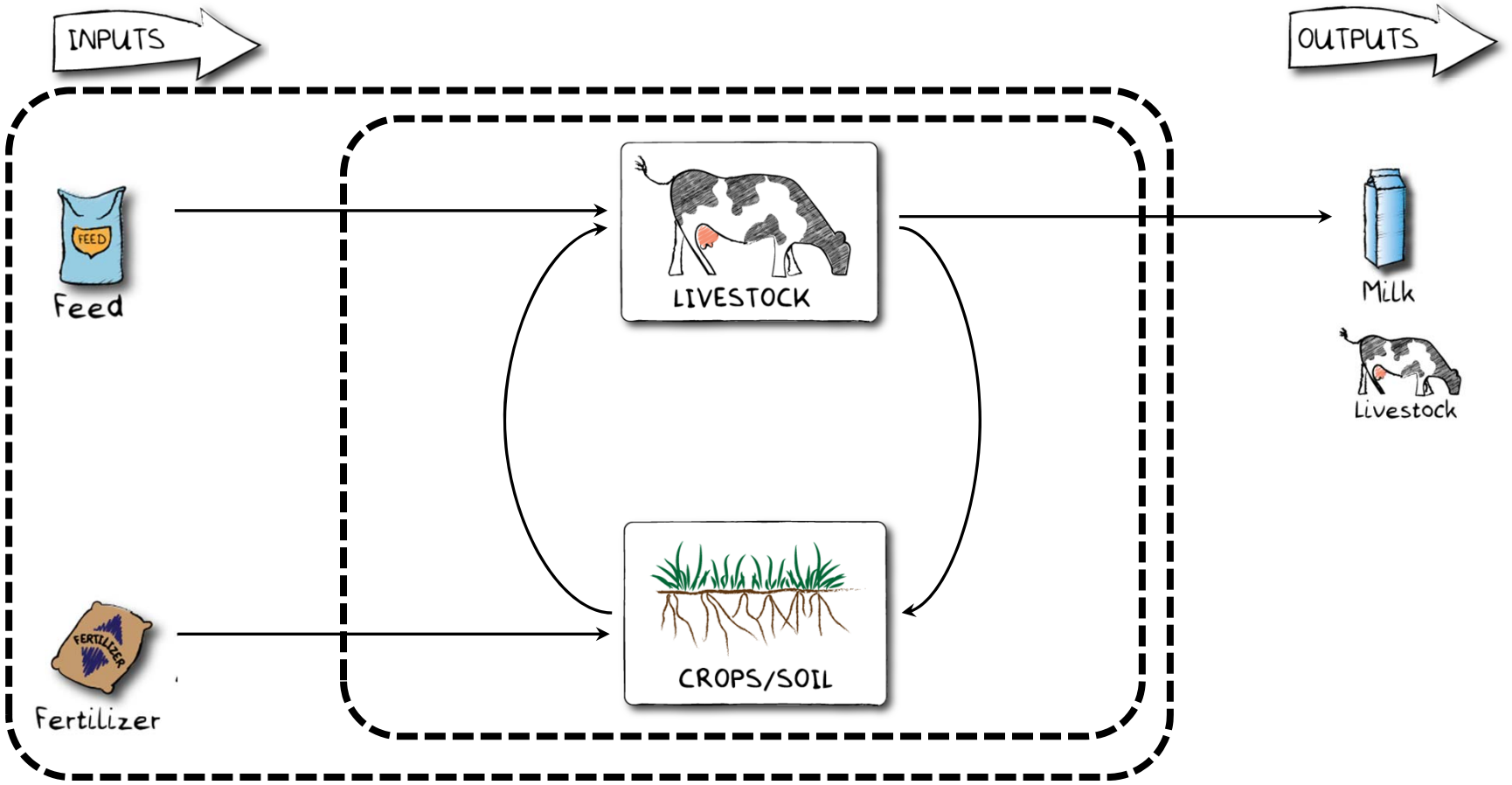
- to define the boundary of food system
- assess its environmental impact

