Research Institute of Organic Agriculture FiBL
info.suisse@fibl.org, www.fibl.org

Climate change and sustainability impacts along the agro-food chain

Christian Schader

Summer School Climate Change Impacts

12 September 2019

FiBL at a glance

Founded in 1973, private foundation

190 permanent staff members

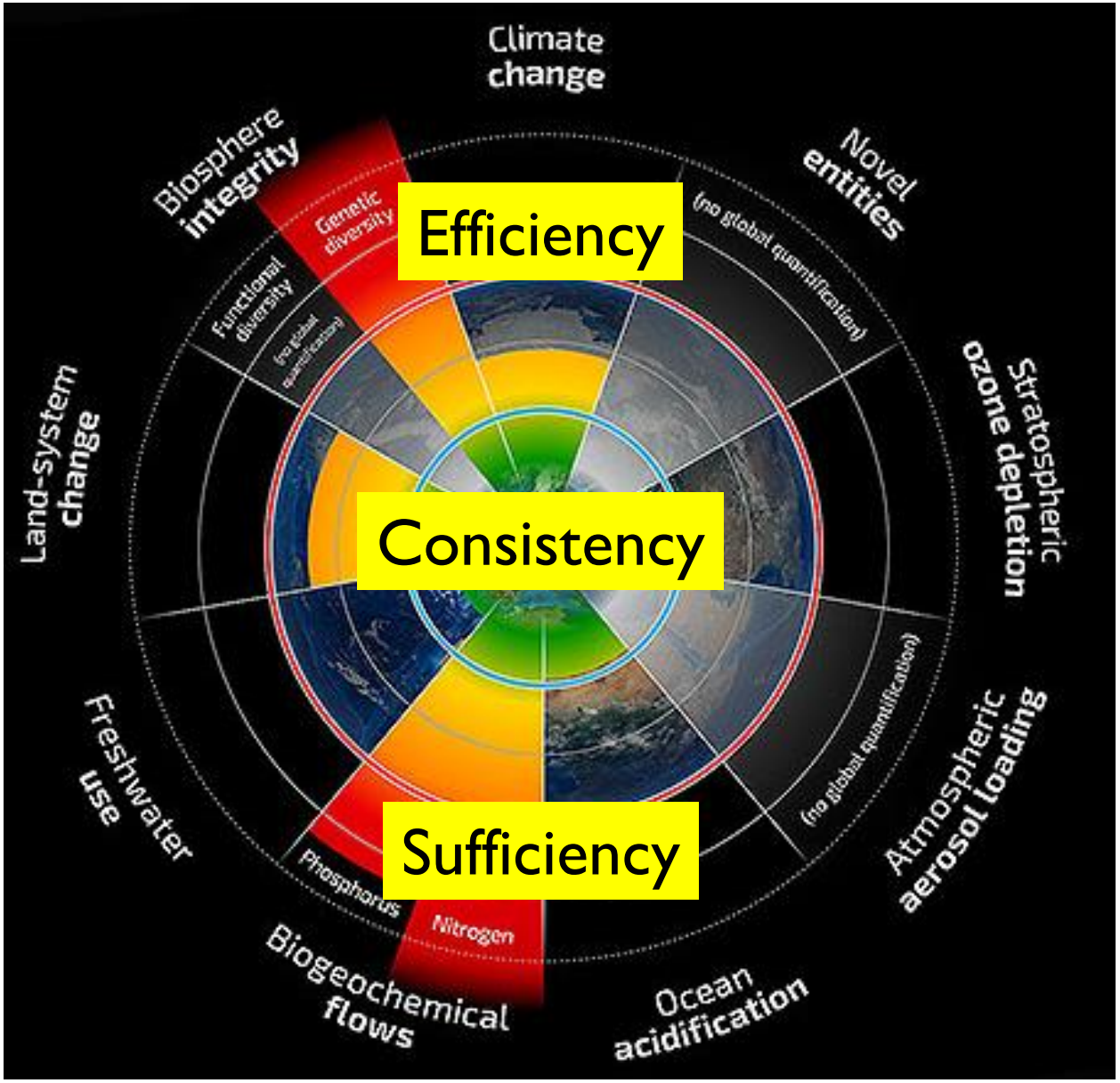
More than 70 interns, B.A./Master/PhD students, apprentices

Sister institutes FiBL-Germany and FiBL-Austria, FiBL-Brussels

GRI Sustainability Reporting


BCI
FAIRTRADE
FSC
BONSUCRO
BSCI
GLOBALG.A.P.
fair for life
FAIR WEAR FOUNDATION
WIN WIN
FAIRWILD
BIOSUISSE
FAMIQS
tft
GRMS
BRITISH RETAIL CONSORTIUM
Clean Clothes Campaign
CARBON TRUST
COTTON AFRICA
EICC
FAIR TRADE USA
Ecolabel
Green-e
IRIS
RTRS
SAI
verifloora
SQF
VCS
USDA ORGANIC
life
ICMM
SGE 21
TourCert
KRAV
Proterra FOUNDATION
WRAP
GMP+ International

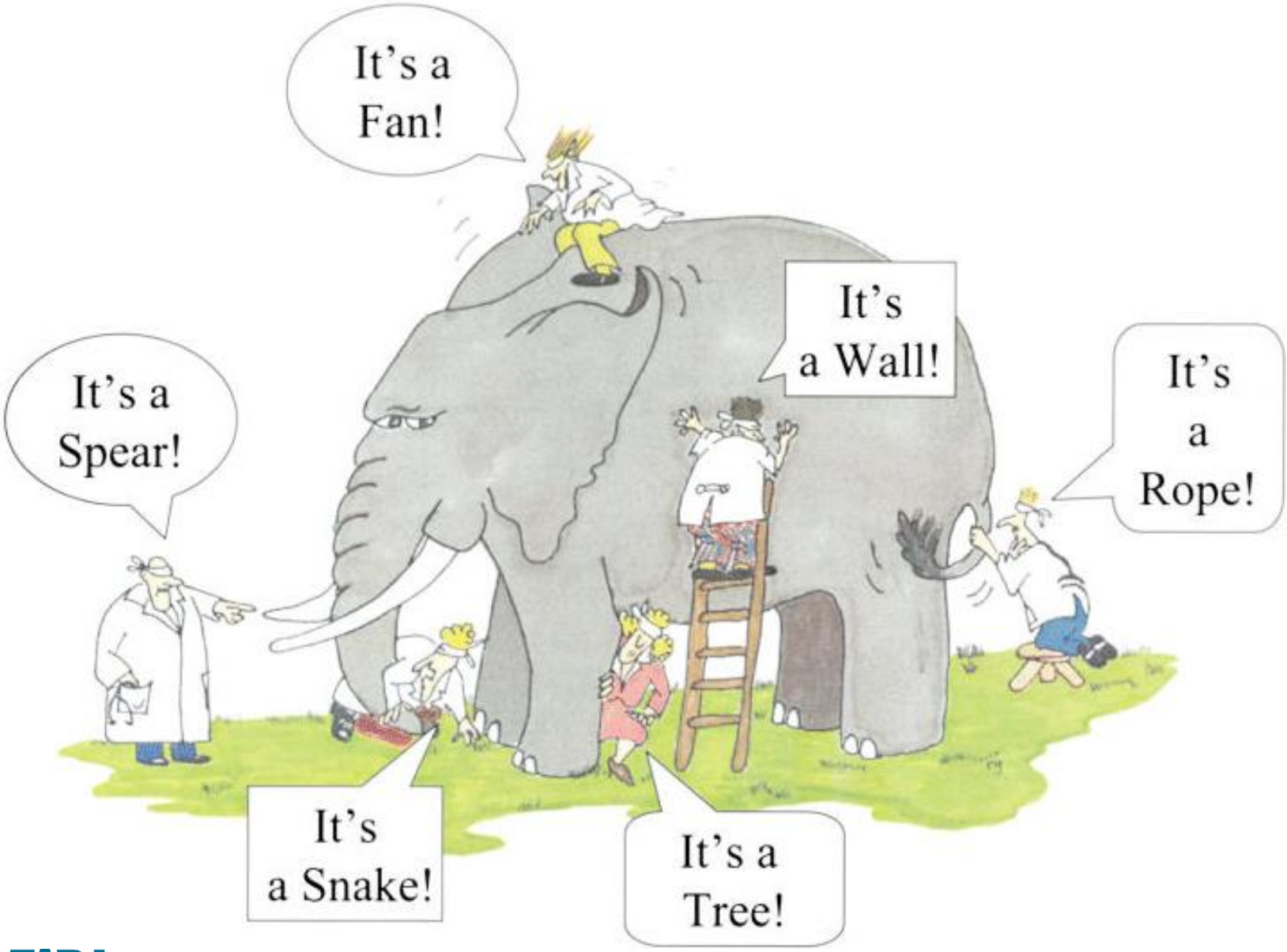
Planetary boundaries



Steffen et al., (2015),

Stockholm Resilience Center (2015),

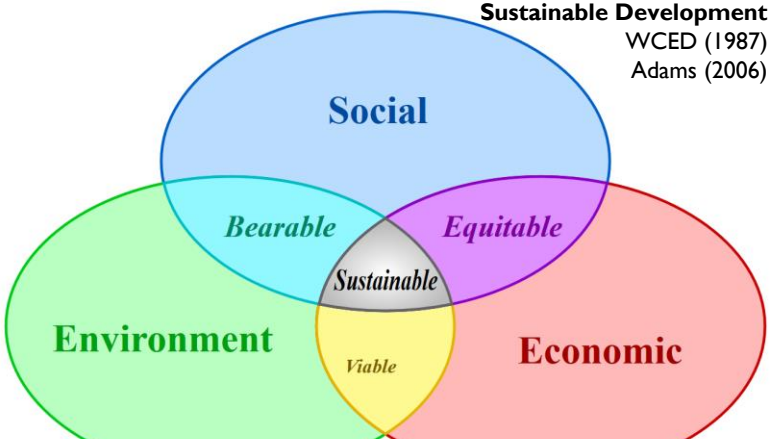
Huber (2000)



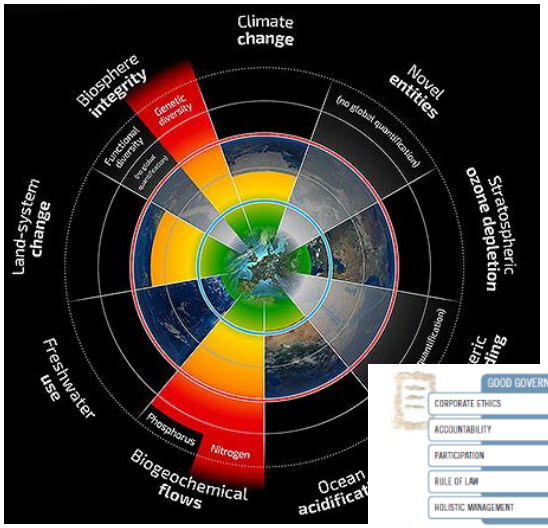
Source: G.R. Guzlas

Definitions and sustainability frameworks

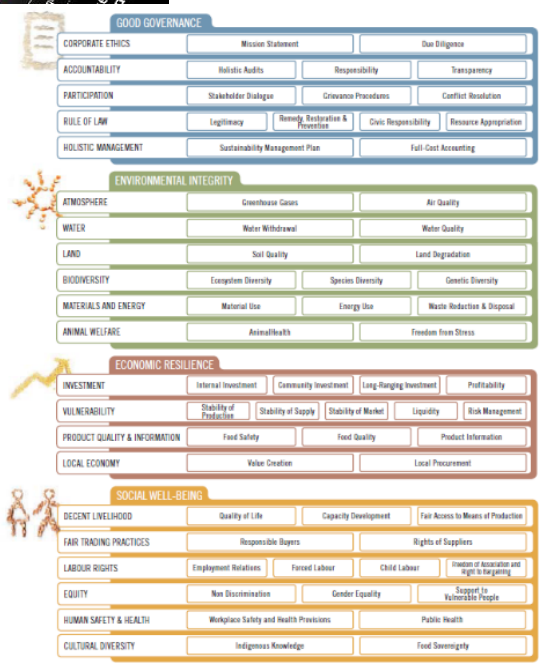
Sustainable Development
WCED (1987)
Adams (2006)



Sustainable Development Goals
Ried et al. (2017)



Planetary boundaries
Rockström et al. (2009)
Steffens et al. (2015)



SAFA Guidelines
Food and Agriculture Organization of the United Nations (FAO) (2013)

FiBL

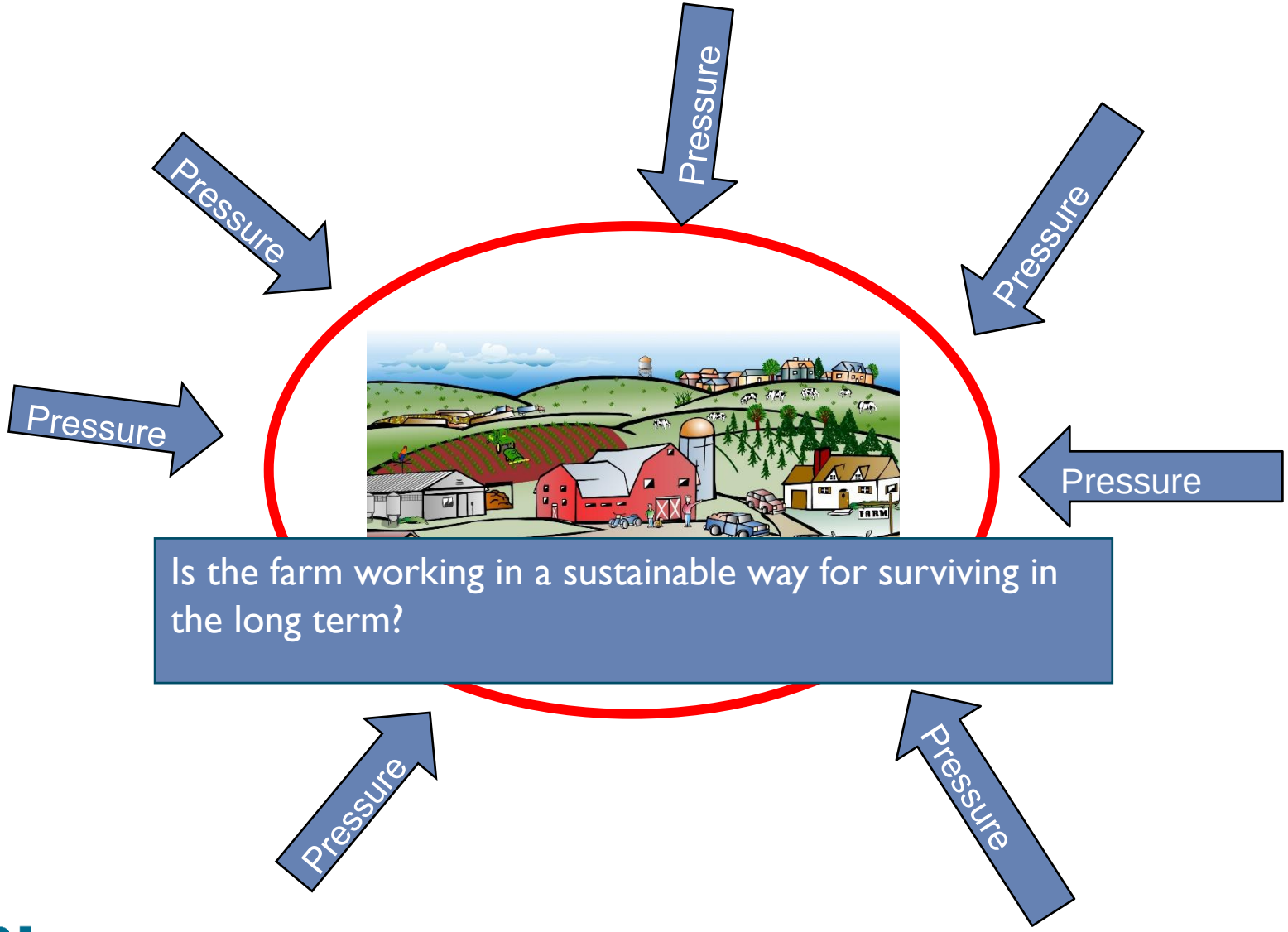
www.fibl.org

Sustainability assessment approaches

Characteristic	Classes
Primary purpose	• Research, • Advisory service, • Supplier assessment, • Certification, • Monitoring, • Policy advice
Level of assessment	• Farm level, • Product / supply chain level, • Agricultural sector level
Dimensions of sustainability covered	• Environmental, • Social, • Economic
Geographical scope	• Applicable globally, applicable to a specific country or region
Sector scope	• Applicable to all agricultural/food products or farm types, • Applicable to specific product or farm types
Perspective on sustainability	• Farm/business perspective (is the company economically healthy and developing on a resilient pathway?), • Societal perspective (does the company contribute to sustainable development of society?), • Mixed perspective (farm/business perspective and societal perspective are mixed)