  use of natural resources - **land**

  emissions
- assess its productivity

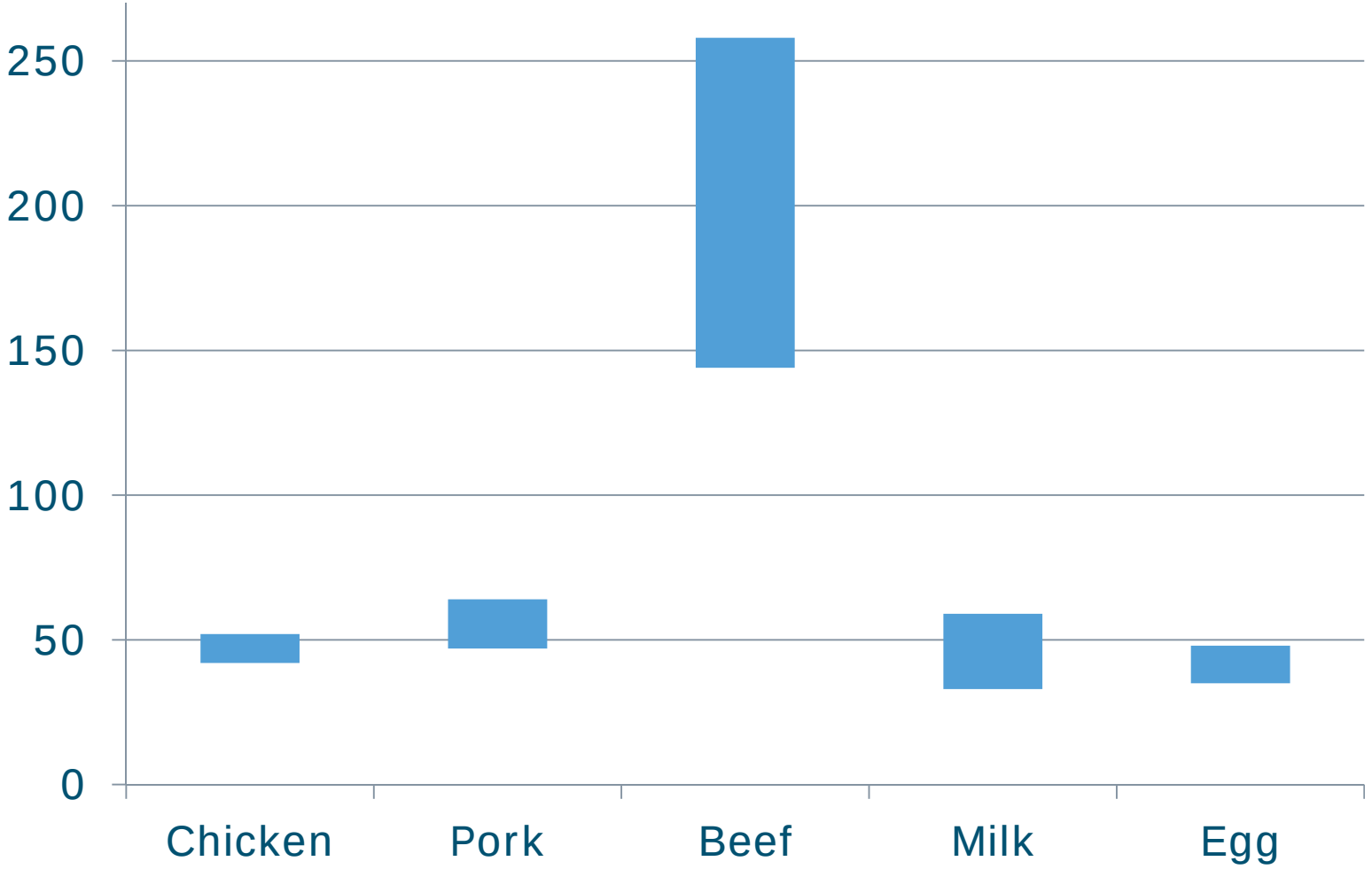
Measuring land use efficiency: present

life cycle perspective: **m² per kg milk**



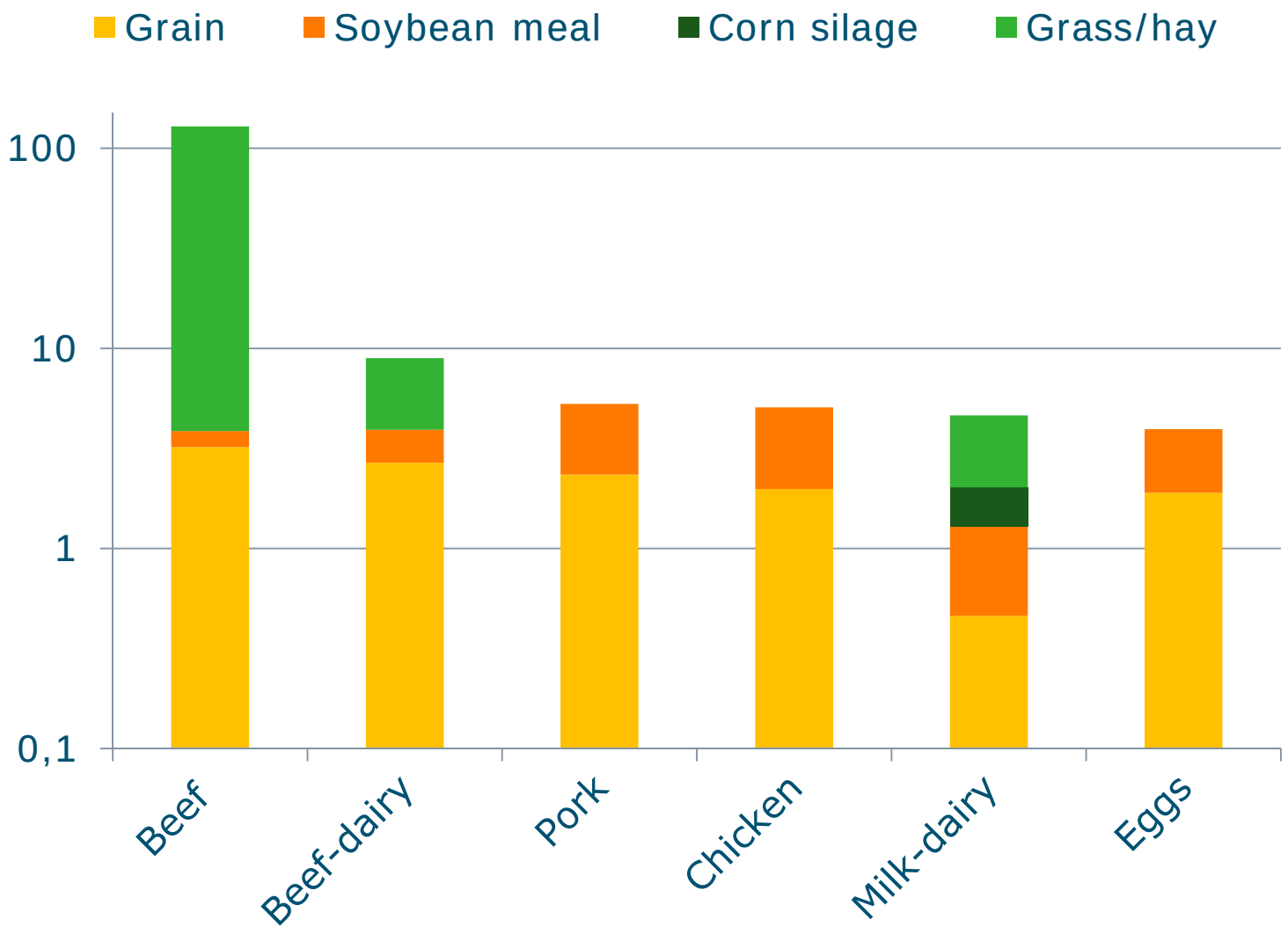
Measuring land-use-efficiency: present

- life cycle perspective: m^2 per kg edible protein -



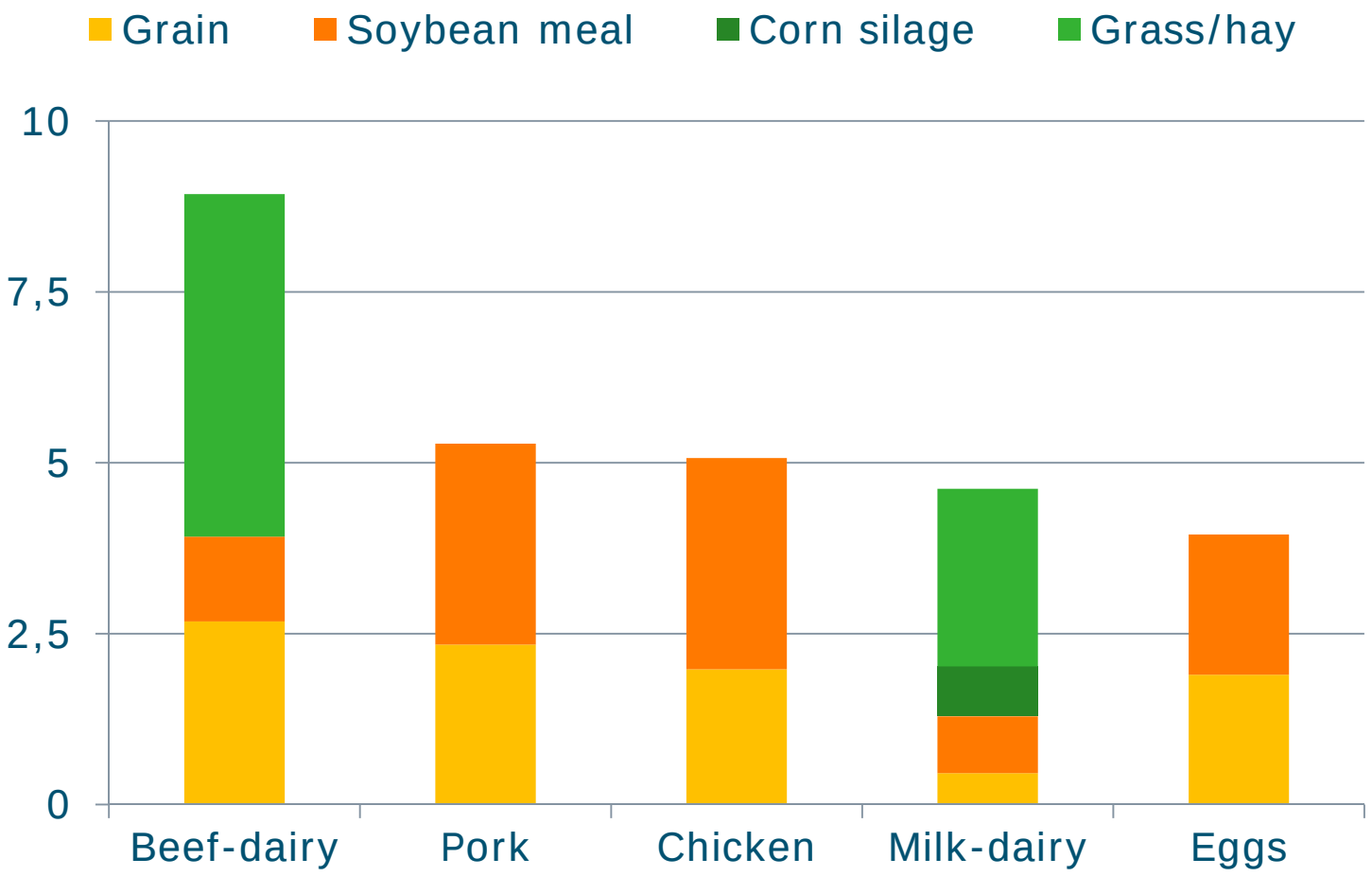
De Vries and De Boer (2010)

m^2 per 100 g edible protein - USA



Peters et al. (2014)

m^2 per 100 g edible protein - USA

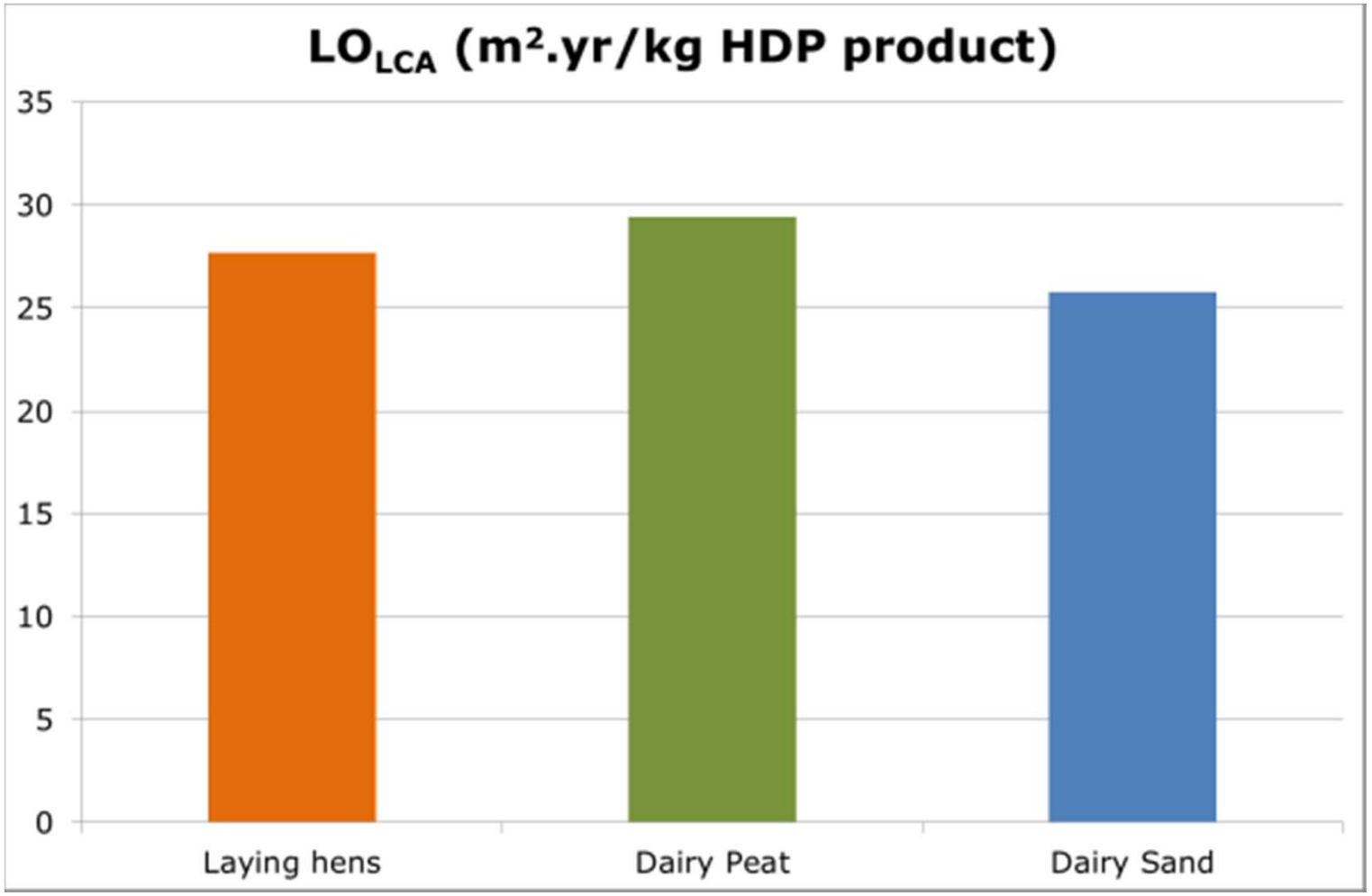


Peters et al. (2014)

Land use efficiency
Dairy vs laying hen systems in NL

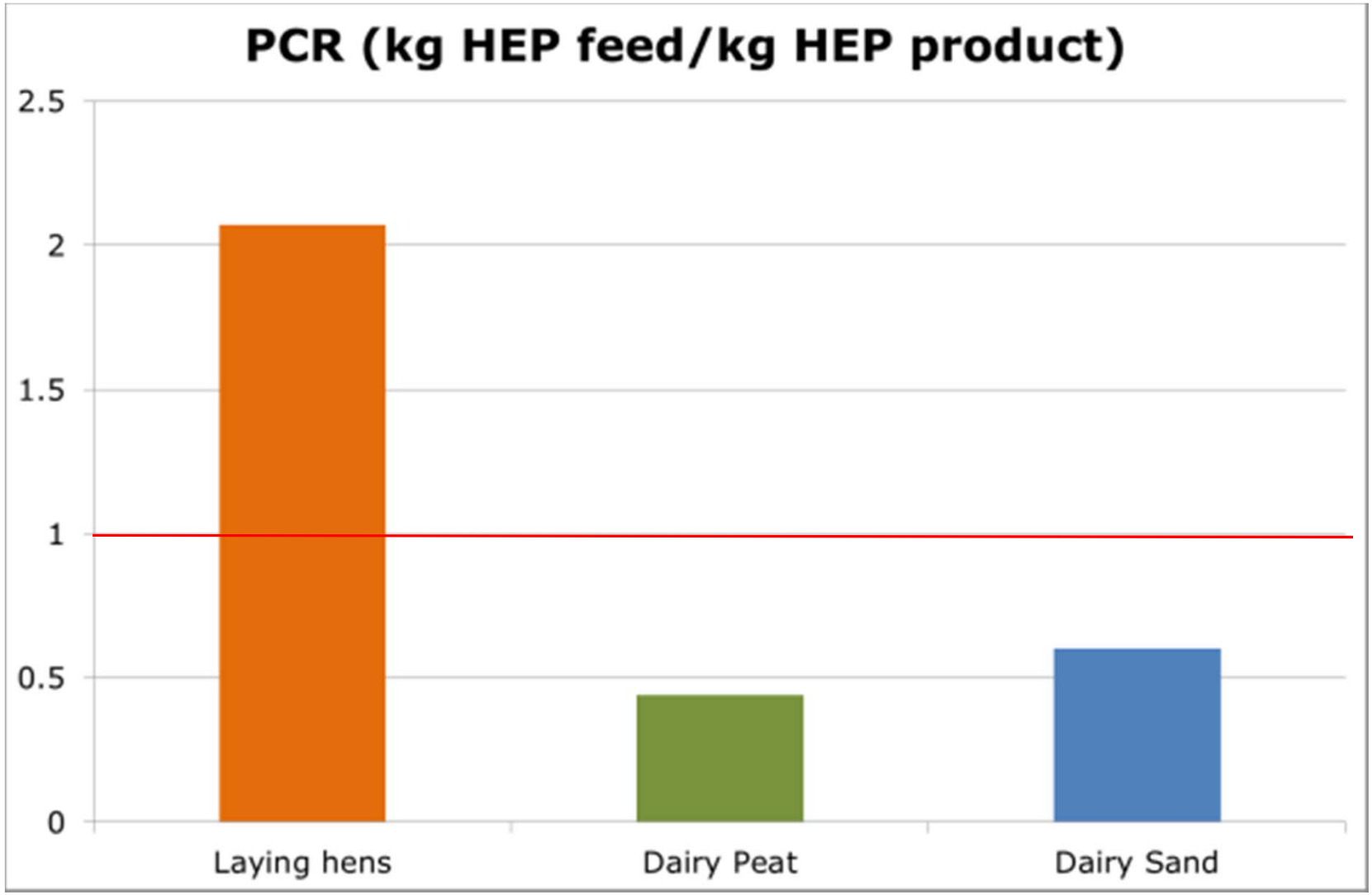
- NL Dairy farms > 90% peat soils
- NL Dairy farms > 90% sandy soils
- NL Egg production – barn system

Milk versus egg production in NL – LCA



Van Zanten et al. (2015) IJLCA

Milk versus egg production in NL



Van Zanten et al. (2015) IJLCA

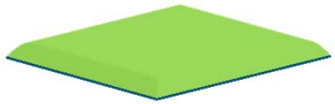
Measuring land use efficiency: future

- Include crop productivity
- Include animal productivity
- Account for competition between feed and food
- Account for suitability of land to cultivate food crop

Land use ratio

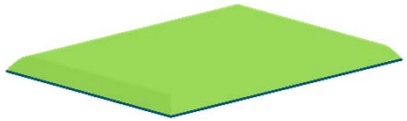
Van Zanten at al. (2015)

Area feed cultivation



+

+



=

1 kg animal-source food

→ kg HDP food crop

+

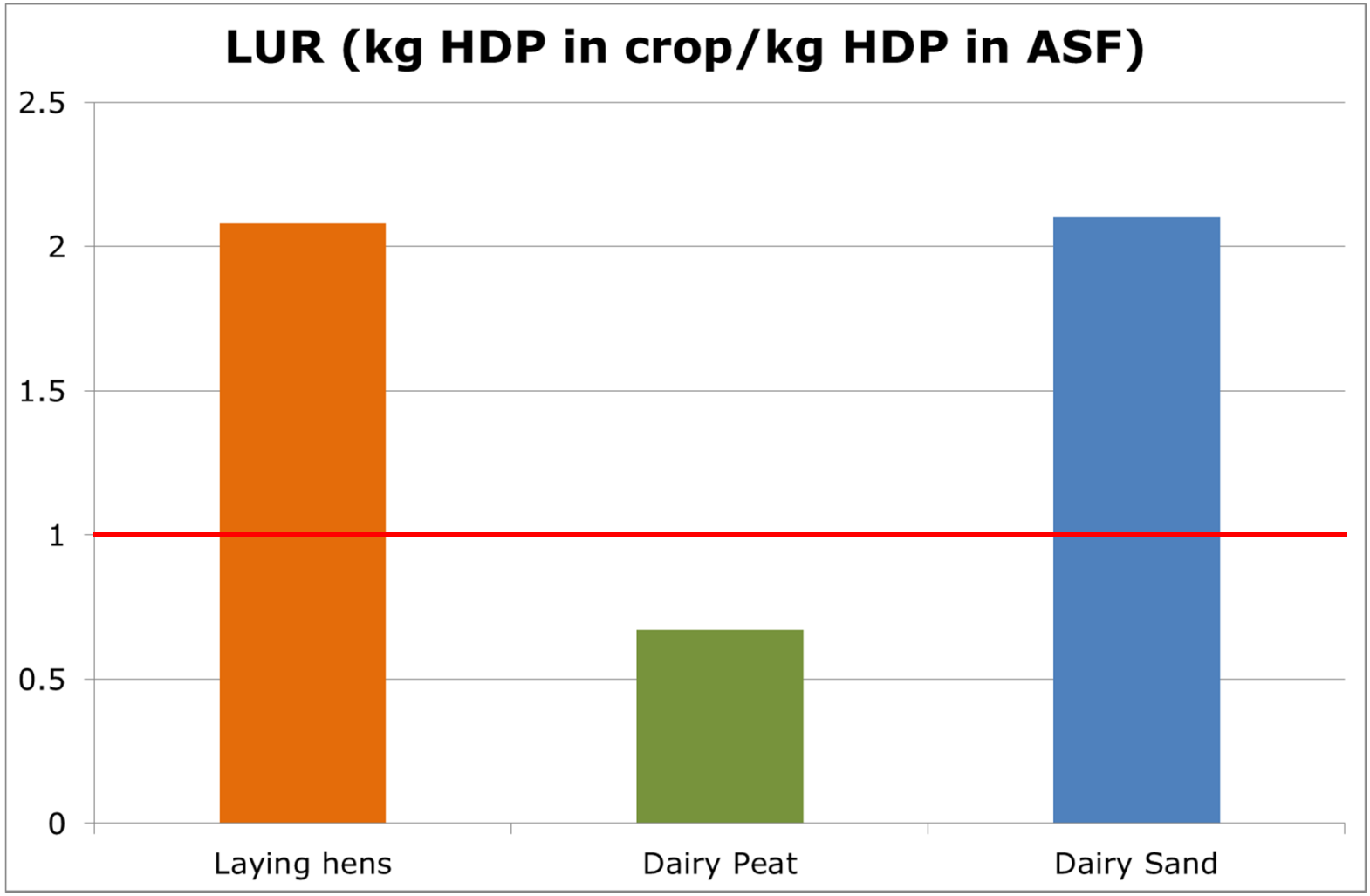
→ kg HDP food crop

+

→ kg HDP food crop

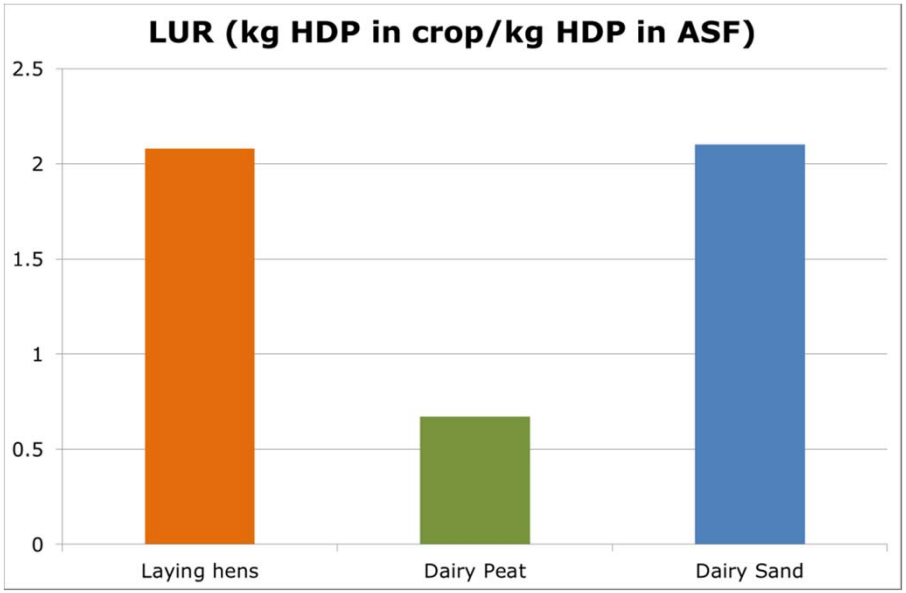
$$\frac{\sum \text{HDP food crops}}{\text{HDP in one kg ASF}}$$