Schader et al. 2014

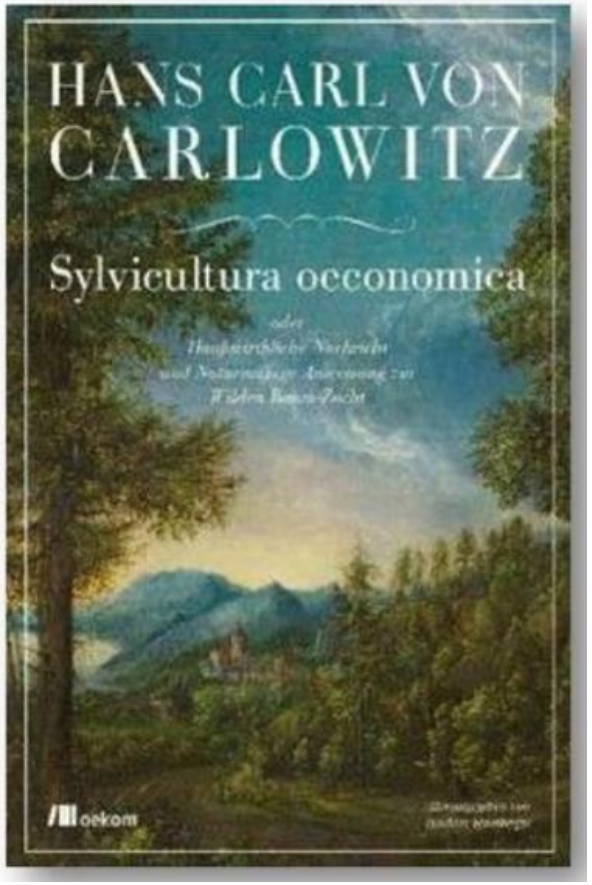
Farm-level vs. societal perspective



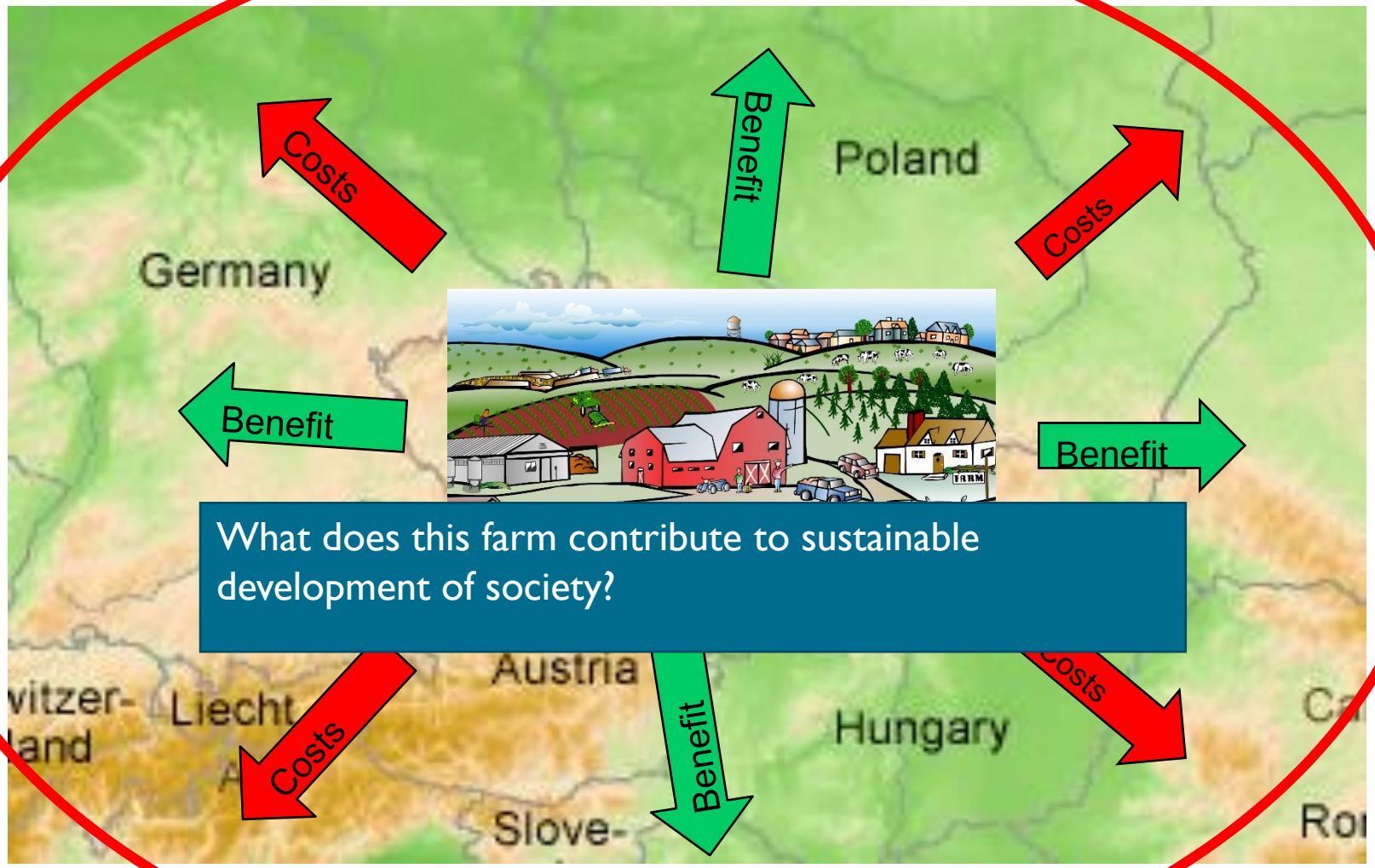
Schader et al. 2014

„Sustainability“ was invented 300 years ago in forestry

Hans Carl von Carlowitz (1713)



Farm-level vs. societal perspective



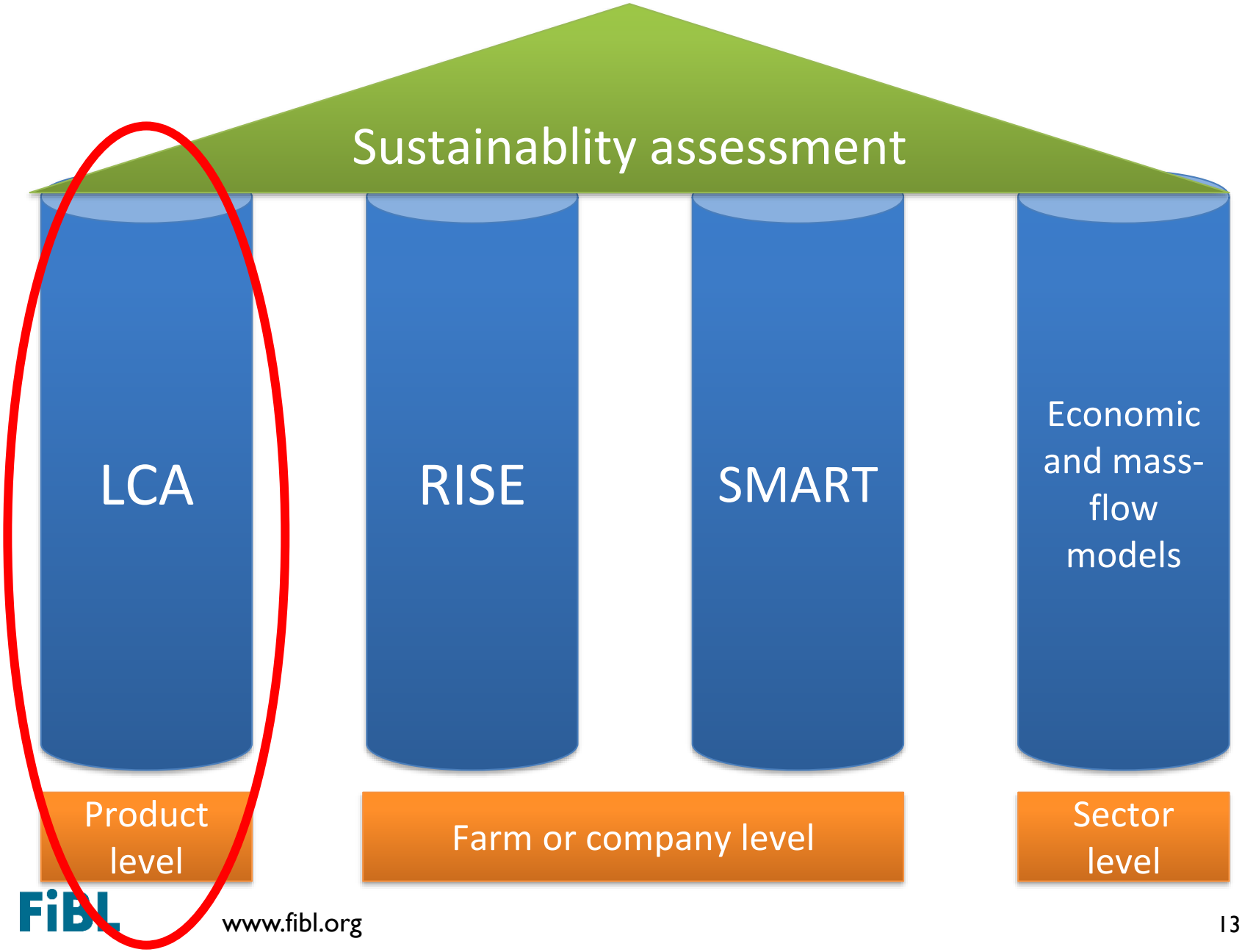
Schader et al. 2014

Determining environmental efficiency

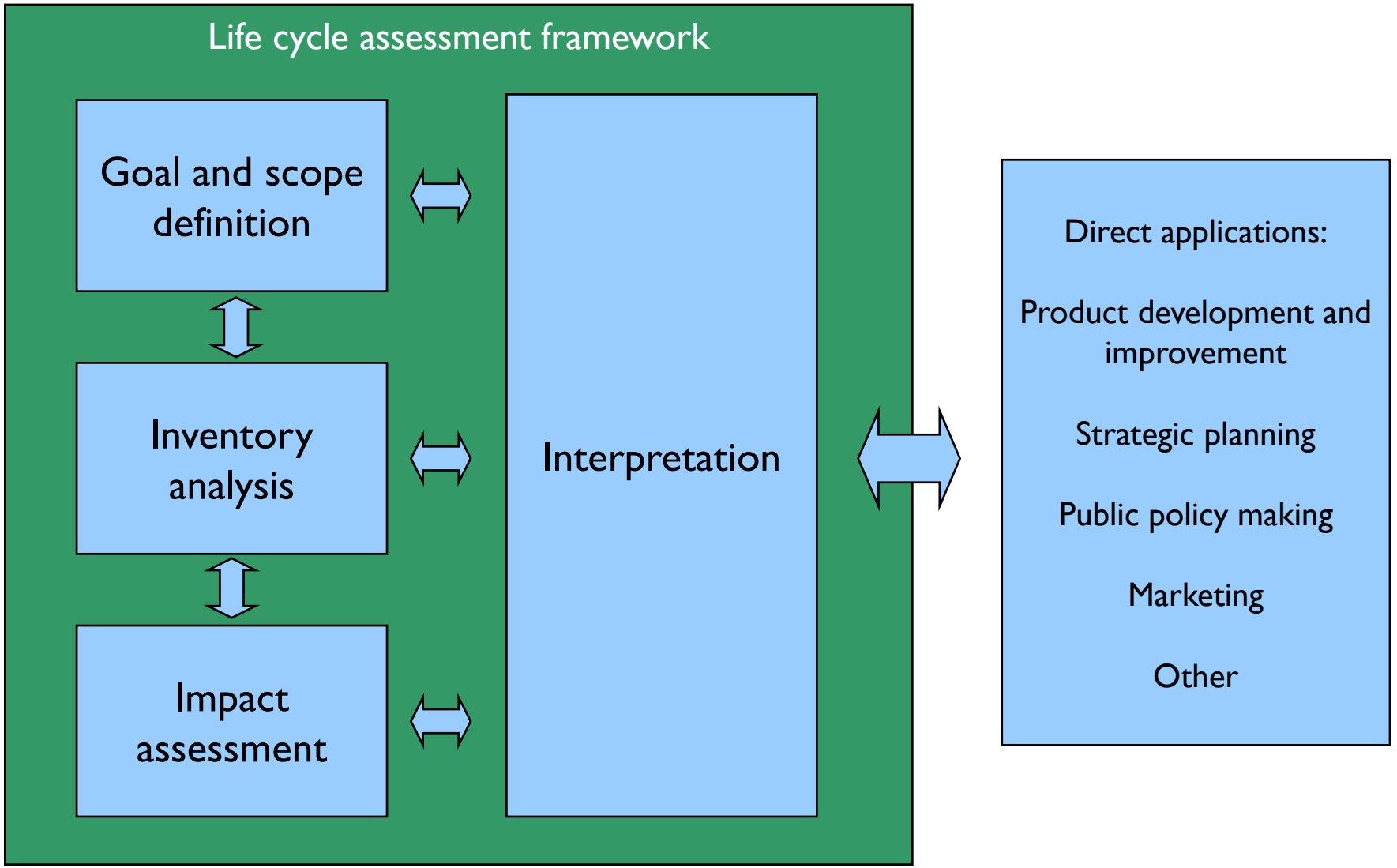
Apple A: Germany
- Short transport
- High fertliser and pesticide input
- High yields
- 7 month storage

Apple B: New Zealand
- Long transport
- Low fertiliser and pesticide input
- Low yields
- 1 month storage

Energy use? GHG emissions? Eutrophication? Toxicity?


Sustainablity assessment
LCA
RISE
SMART
Economic and mass-flow models
Product level
Farm or company level
Sector level

Steps of a LCA (ISO 14040)



What is a life cycle assessment?

Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040)

Product system?

Inputs and outputs?

Environmental impacts?

Life cycle?

Goal and Scope Definition

- The **reason** for executing the LCA, and the questions which need to be answered.
- A **precise definition** of the product, its life cycle and the function it fulfils.
- In case products are to be compared, a comparison basis is defined (**functional unit**).
- A description of the **system boundaries**.
- A description of the way **allocation problems** will be dealt with.
- Data and **data quality requirements**.
- **Assumptions and limitations**.
- The requirements regarding the **LCIA procedure**, and the subsequent interpretation to be used.
- The **intended audiences** and the **way the results will be communicated**.
- If applicable, the way a **peer review** will be made.
- The **type and format of the report** required for the study.

Functional unit

Quantified performance of a product system for use as a reference unit (ISO 14040)

Mass of the product

Digestible energy or protein content

Monetary value of production or net value added

(Area, e.g. hectare)

Life cycle phases

Cradle-to-grave

- Construction phase
- Use phase
- Disposal phase

Cradle-to-(farm-)gate

- Construction phase

Scope Definition

- Functional unit: Quantified performance of a product system for use as a reference unit (ISO 14040).

Examples of functional units

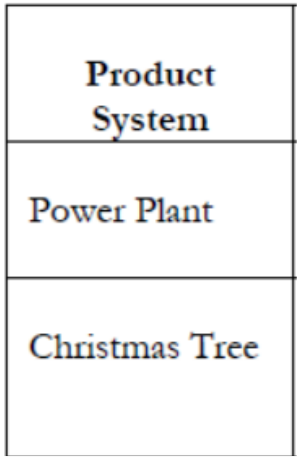


Figure 4-4: Linkages between Function, Functional Unit, and Example LCI Results for hypothetical LCA studies

More examples

- What are the functional unit(s) of:
  - A hectare of wheat grown on a farm?
  - A dairy cow?
  - A Porsche car?
  - A hospital?