Land use ratio

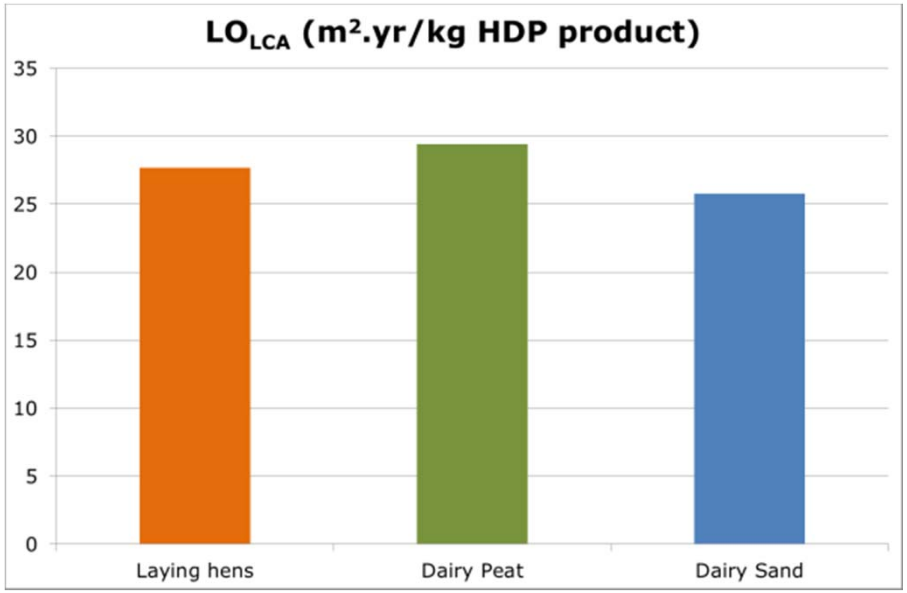


Van Zanten et al. (2015)

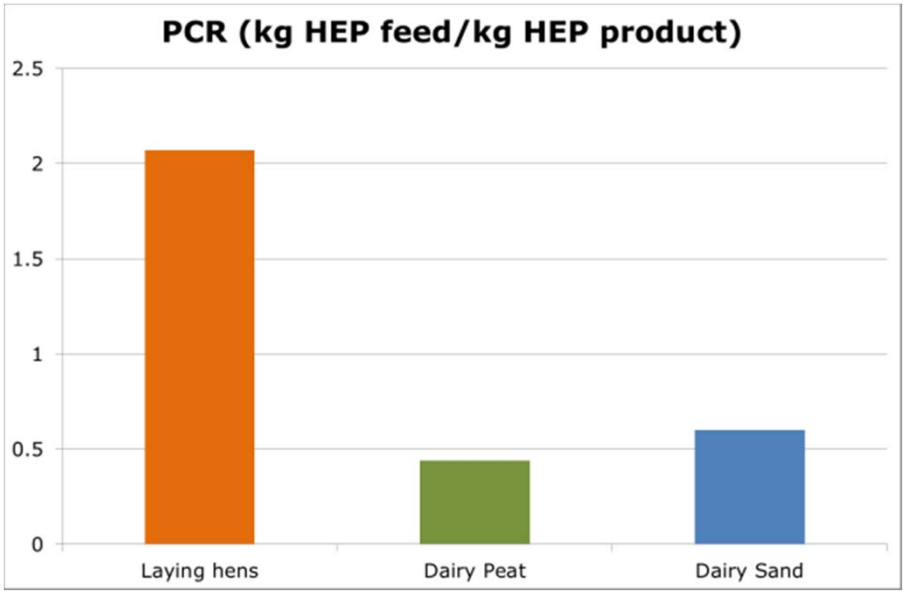
Land use ratio



LCA results



Protein conversion ratio



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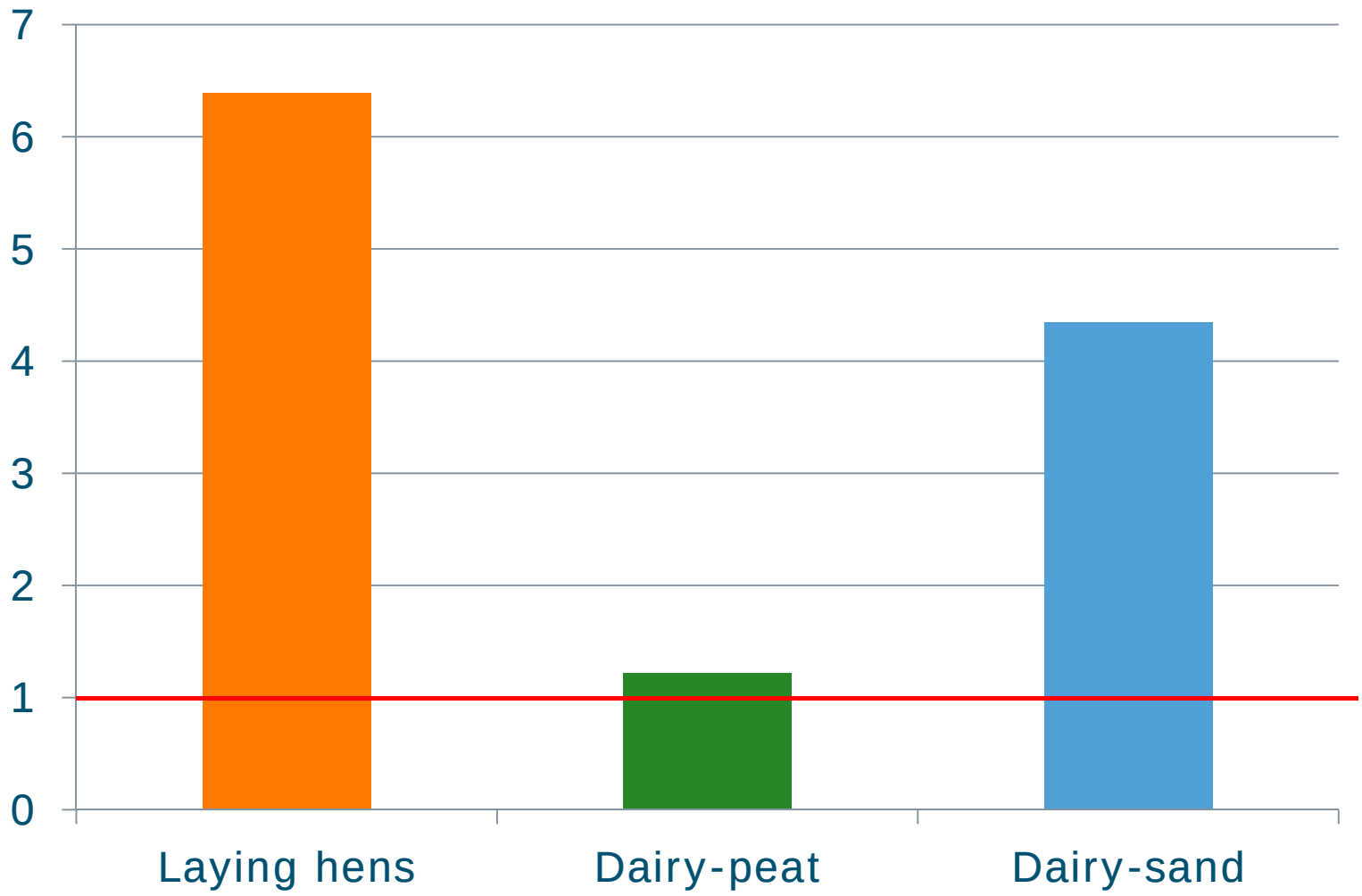
LUR – energy