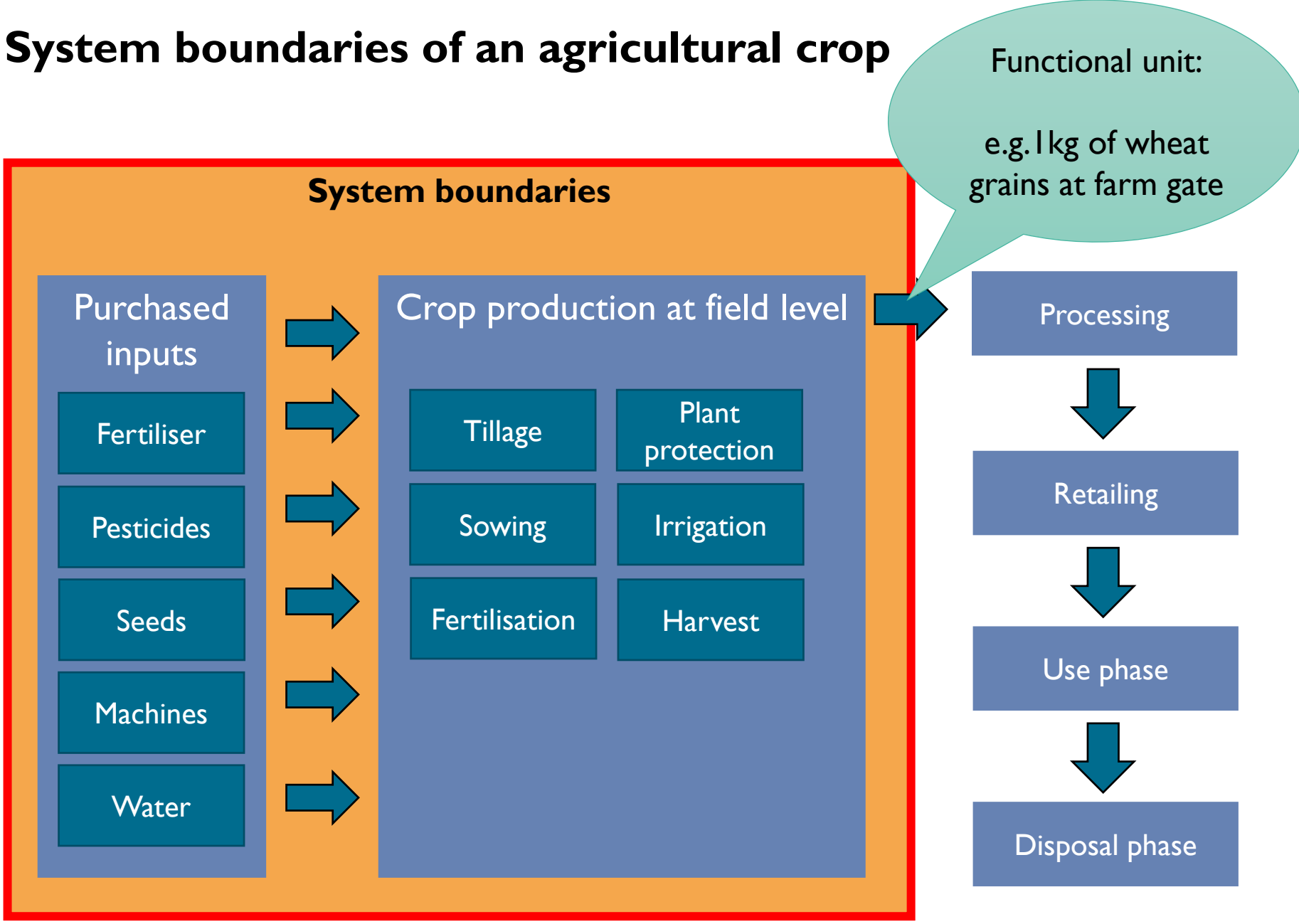
System boundaries

It is impossible to include everything in your LCA. But where to draw the line? Decision criteria:

- Importance (in mass terms? Energy use terms? Environmental relevance?)
- Data availability (are data present in LCA databases, can they be collected at all?)
- Inclusion of capital goods?

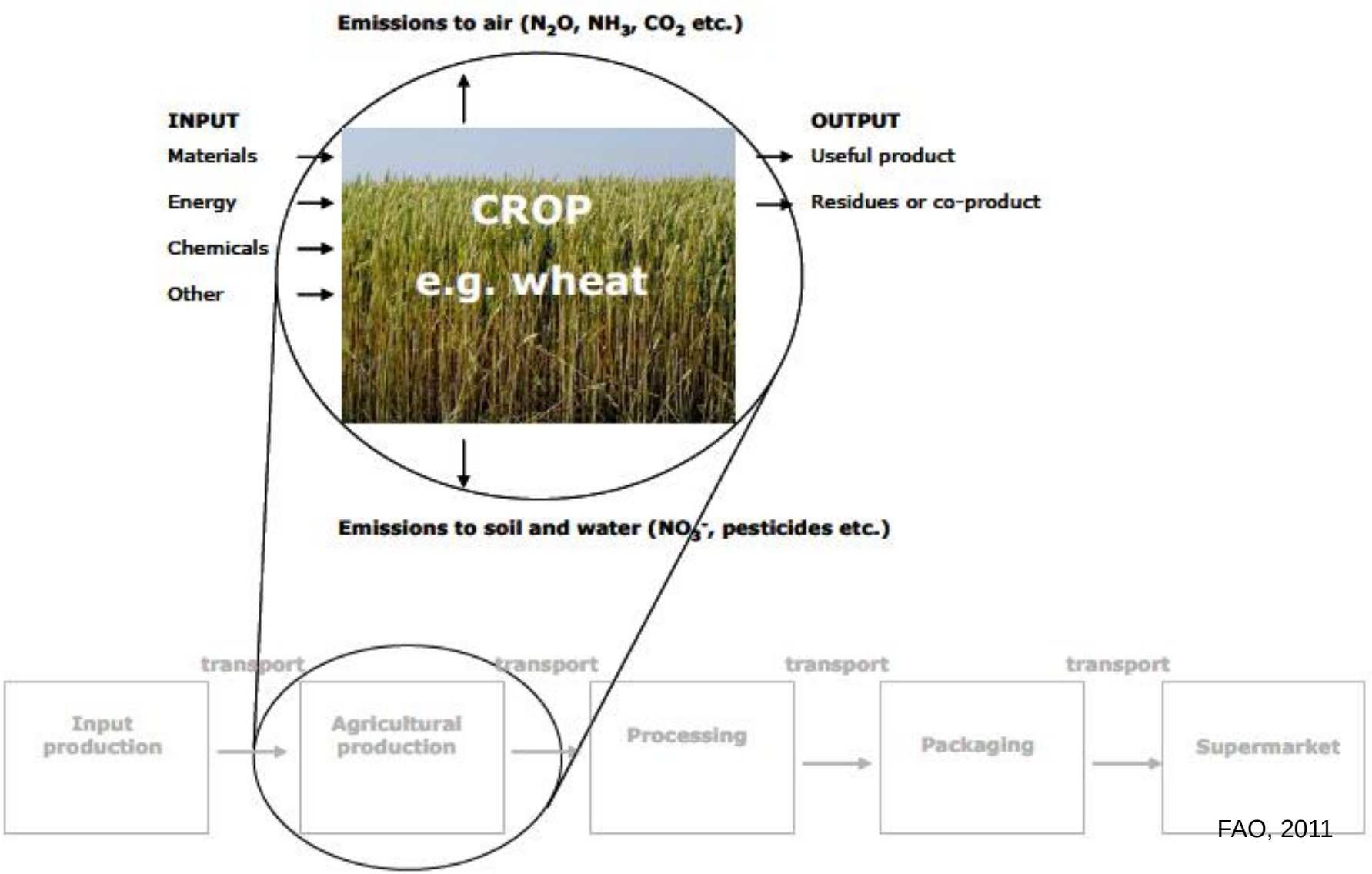
(Capital goods: Goods that are a one-off investment, like trucks or machines.)

System boundaries of an agricultural crop



Life cycle inventories in agriculture

- Foreground vs. Background data

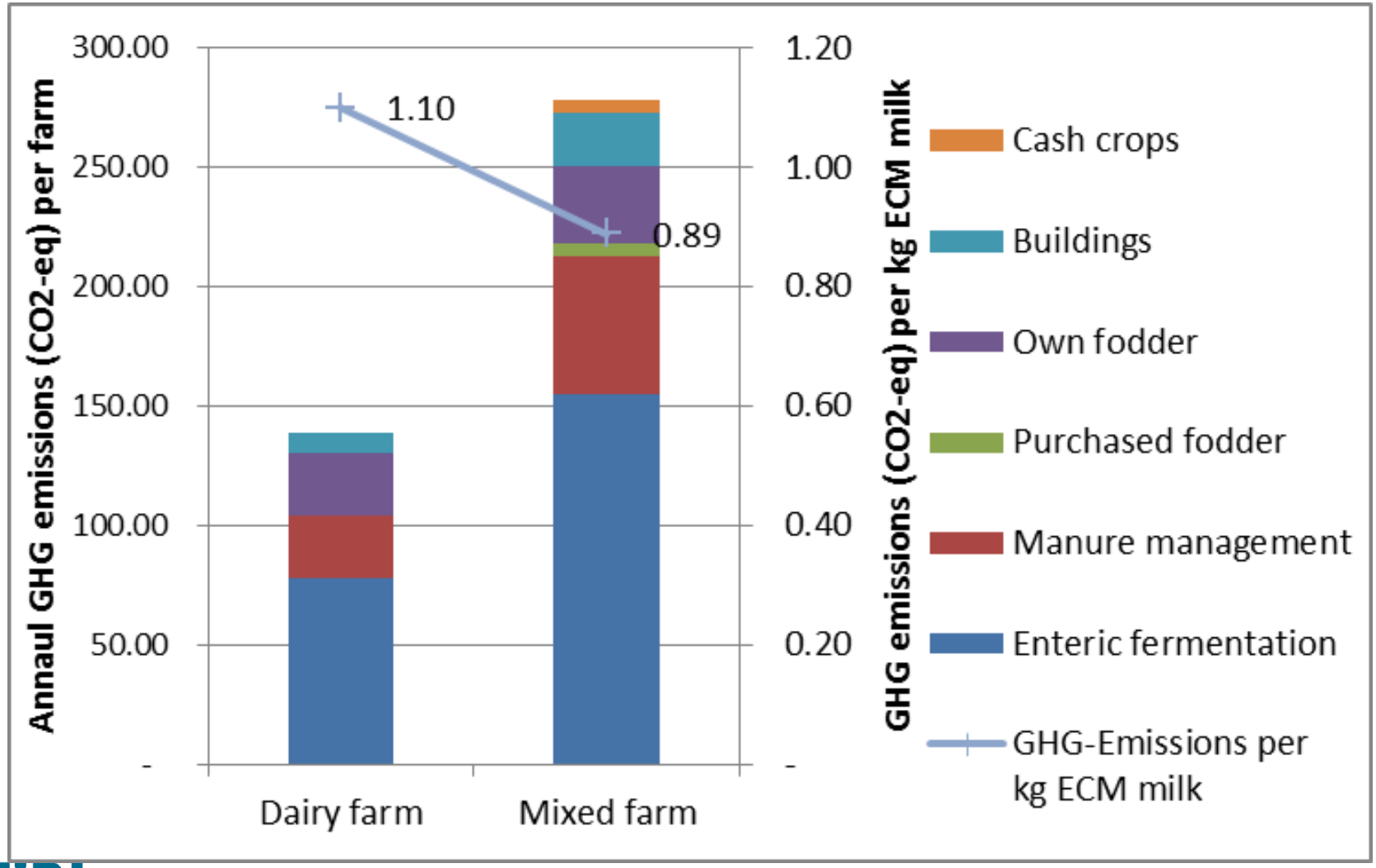


FAO, 2011

Impact assessment

LCI Result
1000 g CO2
100 g CH4
100 g SO2
Total result

GHG emission profile of farms



Schader et al. 2014

Effectiveness of measures (kg CO_2-eq / per farm and year)

Potential reduction of GHG emissions	Specialised dairy farm		Mixed farm (dairy/arable)	
	Absolute	Relative	Absolute	Relative
Total GHG emissions	***139,066***	***100.00%***	***277,911***	***100.00%***
Composting livestock manure	-4429	-3.1%	-12,128	-4.4%
Increased number of lactations of dairy cows	-7,788	-5.6%	-8,677	-3.1%
Use of dual-purpose cattle breeds	-3,977	-2.9%	-7,357	-2.7%
Use of photovoltaics (on total roof area)	-4,073	-2.9%	-6,153	-2.2%
Conversion to full-grazing system	-4,672	-3.4%	-6,128	-2.2%
Optimisation of machine life	-2,206	-1.6%	-4,237	-1.5%
Application of Eco drive mode	-728	-0.5%	-2,206	-0.8%
Optimization of machines and tractors	-111	-0.1%	-1,935	-0.7%
Shade trees on pastures	-226	-0.2%	-753	-0.3%
Reduced tillage	-	-	-564	-0.2%
Energy-efficient milk cooling devices	-235	-0.2%	-518	-0.2%
Concentrate-free feeding rations	-371	-0.3%	-343	-0.1%
Use of solar heat (for process water on farm)	-139	-0.1%	-262	-0.1%
GHG savings if all measures are implemented	**-28,955**	**-20.8%**	**-51,261**	**-18.5%**

Schader et al. 2014

Impact assessment

Most frequently used impact categories:

Land occupation

Energy use (non-renewable energy demand)

Climate change (Global Warming Potential)

Eutrophication (N and P)

Acidification (mainly ammonia)

Toxicity (Ecotoxicity and Humantoxicity)

Anything missing?

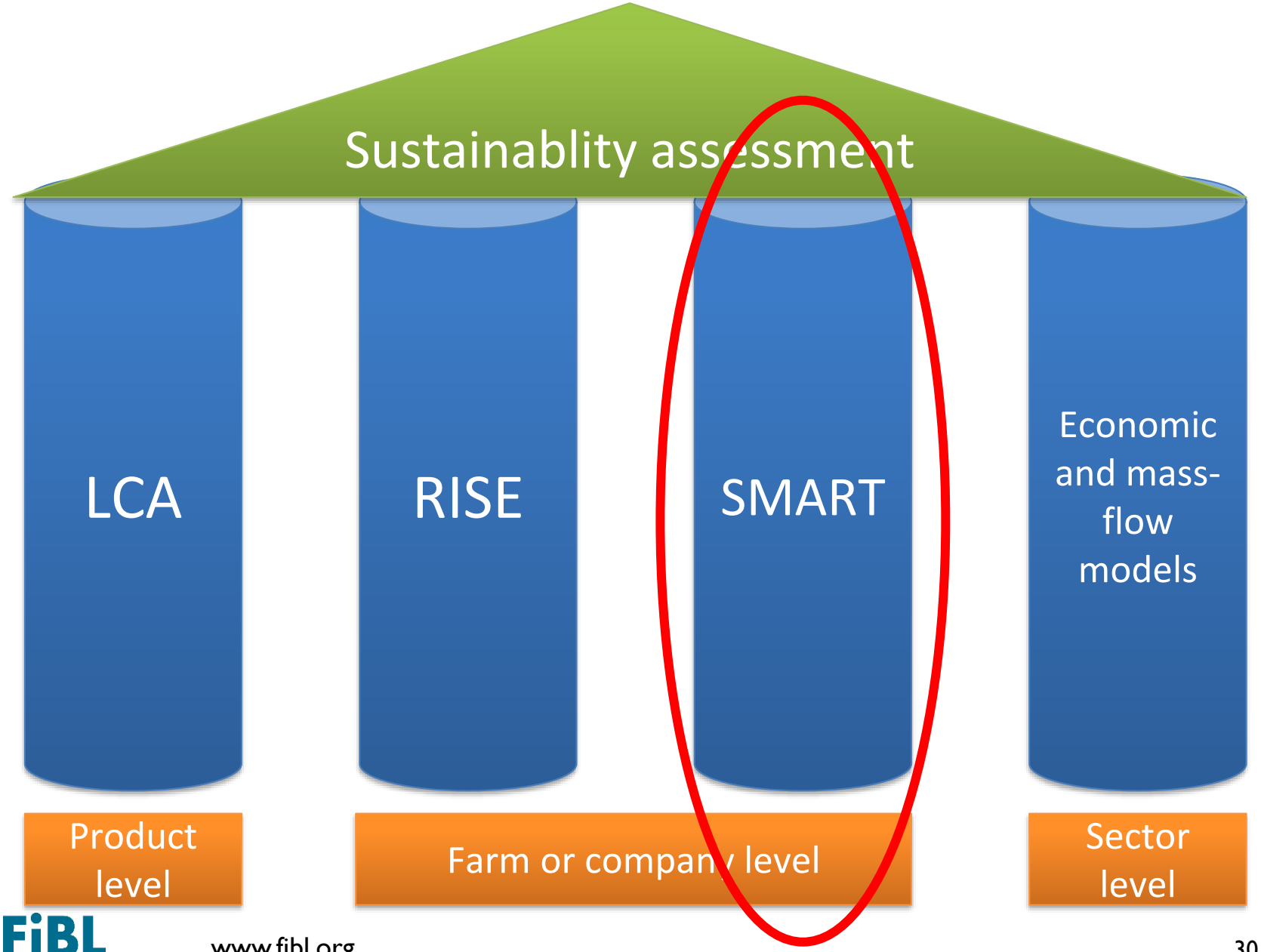
LCA of food and agriculture – State of the art