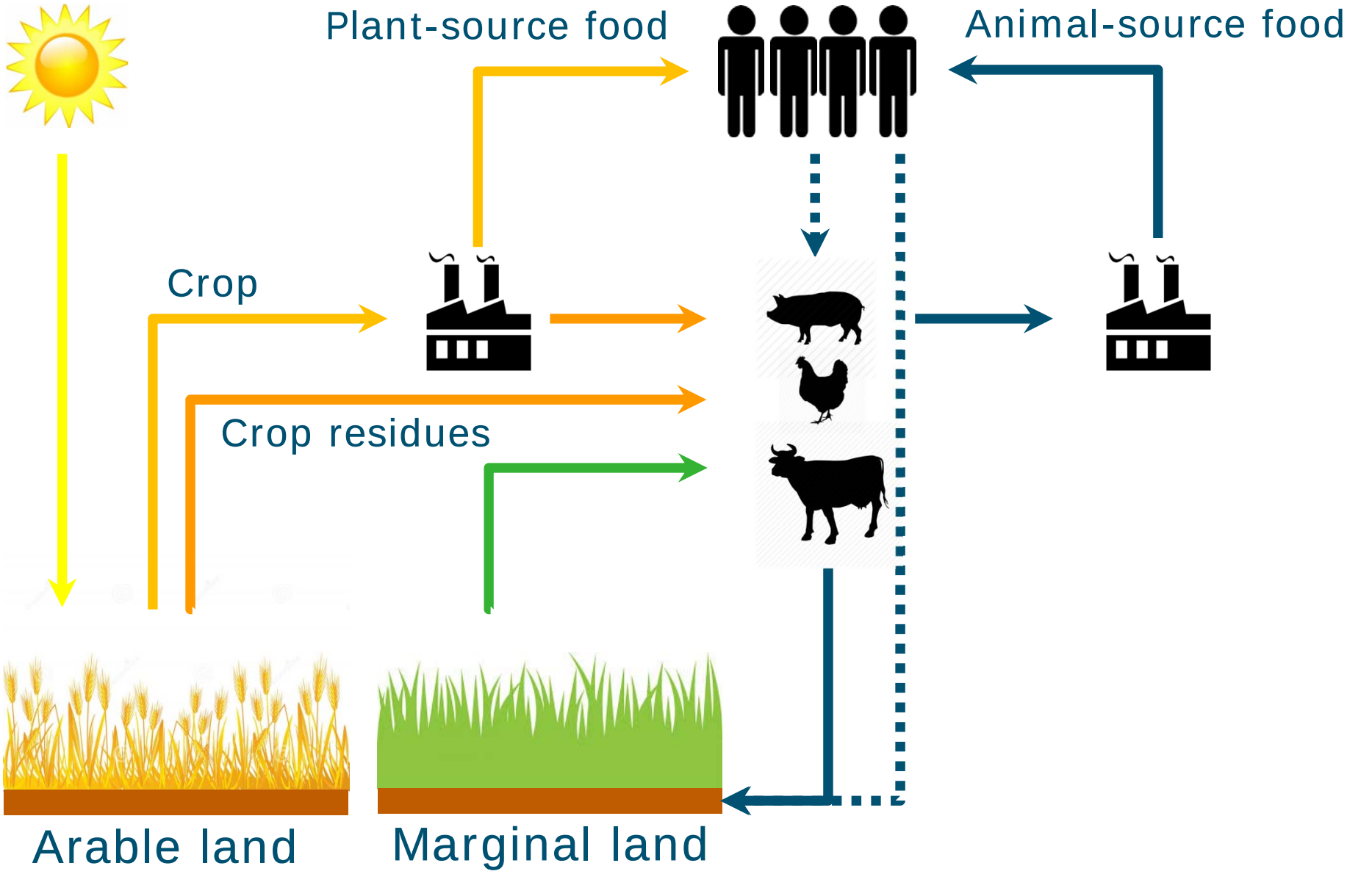
(kg HDE crop/kg HDE ASF)



Measuring land use efficiency

Measures	System	Productivity	What do you improve?
FCR – animal	animal	kg animal product	feed efficiency animal
FCR - herd	herd	kg product herd	feed efficiency herd
LCA	life cycle	kg milk	crop – herd efficiency
PCR - herd	herd	Kg milk	conversion non-edible protein into edible protein
LUR	life cycle	kg food protein	land use efficiency food production

Optimal use of biomass



Take home message

The choice of your measure

to assess environmental impact of food production systems

affects your conclusion

Shift our focus from improving efficiency at animal level to improving the number of people to be nourished per ha (unit of resource)

Crop and livestock

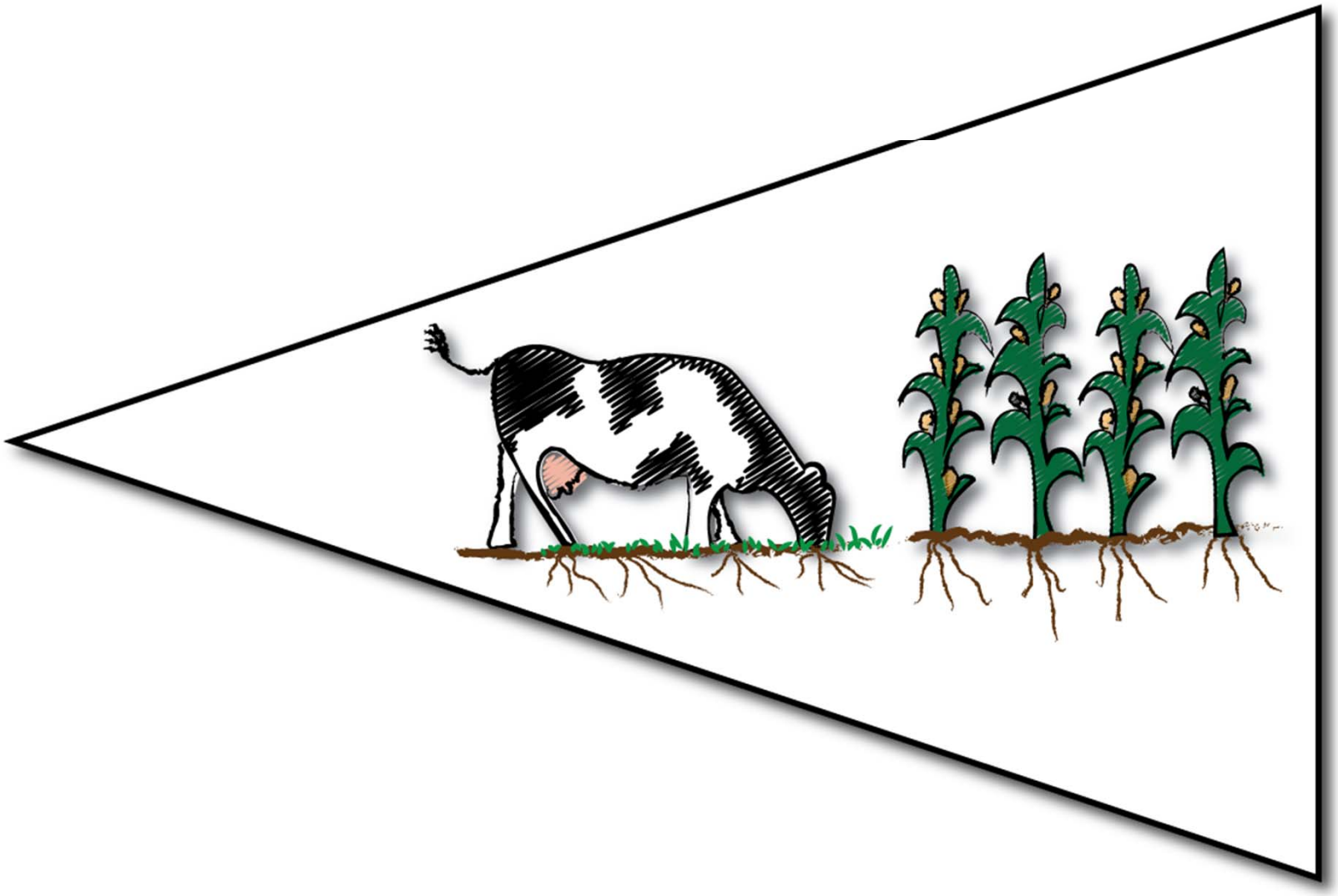


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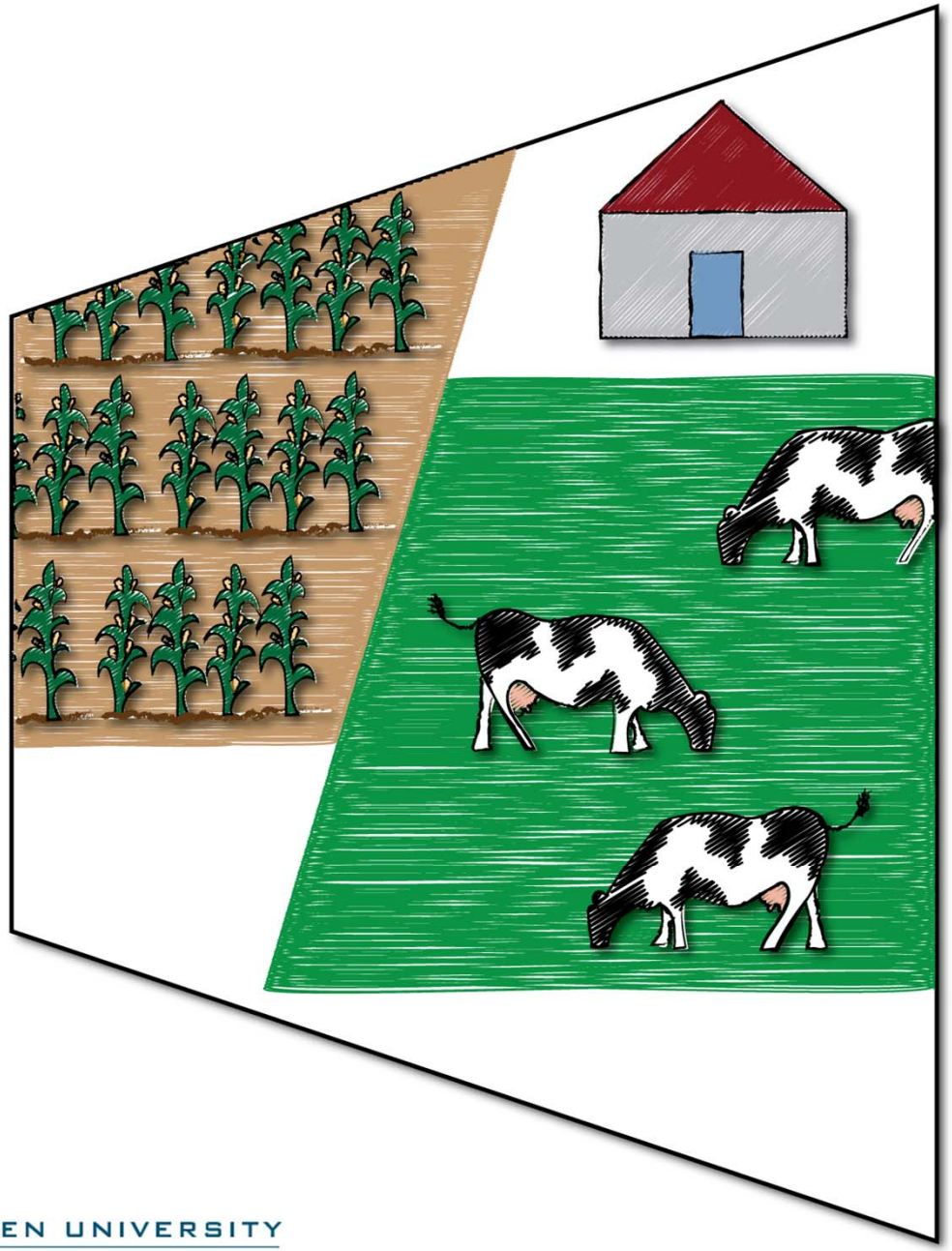
Illustration by Birgit Boogaard (www.kuwona.nl)

Farm



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Region

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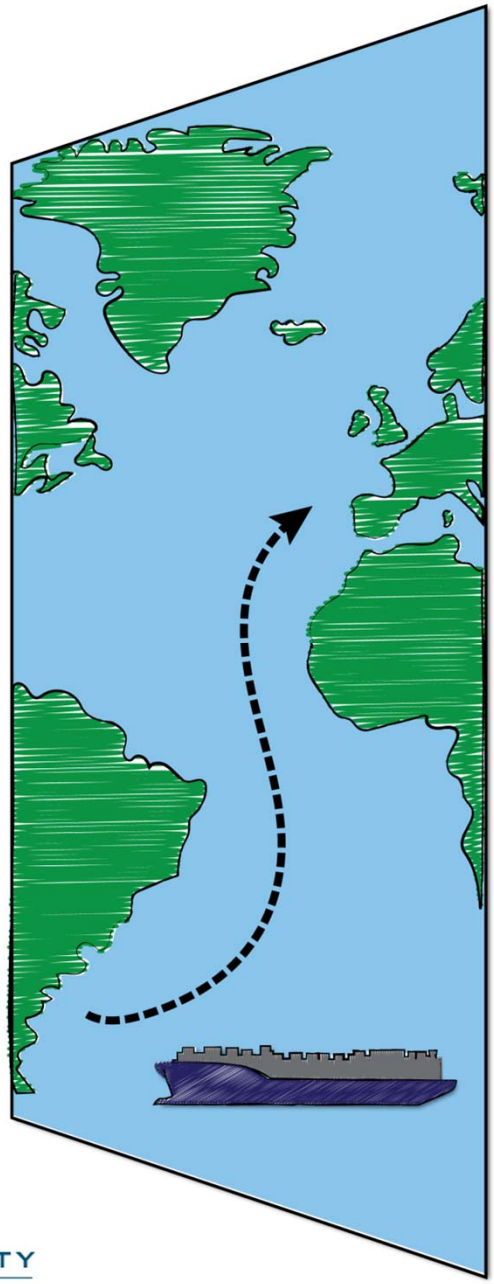
Continent



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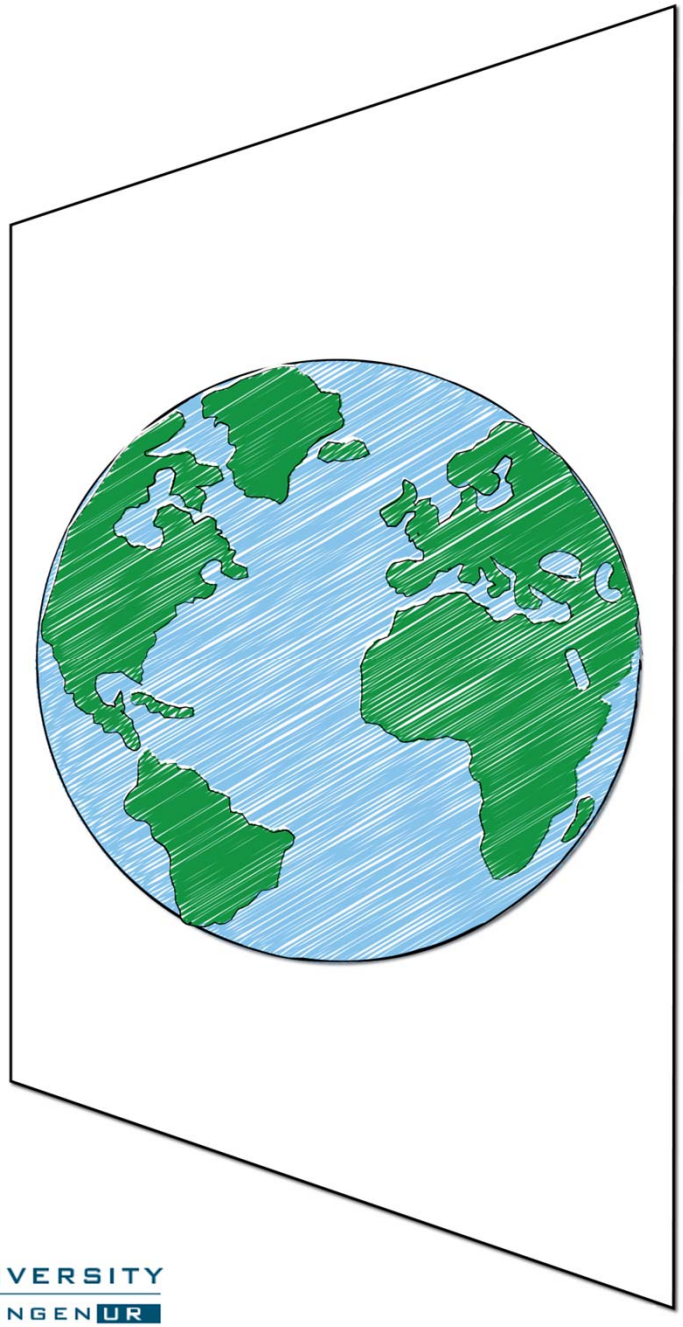
Globe



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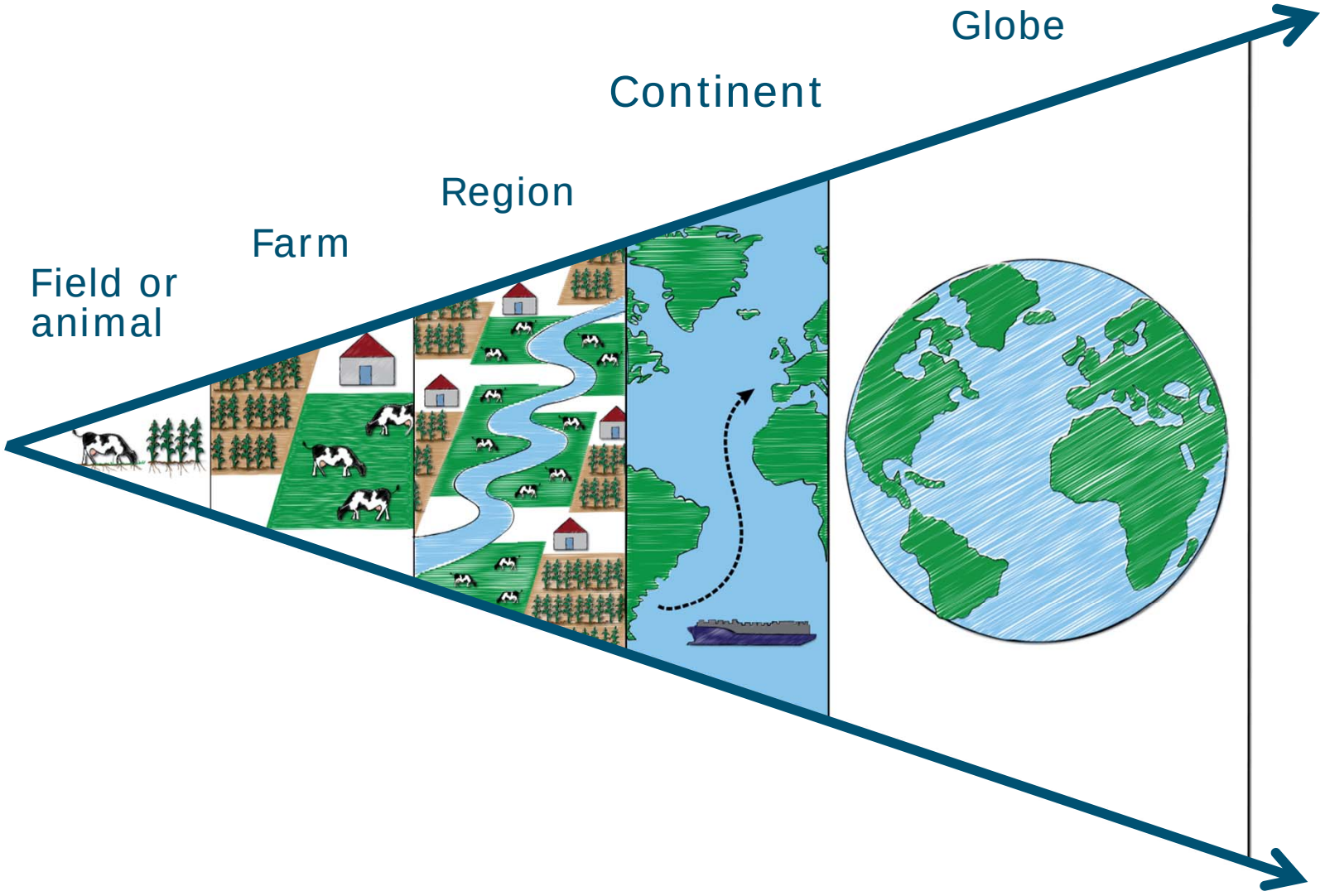
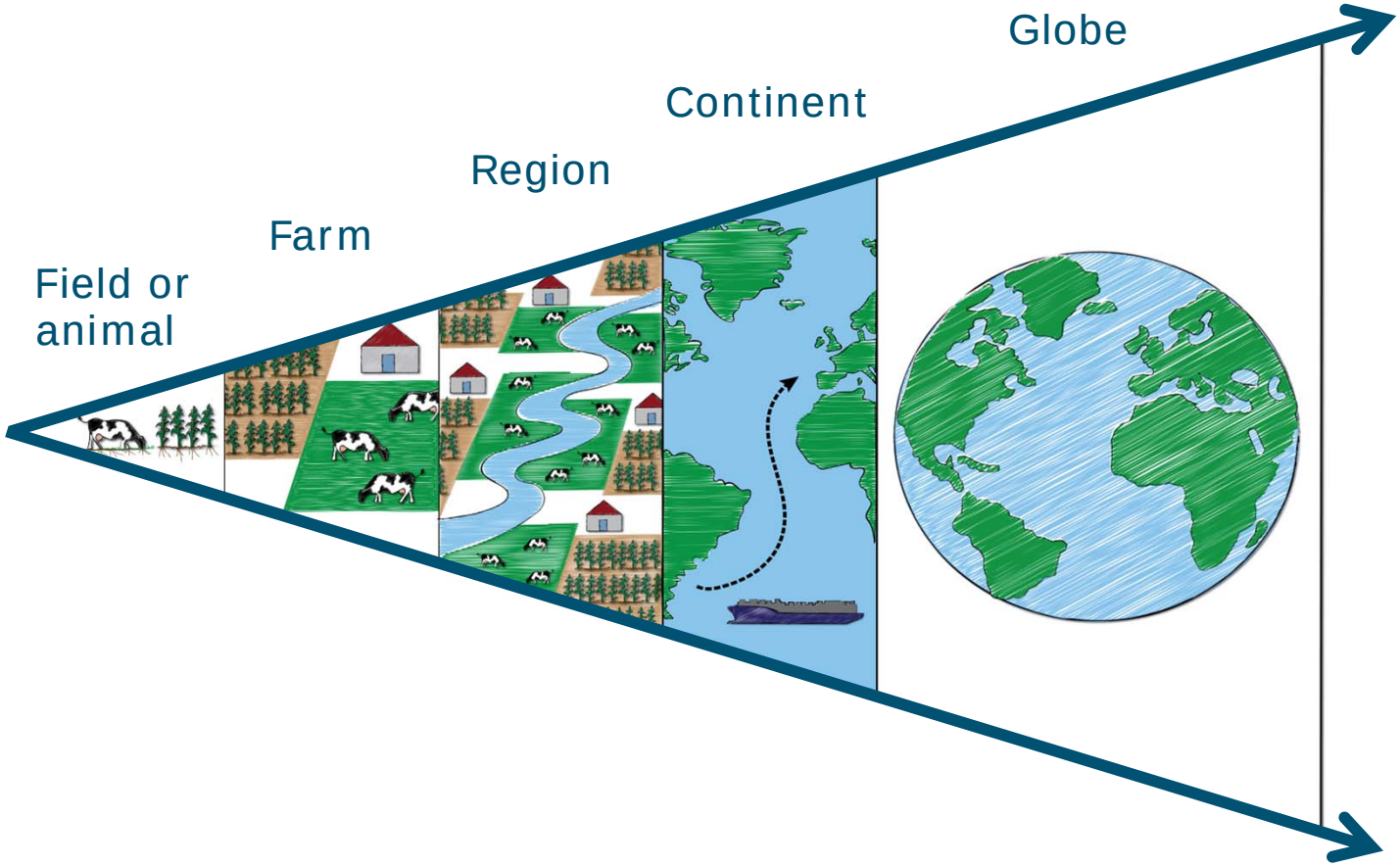
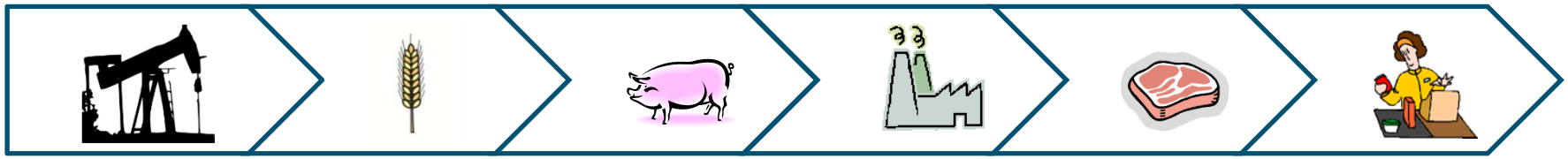
System hierarchy