Very useful method for comparing resource use efficiency at product level or supply chain level

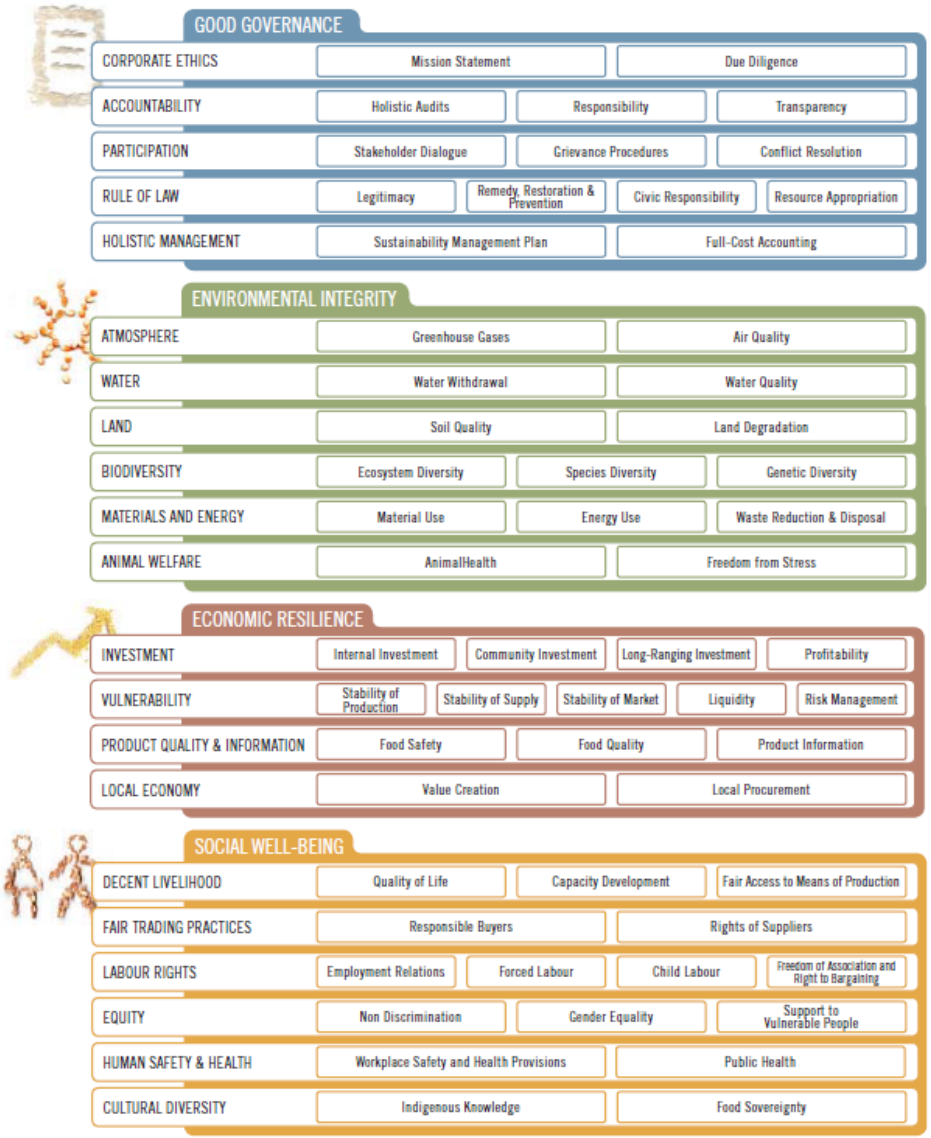
- Relates environmental impacts to a functional unit
- Takes into account also impacts of input production
- Purely quantitative approach

But several drawbacks for food and agriculture

- Only a limited set of environmental impacts can be assessed
- Many hard assumptions
- Social and economic dimensions mostly excluded
- Comparison between production systems with different environmental conditions


Sustainablity assessment
LCA
RISE
SMART
Economic and mass-flow models
Product level
Farm or company level
Sector level

SAFA Guidelines

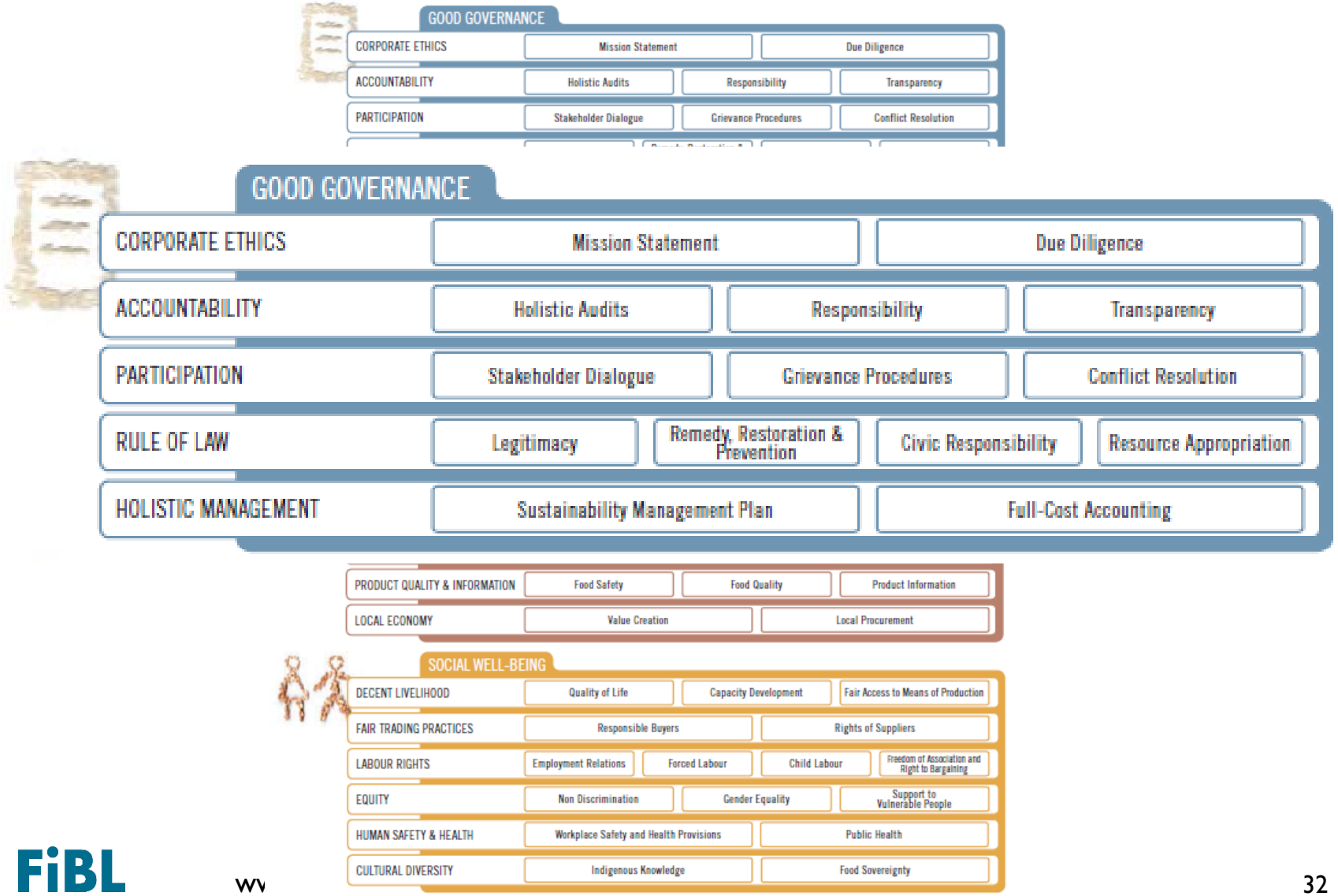


- 4 Dimensions
- 21 Themes
- 58 Sub-themes with sustainability objectives

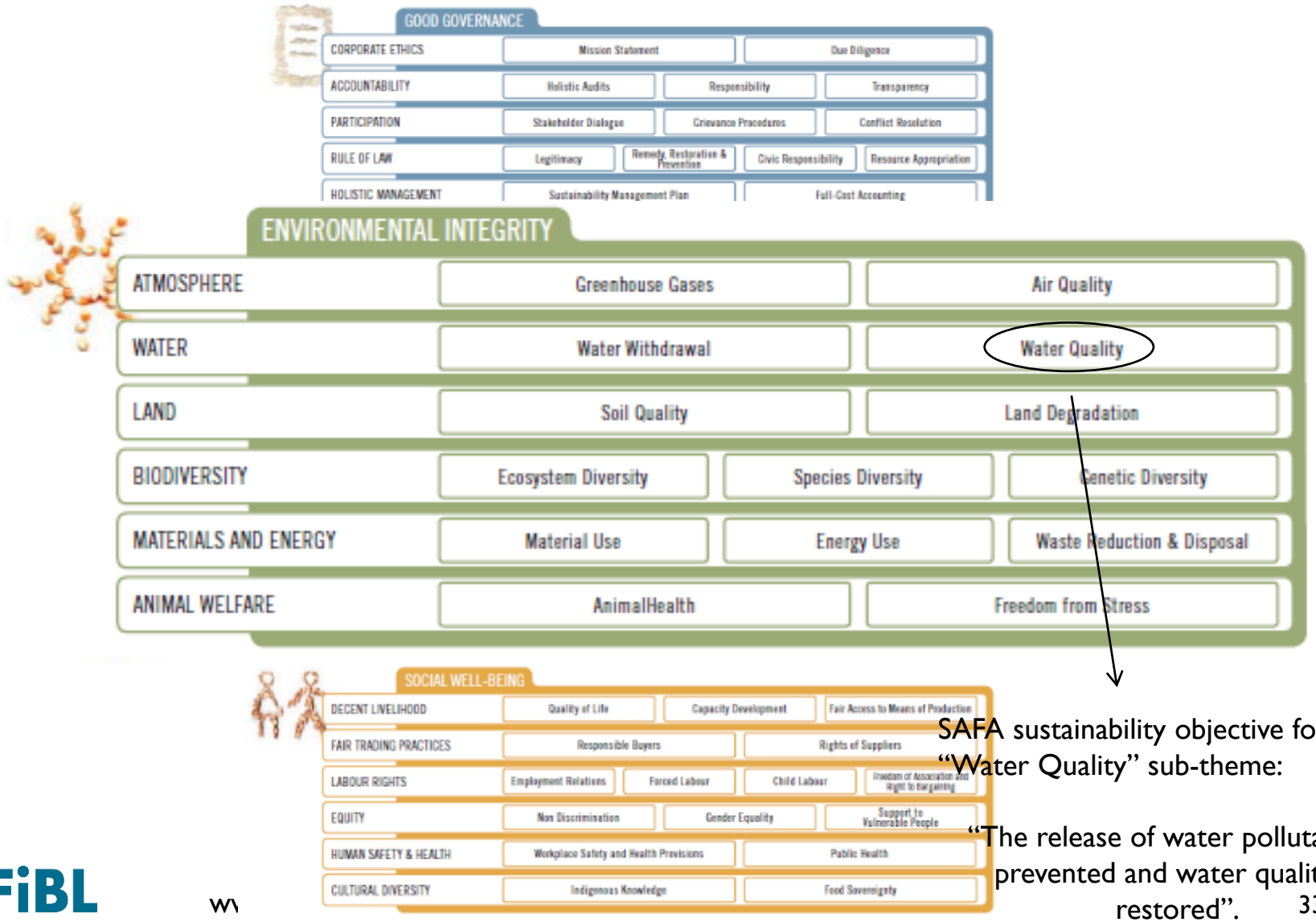
SAFA
SUSTAINABILITY ASSESSMENT OF FOOD AND AGRICULTURE SYSTEMS

Food and Agriculture Organization of the United Nations

SAFA Guidelines



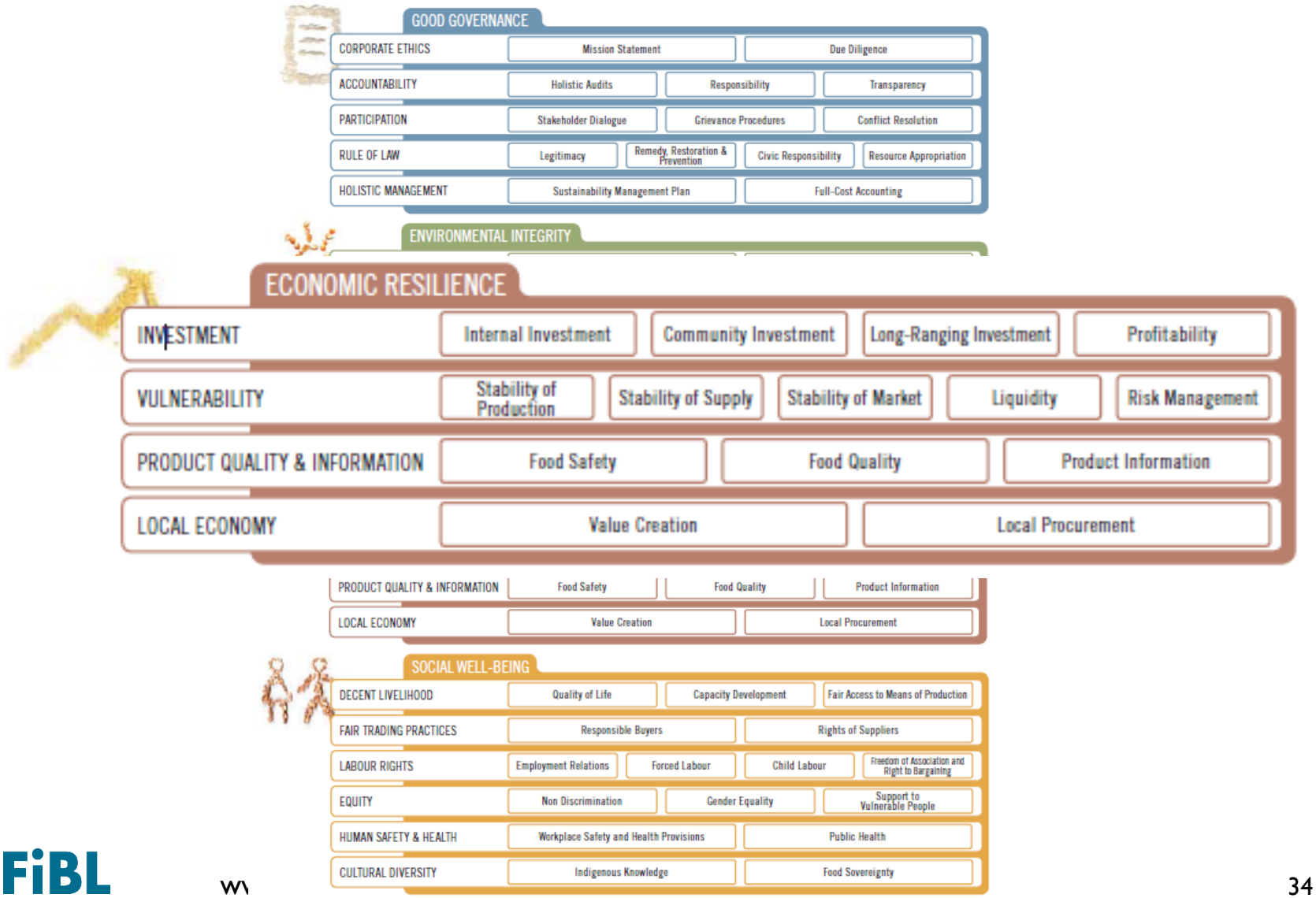
SAFA Guidelines



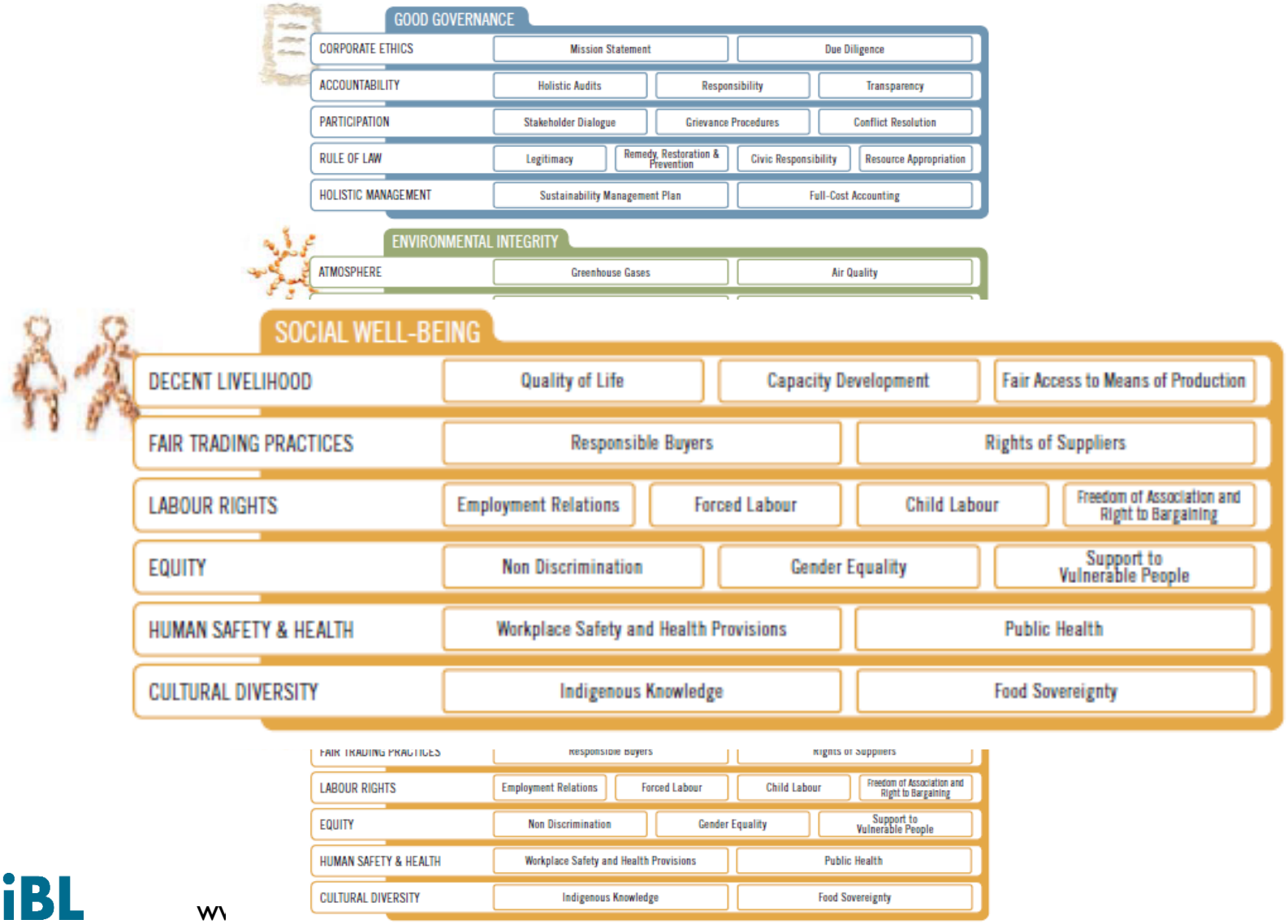
SAFA sustainability objective fot the "Water Quality" sub-theme:

"The release of water pollutants is prevented and water quality is restored".

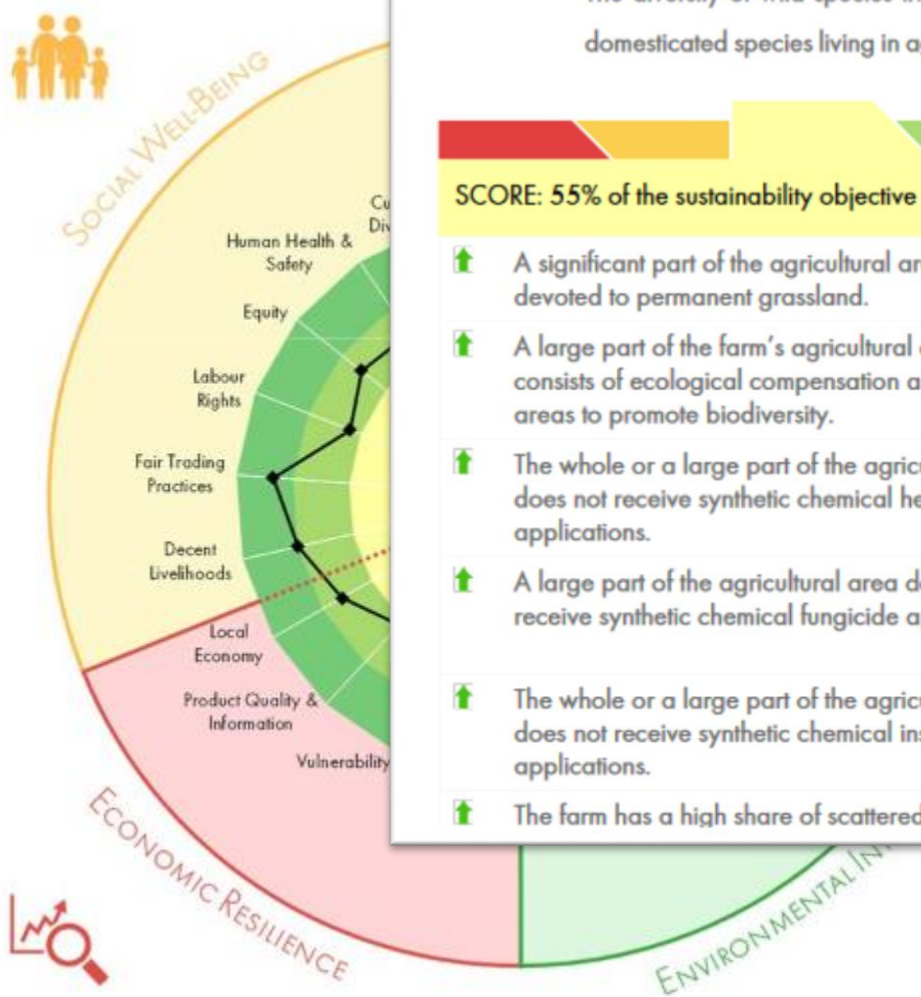
SAFA Guidelines



SAFA Guidelines



Results of a SMART Assessment



Sub-Theme: Species Diversity

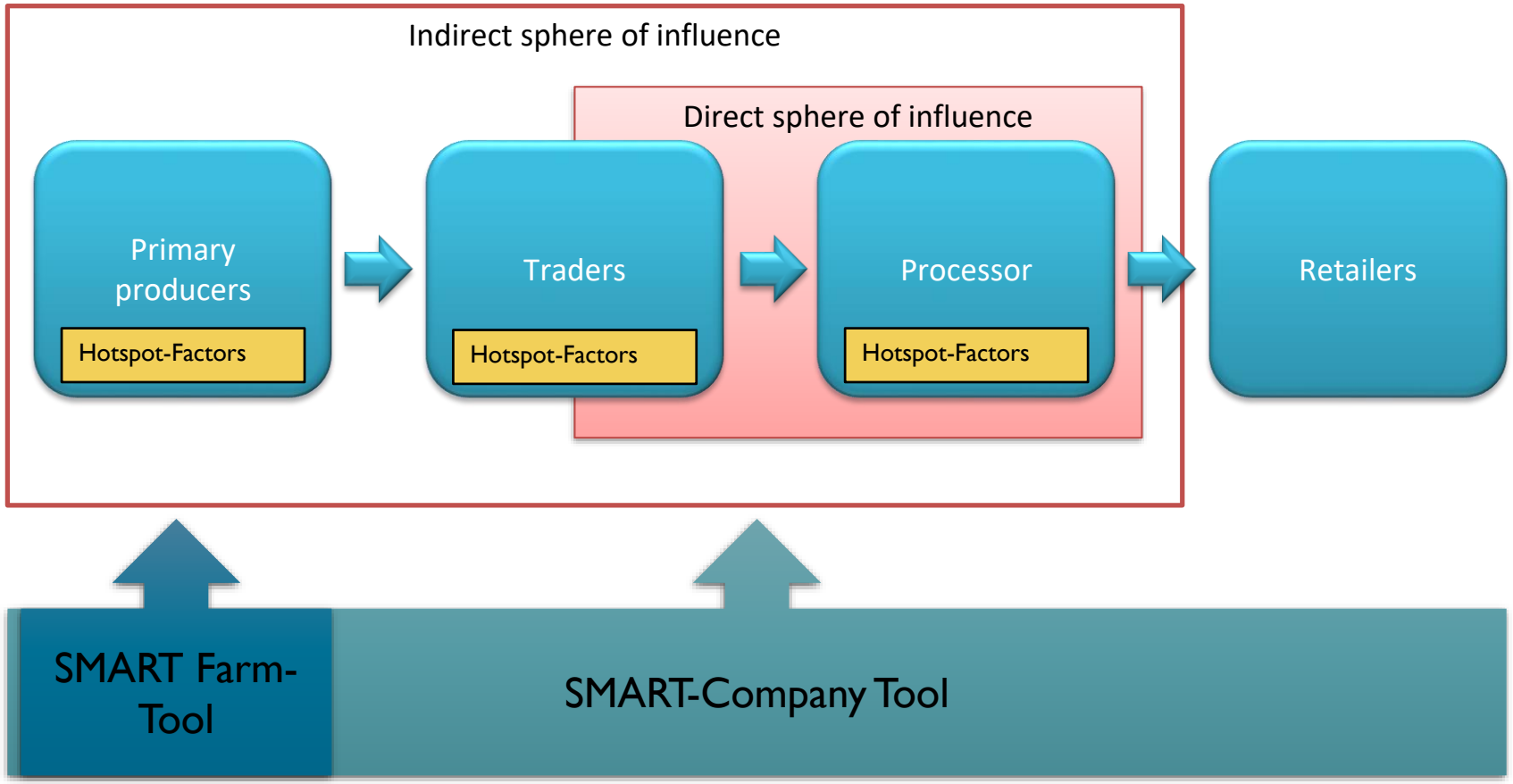
Objective:

The diversity of wild species living in natural and semi-natural ecosystems, as well as the diversity of domesticated species living in agricultural, forestry and fisheries ecosystems is conserved and improved.

SCORE: 55% of the sustainability objective achieved.

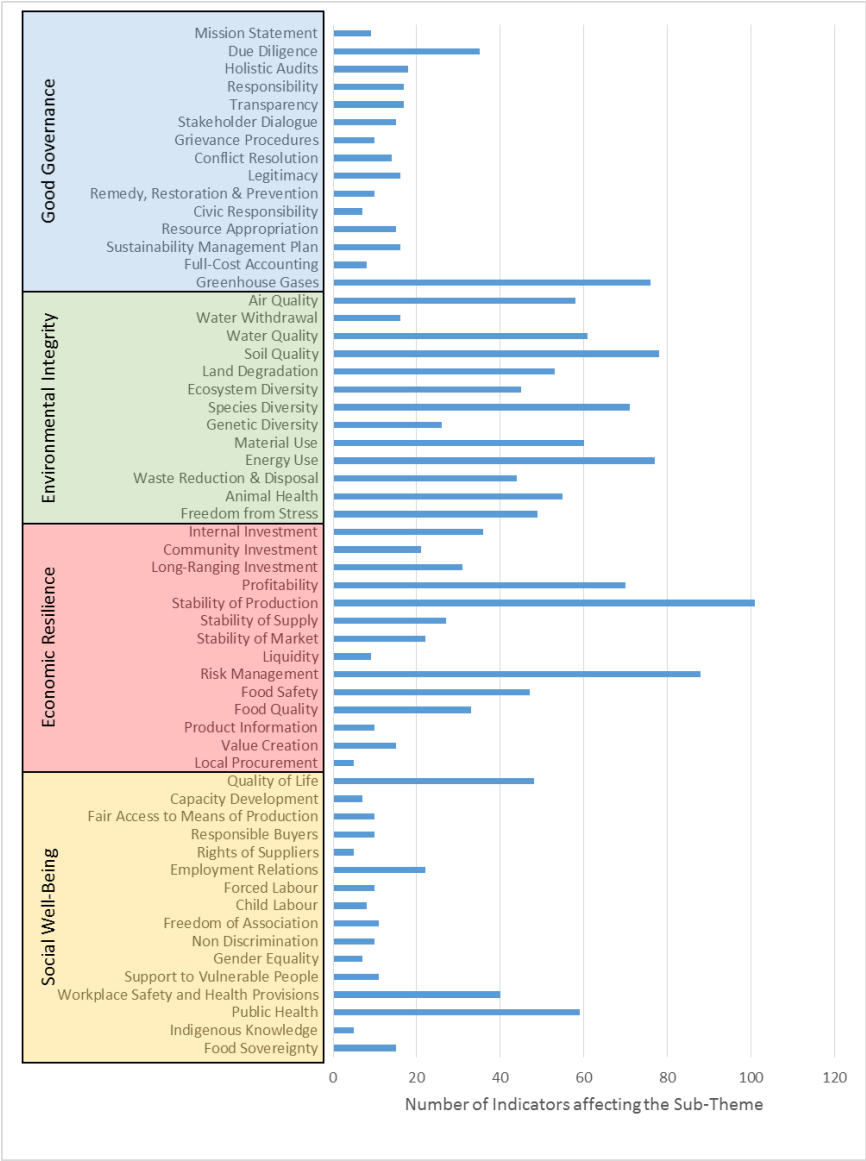
A significant part of the agricultural area is devoted to permanent grassland.	No or only a small part of the farm's agricultural area is devoted to agro-forestry systems.
A large part of the farm's agricultural area consists of ecological compensation areas resp. areas to promote biodiversity.	A small part of the area of permanent grassland is under intensive management.
The whole or a large part of the agricultural area does not receive synthetic chemical herbicide applications.	The pesticides used are considered to be toxic to bees according to the "PAN Pesticide Database".
A large part of the agricultural area does not receive synthetic chemical fungicide applications.	The pesticides used are considered to be toxic to aquatic organisms according to the "PAN Pesticide Database".
The whole or a large part of the agricultural area does not receive synthetic chemical insecticide applications.	Some of the pesticides used are considered to have adverse long term effects on the users according to the "PAN List of HHPs" or "PAN Pesticide Database".
The farm has a high share of scattered fruit trees.	Some of the pesticides used are considered to be

Sphere of influence



Number of indicators in the SMART-Farm Tool

- Multi-Criteria Analysis
- 327 Indicators
- Ca. 1700 algorithms specifying the impact of an indicator on a subtheme
- On average 30 Indikators for calculating the degree of goal achievement of a SAFA Sub-Theme



Schader et al. 2016

SMART: Degree of goal achievement (DGA)

$$DGA_{ix} = \sum_{n=1}^{N}(IM_{ni} \times IS_{nx}) / \sum_{n=1}^{N}(IM_{ni} \times ISmax_n) \; \forall \; i \; and \; x$$

i	*: index of sub-themes*
x	*: index of farms*
n	*: index of indicators*
DGA	*: Degree of goal achievement*
IM	*: Impact of an indicator on a sub theme*
IS	*: Performance of a farm with respect to indicator n*
ISmax	*: Best performance possible with respect to indicator n*

More details: Schader et al. 2016

Multi-Criteria Assessment in SMART

Sub-theme for which a SAFA objective is defined

Impacts of each indicator in the sub-theme

Capacity Development	Impact Weight	Indicator Rating	Impact weight * score	Sustainability Score at the Sub-theme level
Further training for farm staff	0.93	100%	0.93	44.36%
Apprenticeships	0.71	100%	0.71	
Training on sustainability	0.73	0%	0.00	
Employees: Access to external training	0.85	25%	0.21	
Access to advisory services	0.91	25%	0.23	
Education and training at master level (master crafts men places)	0.56	0%	0.00	
	4.69		2.08	