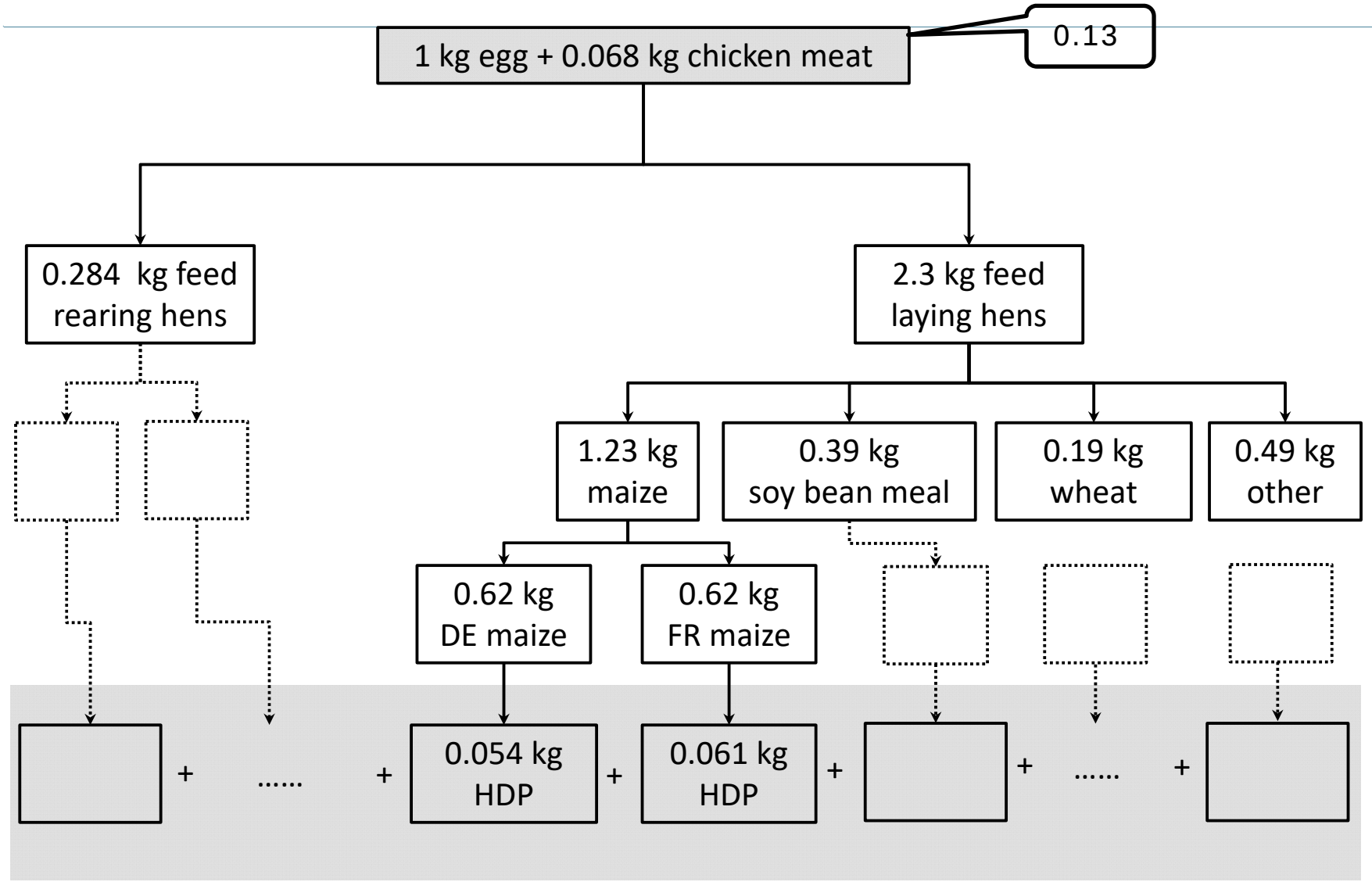
System boundary



life cycle of a product or service

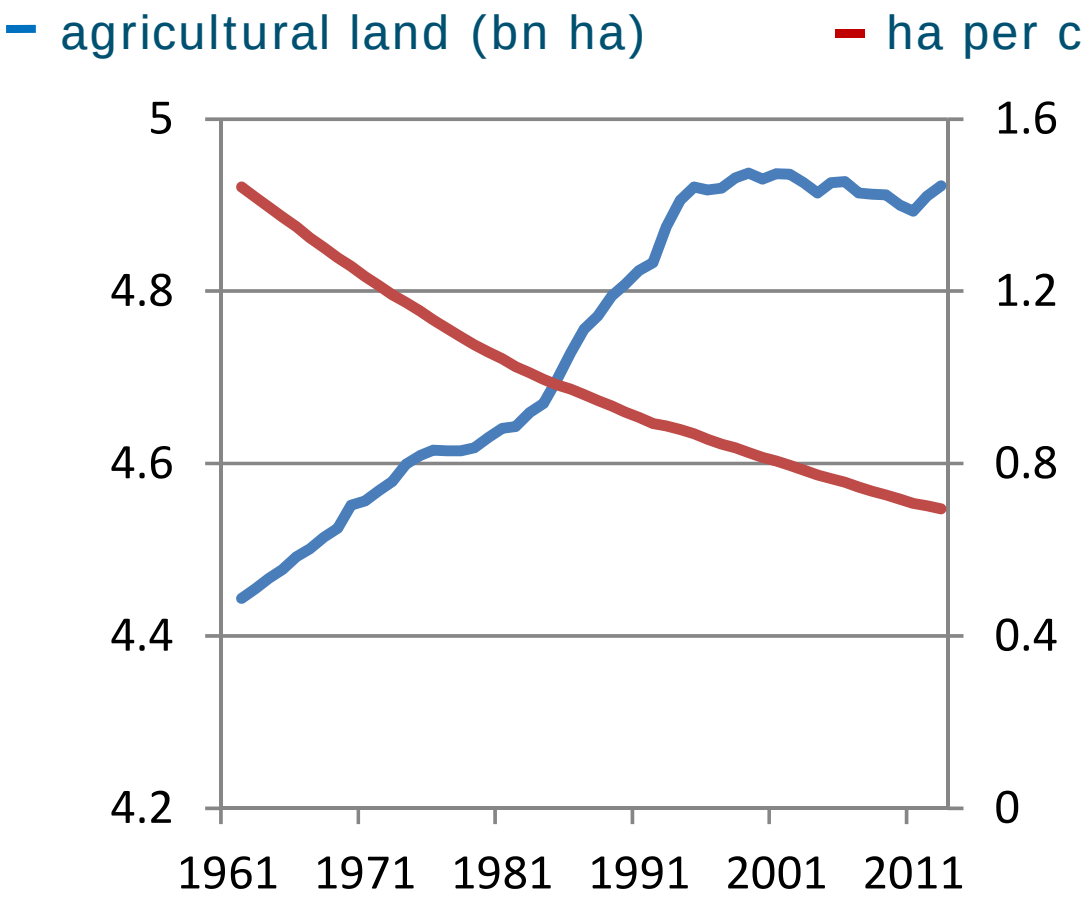


Computation structure for laying hens



0.27 kg HDP

Example – land use efficiency (FAOSTAT, 2015)