Relevant indicators impacting on degree of goal achievement

Sum of impacts = maximum achievable points

Sum of impacts * actual performance = achieved points

SMART-Farm Tool: Characteristics

Globally applicable, producing comparable results according to the 58 Goals from the FAO-SAFA Guidelines

- Till now about 3000 farms have been evaluated with SMART (Switzerland, Germany, Austria, Hungary, Kenya, Ghana, Uganda, Costa Rice, Dominican Republic, Mexico)
- Applicable to all farm types and sizes: Arable farming, vegetables (including greenhouses), fruits, tree nurseries, viticulture, grasslands/rangelands, cattle, dairy, pigs, goats, sheep, poultry, bees, aquaculture)

Method independent and science-based

- Based on scientific knowledge
- Development financed independently from commercial interests
- Not tailored to a specific context or company

Complementary to RISE

- Not an „advisor“ but an „auditor“ visits the farm
- Harmonisation of standard data for applying as package solution

SMART-Farm Tool: Characteristics (2)

Reproducibility, quality assurance

- Training curriculum for SMART-Auditoren 1-2 weeks, incl. theoretical and practical lessons and tests
- Review of a subsample of reports by 2nd auditor

Useful for a large-scale benchmarking and monitoring

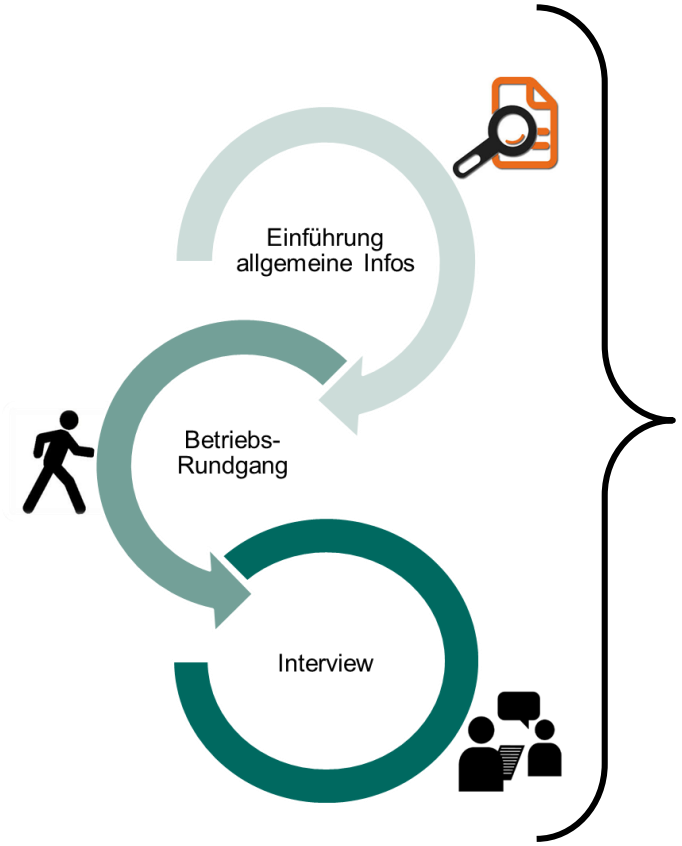
- Comparable low cost per farm
- Automatised as far as possible
- Required data needs to be available

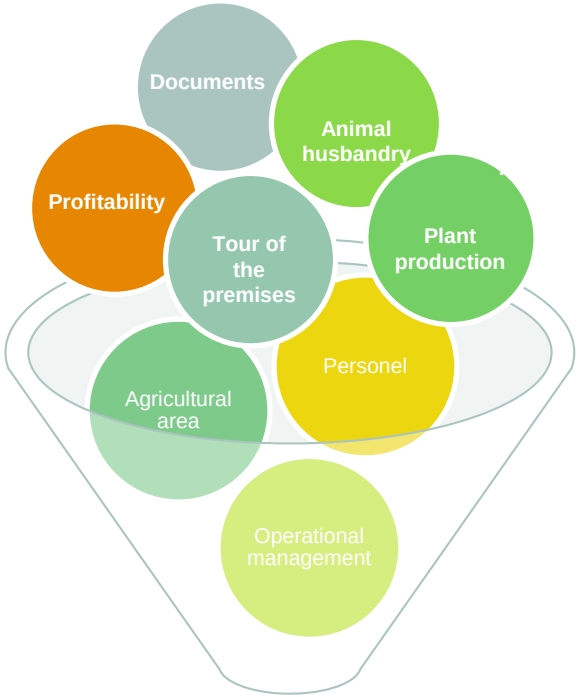
Coverage of most important drivers for sustainability, drivers being made transparent

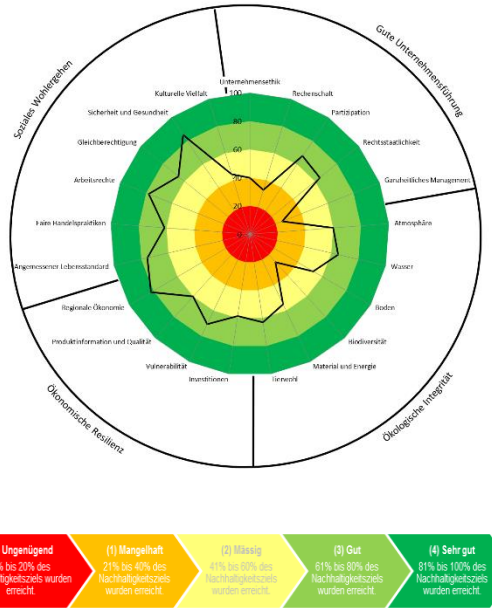
Version 2.1:

- 327 Indicators, partly applicable to only a set of farm types
- Consideration of trade-offs and synergies
- 1769 impact relations between indicators and subthemes

Process flow SMART Farm-Assessment







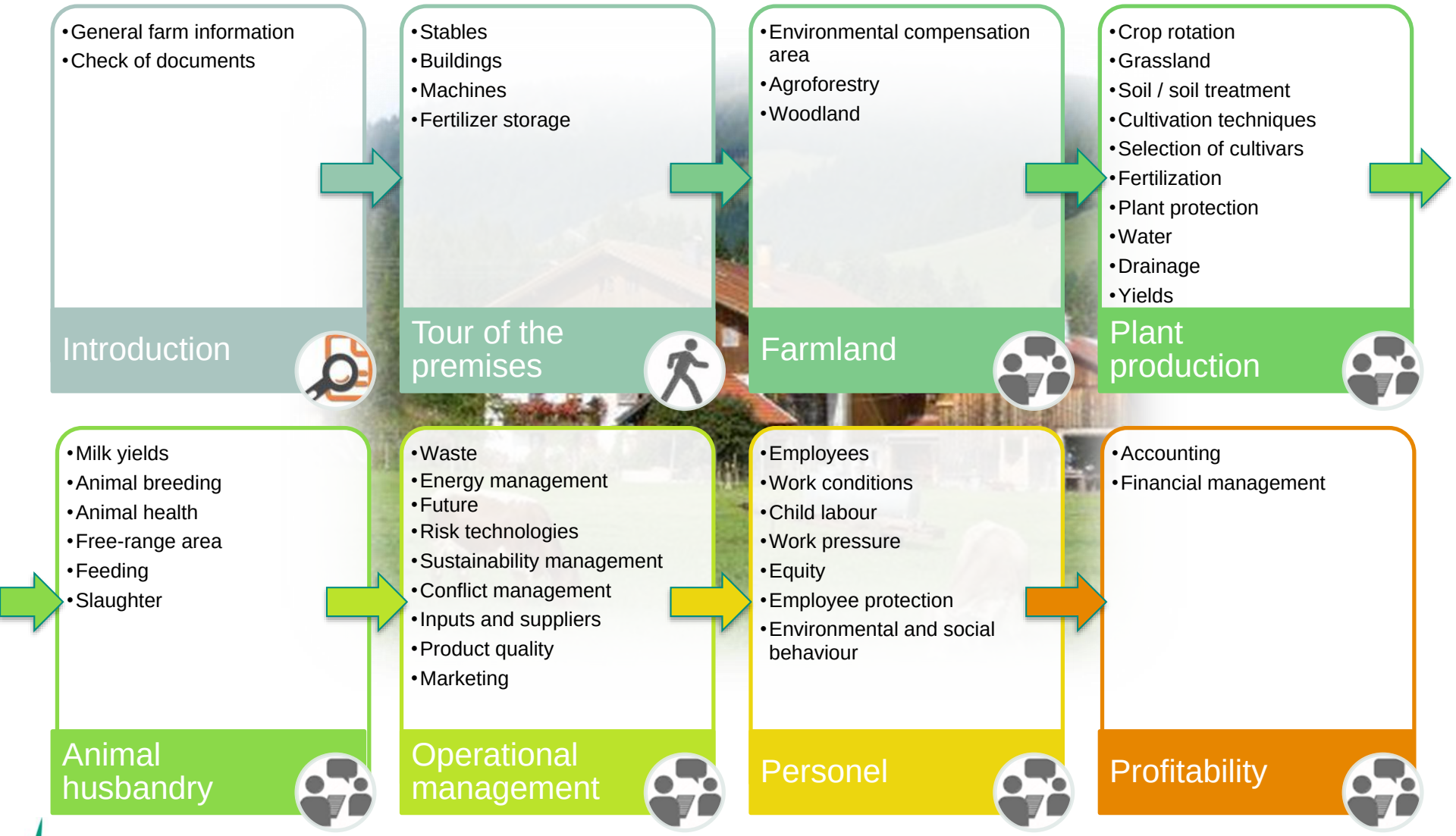
Farm Survey
(appr. 2-3 h)

Analysis

Evaluation

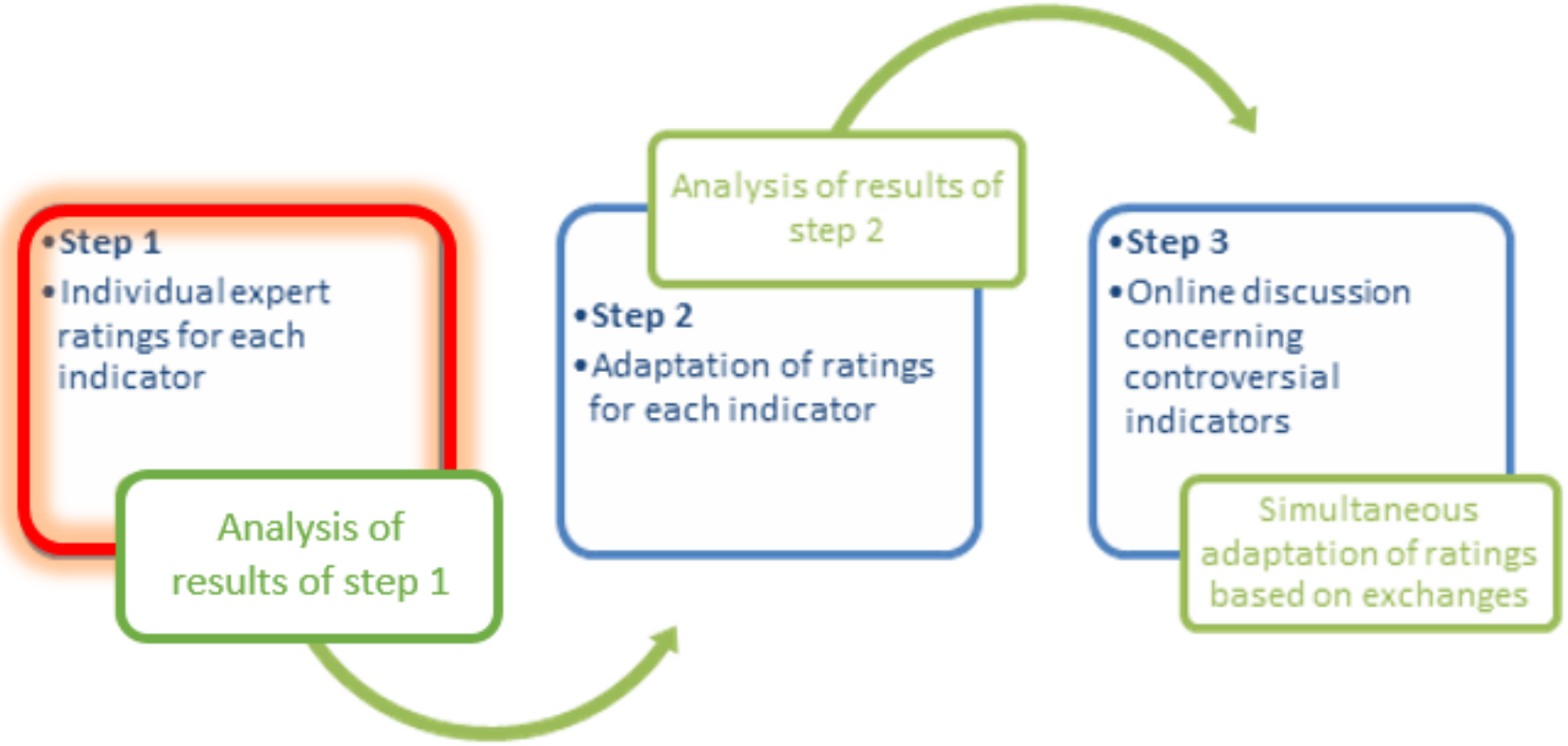
Data collection on farm

Data collection on farm

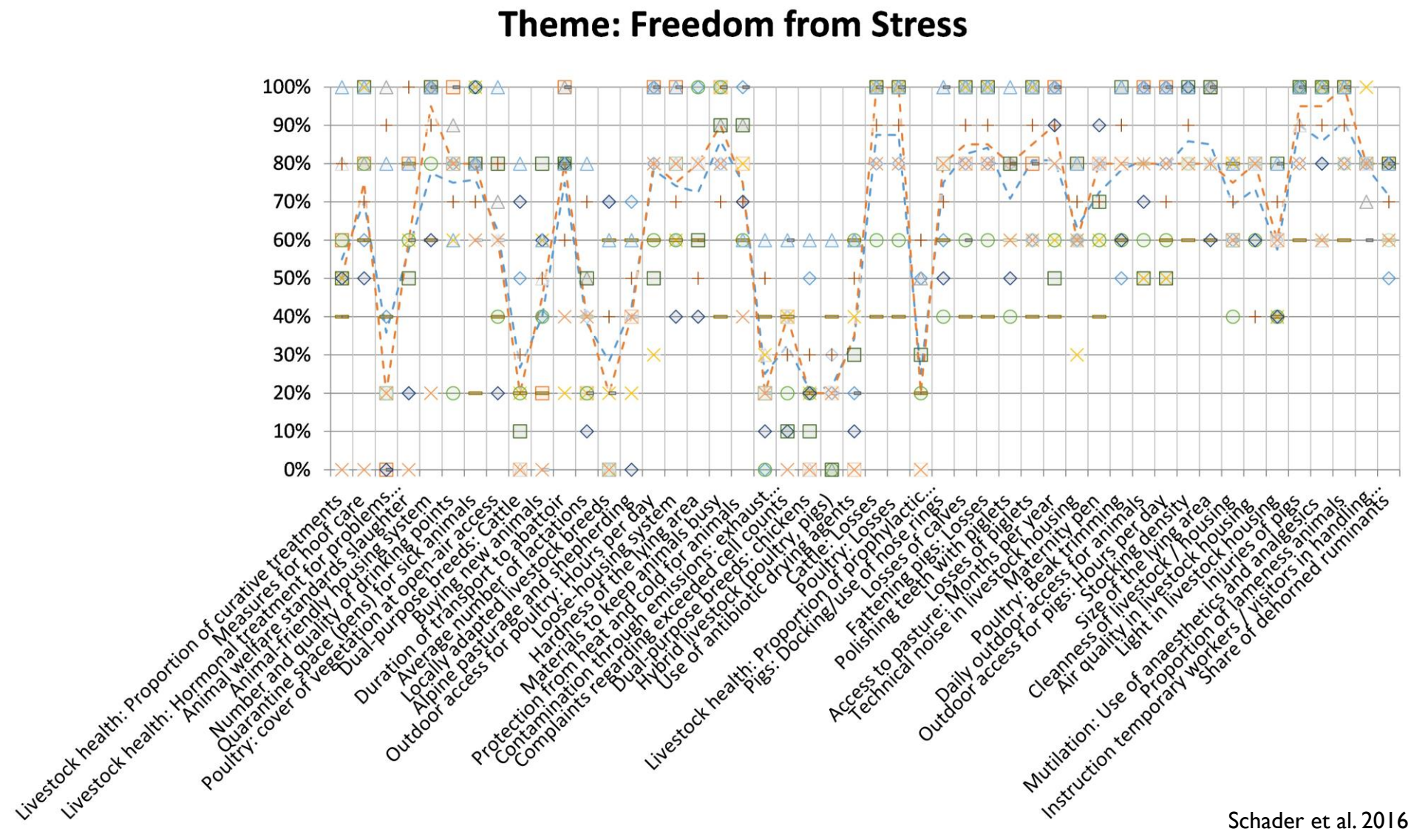


SMART Indicators: Expert-based weighting

Nominal Group Technique / Delphi

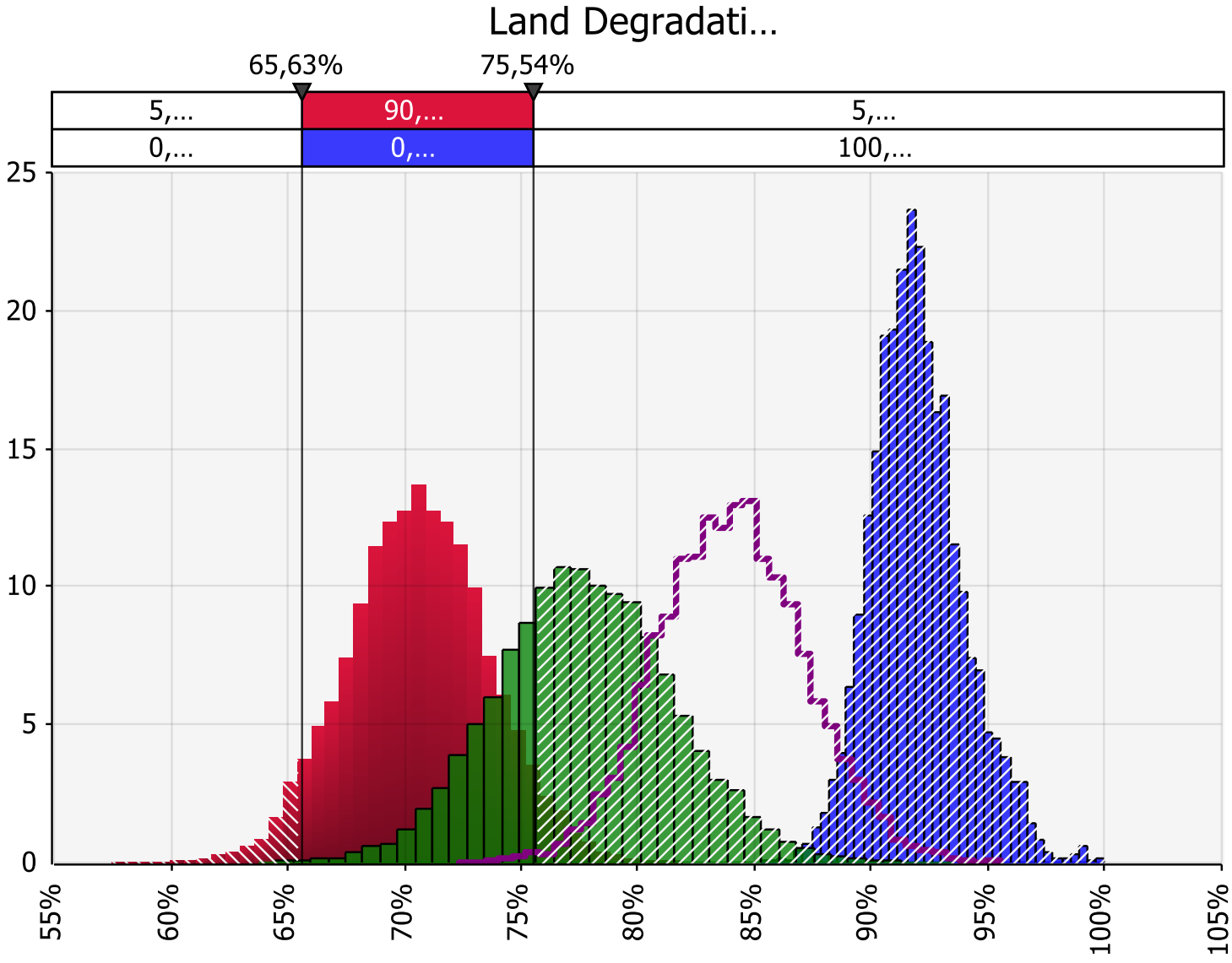


Example of an expert based scoring: Animal welfare indicators



Schader et al. 2016

Example of an uncertainty analysis with the SMART-Farm Tool



Land Degradation	
Minimum	57,487%
Maximum	81,868%
Mean	70,608%
Std Dev	3,013%
Values	10000

Land Degradation	
Minimum	85,226%
Maximum	100,000%
Mean	91,989%
Std Dev	1,958%
Values	10000

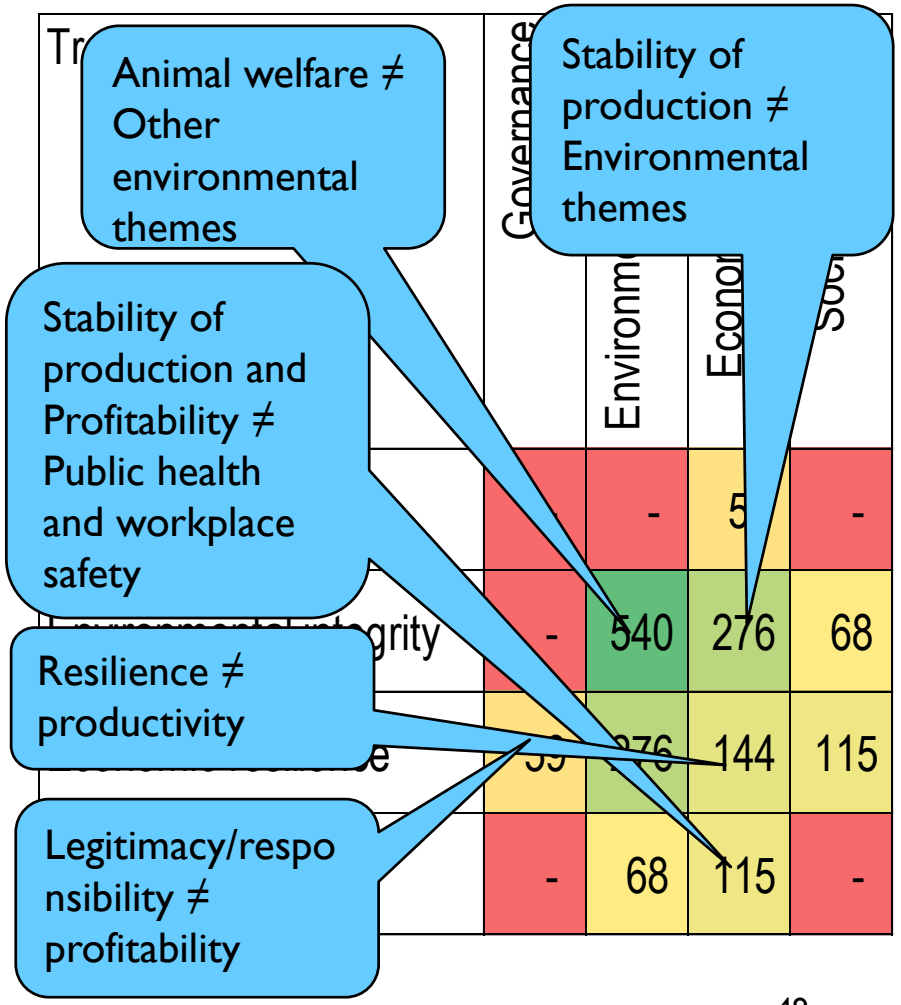
Land Degradation	
Minimum	63,765%
Maximum	93,478%
Mean	77,724%
Std Dev	3,778%
Values	10000

Land Degradation	
Minimum	72,319%
Maximum	95,513%
Mean	84,021%
Std Dev	3,107%
Values	10000

Schader et al. 2016

Results: Synergies and trade-offs between sustainability dimensions

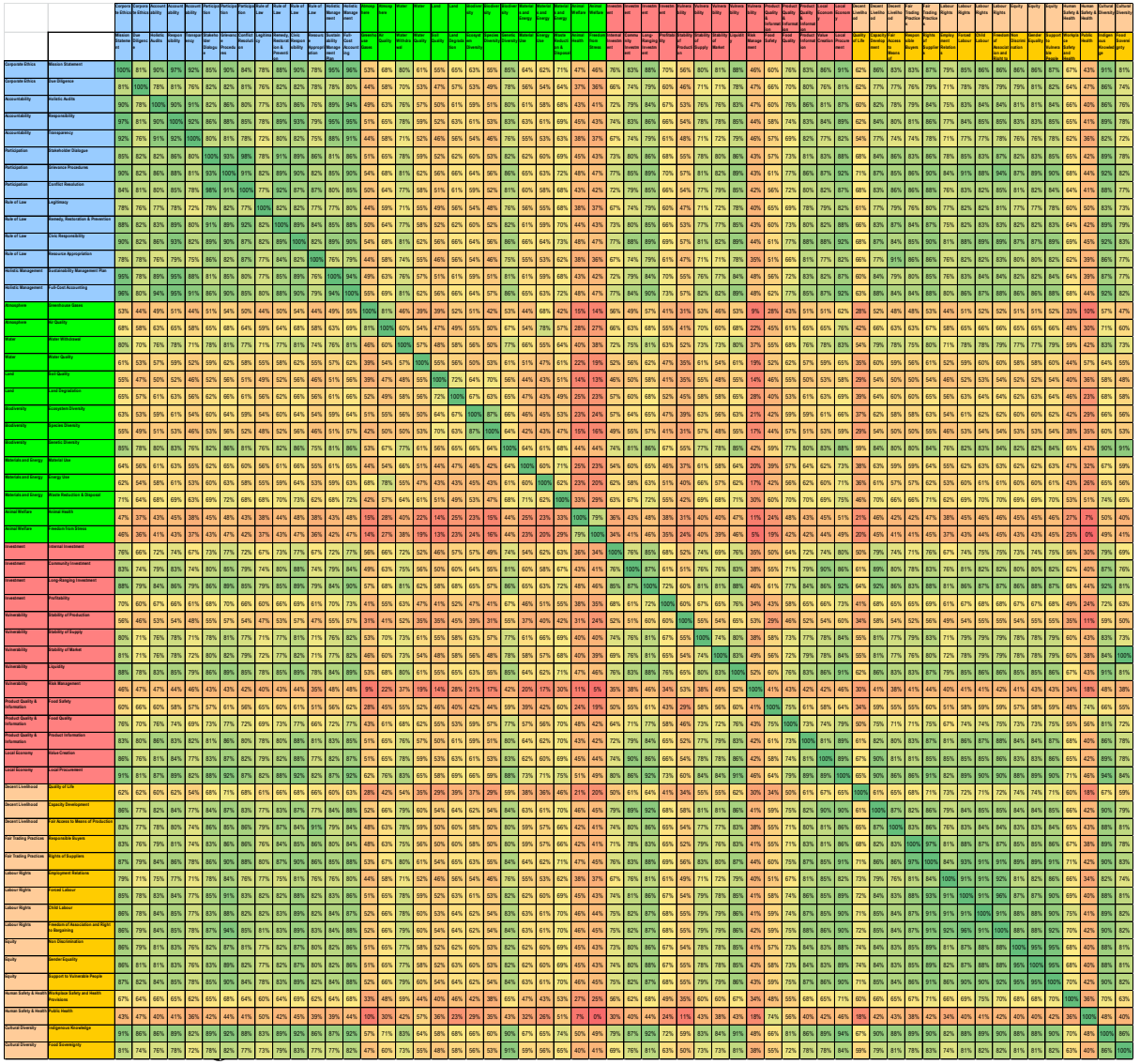
Synergies	Governance	Environmental integrity	Economic resilience	Social Well-Being
Governance	86%	59%	73%	78%
Environmental integrity	59%	52%	54%	56%
Economic resilience	73%	54%	69%	69%
Social Well-Being	78%	56%	69%	78%



FiBL www.fibl.org

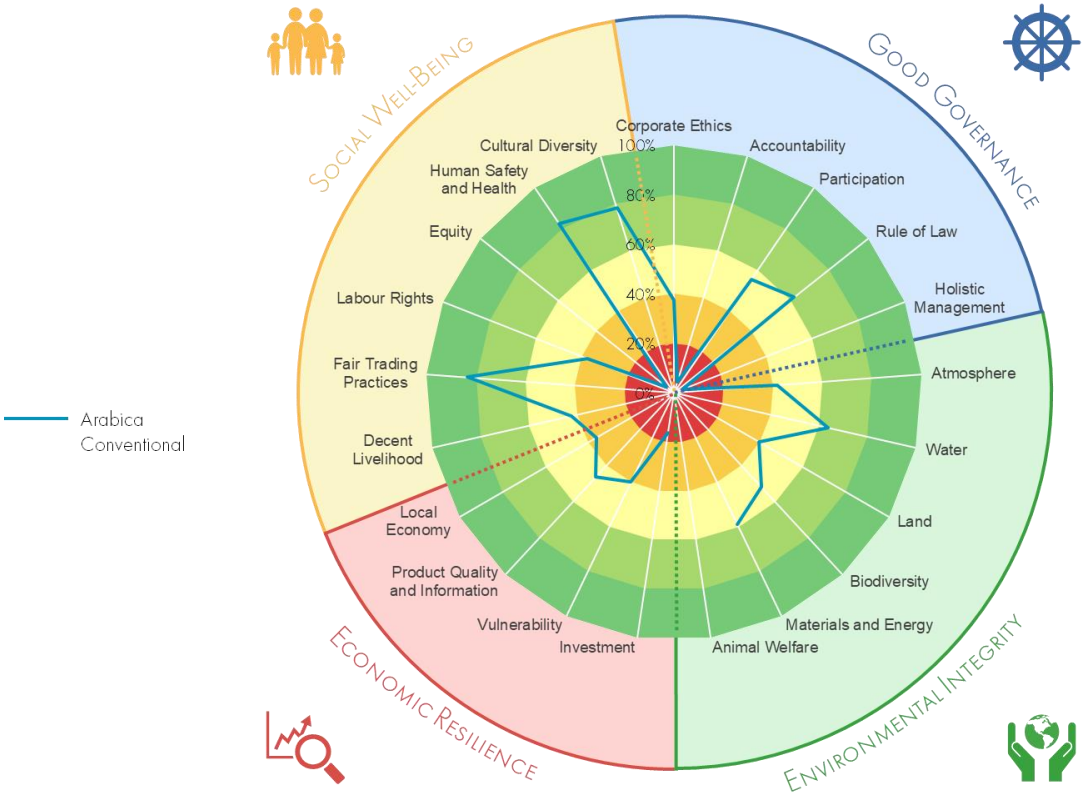
Schader et al. 2016

Synergies between sustainability themes



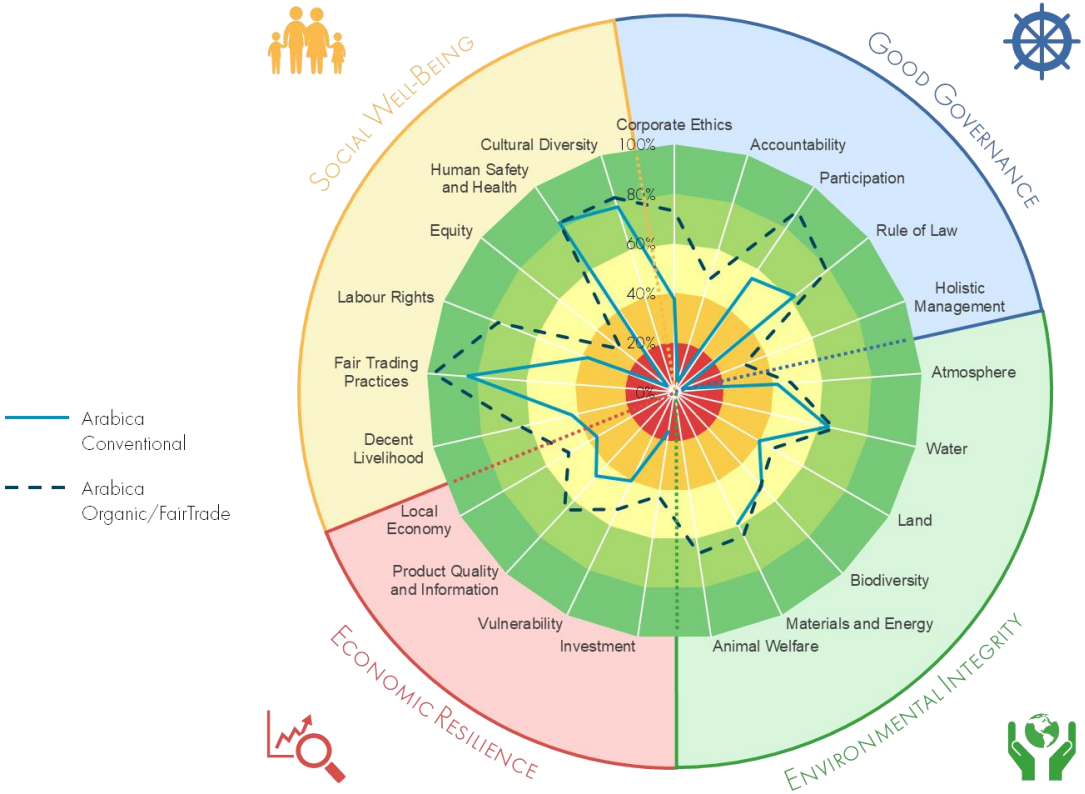
Schader et al. 2016

Comparing Production Systems & Labels (conventional, Fair Trade, Organic) in Uganda