Prediction 2050

0.5 ha per capita

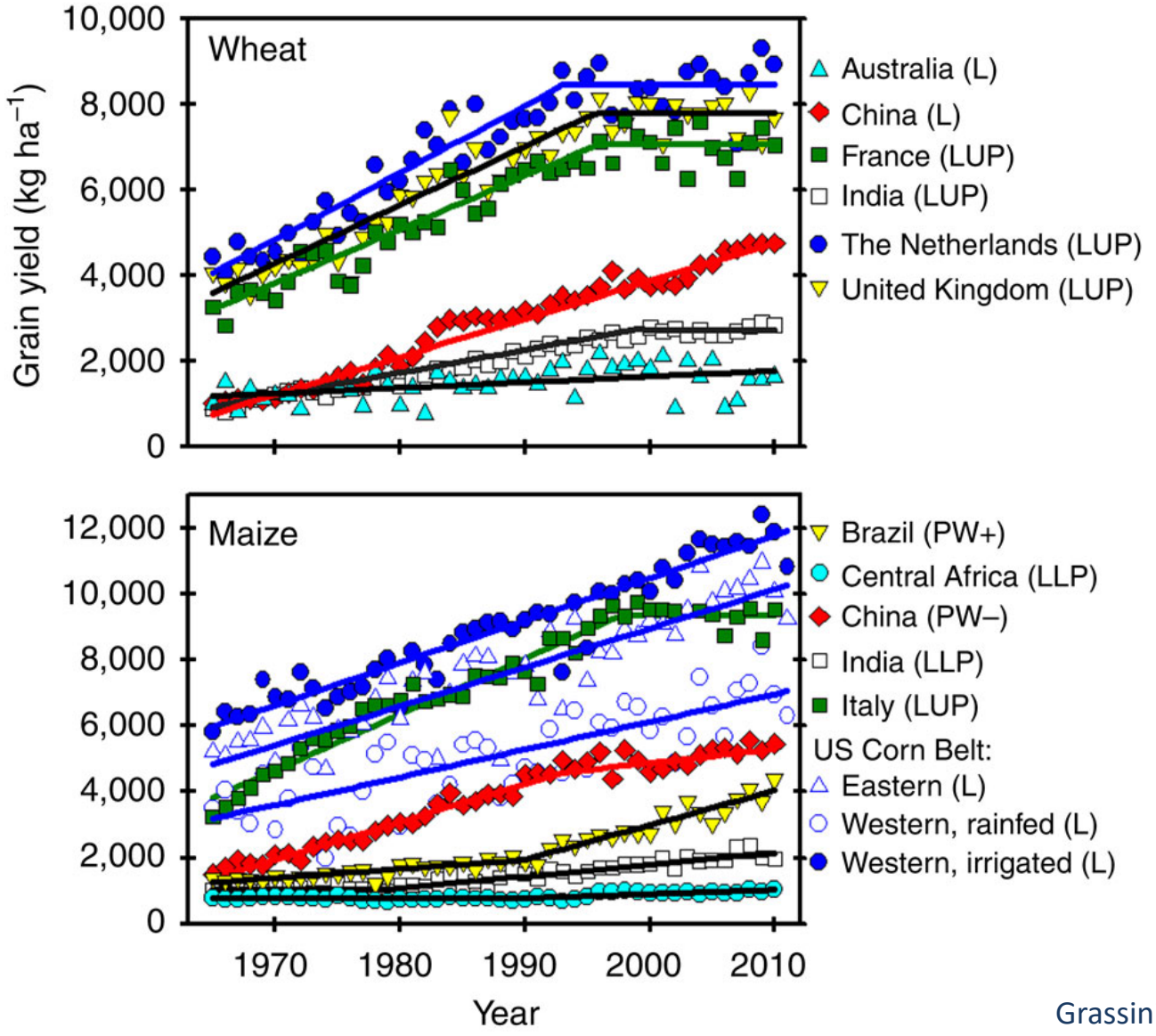
We have to increase land-use efficiency of food production

Trends in livestock productivity

Species	Trait	Performance level		
		1960	2005	**Δ (%)**
Pig	# weaned/sow/year	14	21	**50**
	meat %	40	55	**37**
	kg meat/ton feed	85	170	**100**
Broiler	# days until 2 kg	100	40	**60**
	kg feed/kg live weight	3,0	1,7	**43**
Laying hen	# eggs per year	230	300	**30**
	# eggs/ton feed	5.000	9.000	**80**
Dairy	kg milk/cow/year	6.000	10.000	**67**

Hume et al. (2011)

Trends in wheat and maize yield



Grassini et al. (2013)

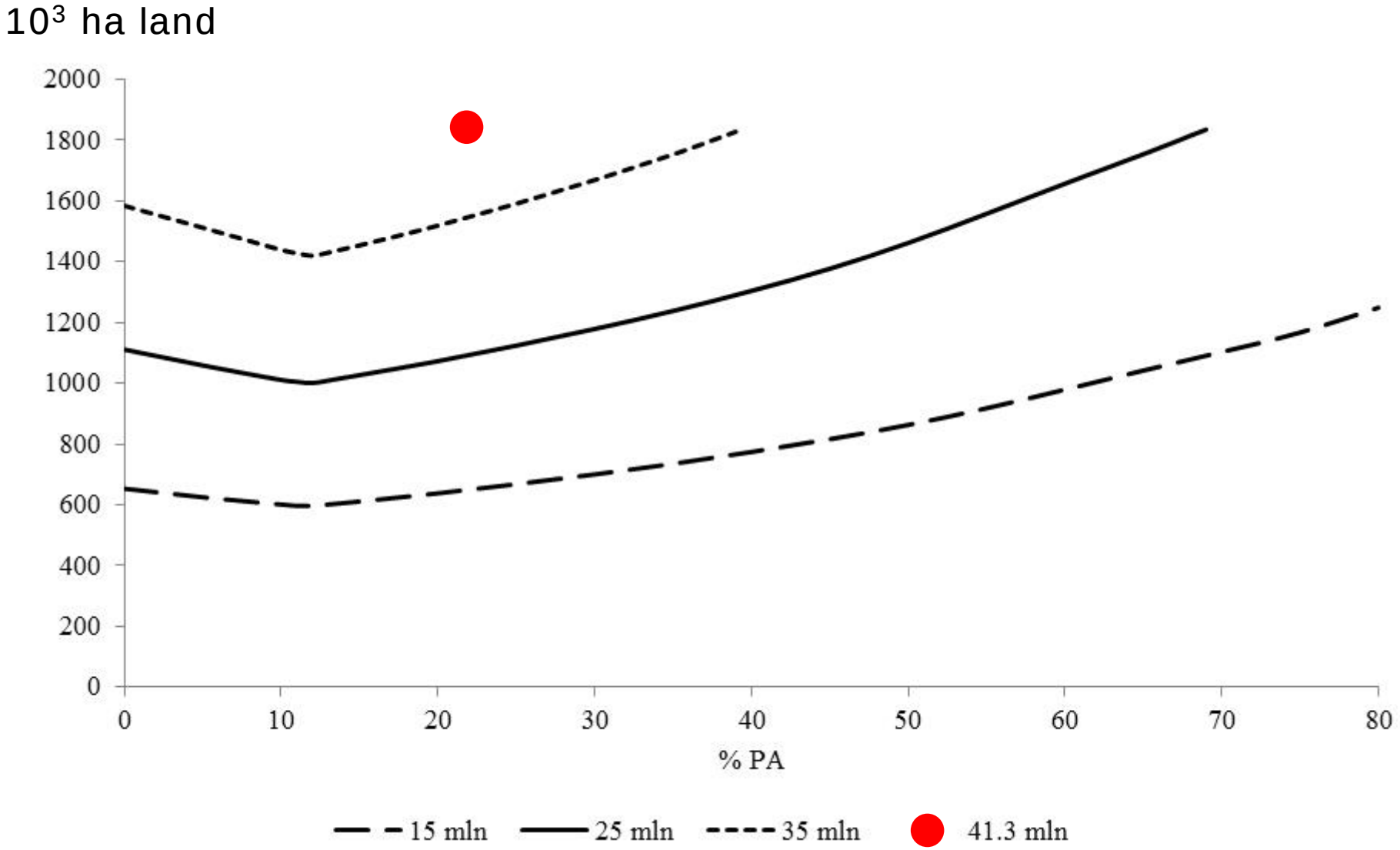
Thought experiment – the Netherlands

Assumptions: 1.8 M ha land

- Closed system — no import, export
- Peat (12%) — grass
- Sand (42%), clay (46%) — wheat, potatoes, sugar beets, rapeseed, beans, maize silage, grass
- Dairy cattle (milk/meat) & pigs (meat)

Feeding population (15-45 M) with minimal amount of land

Land use – increasing % protein animals



Van Kernebeek et al. (2015) IJLCA

The role of LCA in environmental decision making in livestock production

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