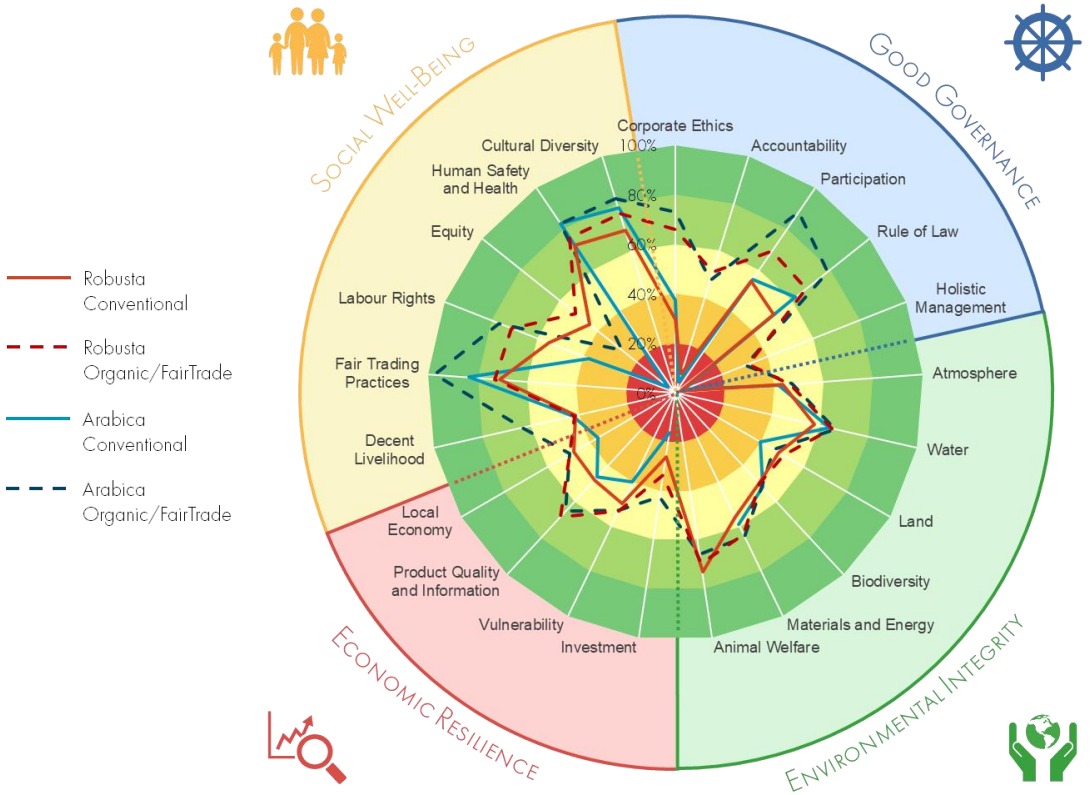
Source: Ssebunya et al 2019

Comparing Production Systems & Labels (conventional, Fair Trade, Organic) in Uganda



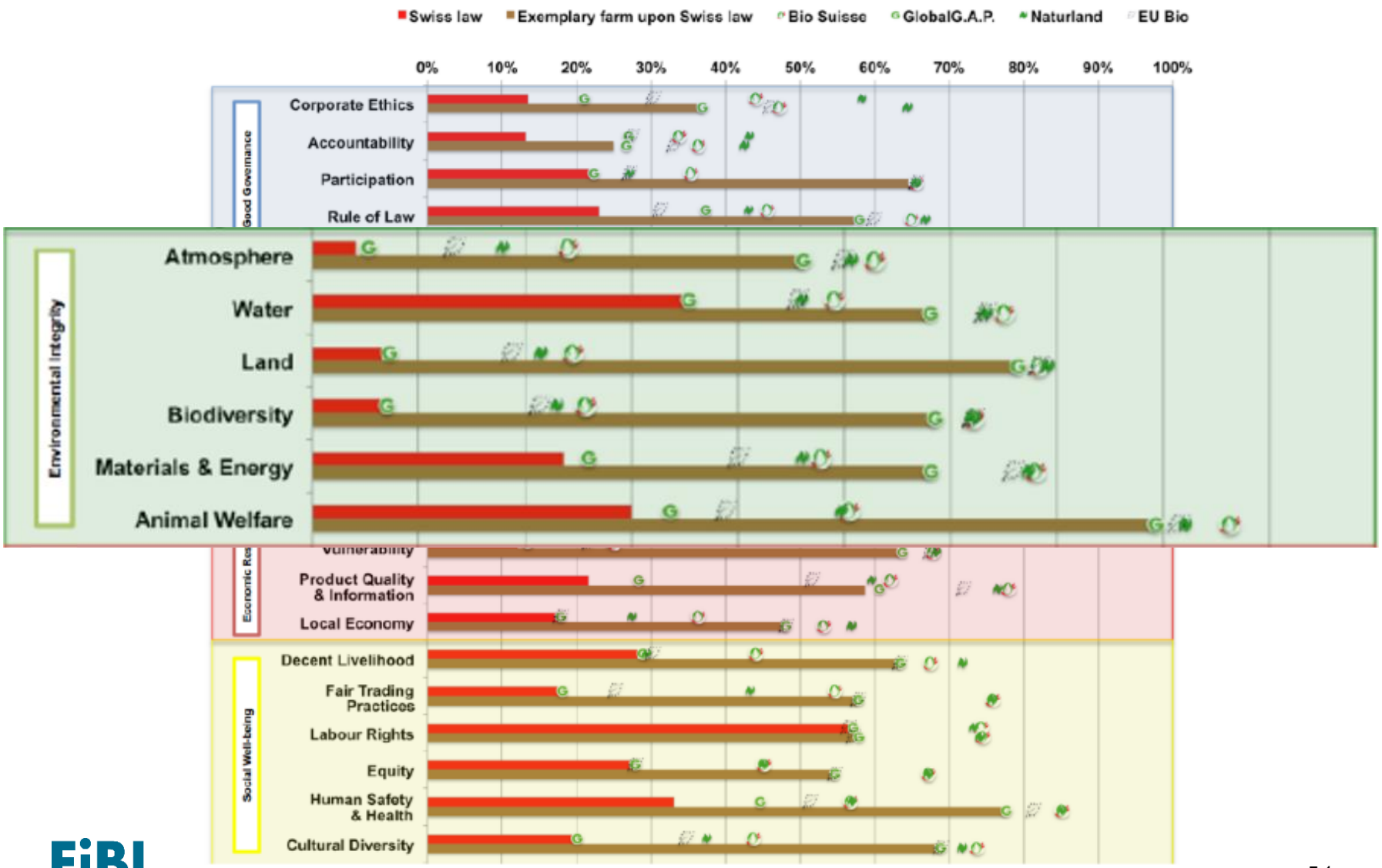
Source: Ssebunya et al 2019

Comparing Production Systems & Labels (conventional, Fair Trade, Organic) in Uganda



Source: Ssebunya et al 2019

Comparison of standards



FiBL

Practice-oriented policy rationale:
Monitoring/Payment based on implementation of practices

Farm

Practices

Implementation of practices deemed to provide public goods

Results

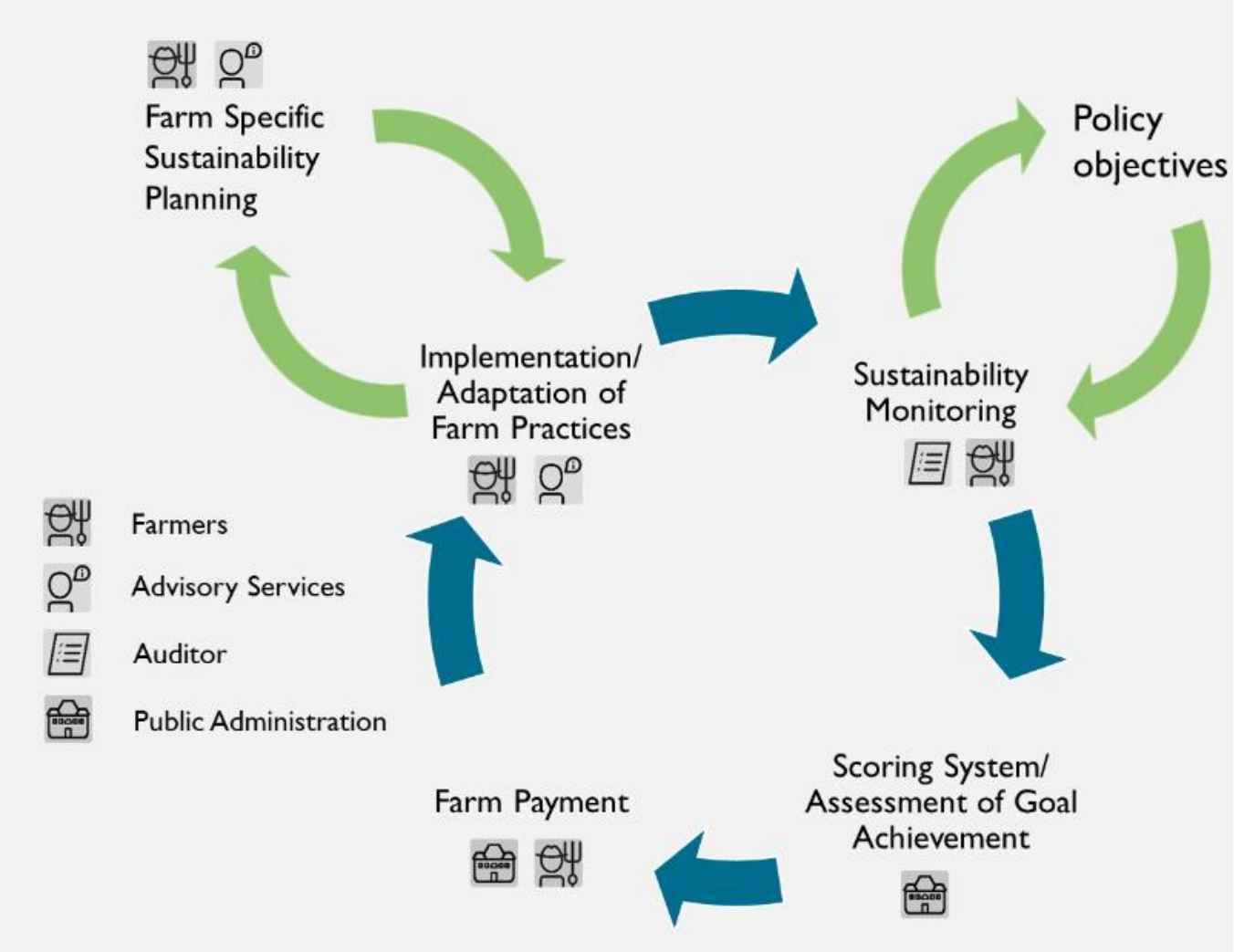
Achievement of results in terms of public goods provisioning

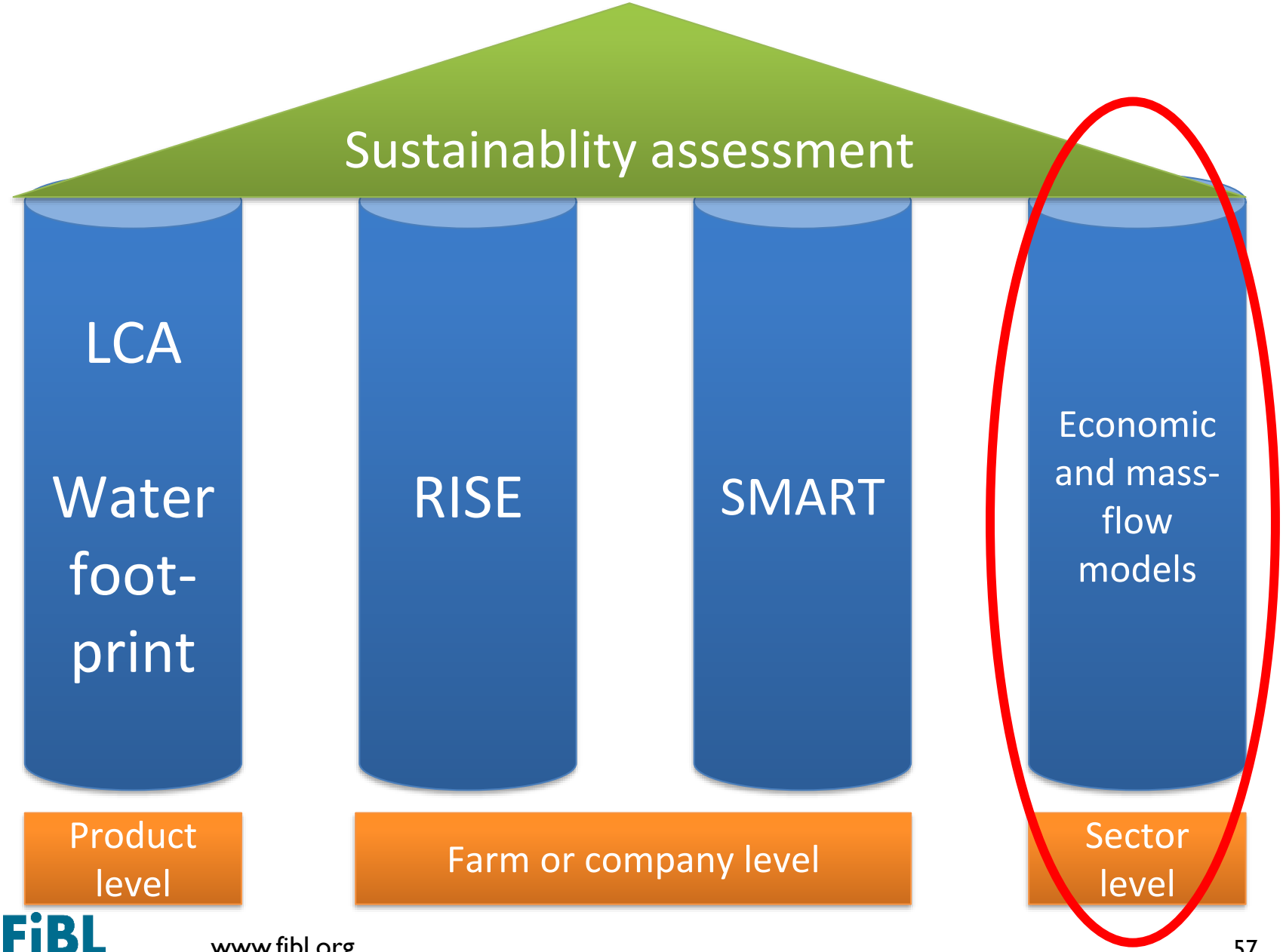
Policy rationale based on Sustainability Assessment:

- Basis for Advisory Services and Strategic Development
- Monitoring/Payment based on Sustainability Indicators

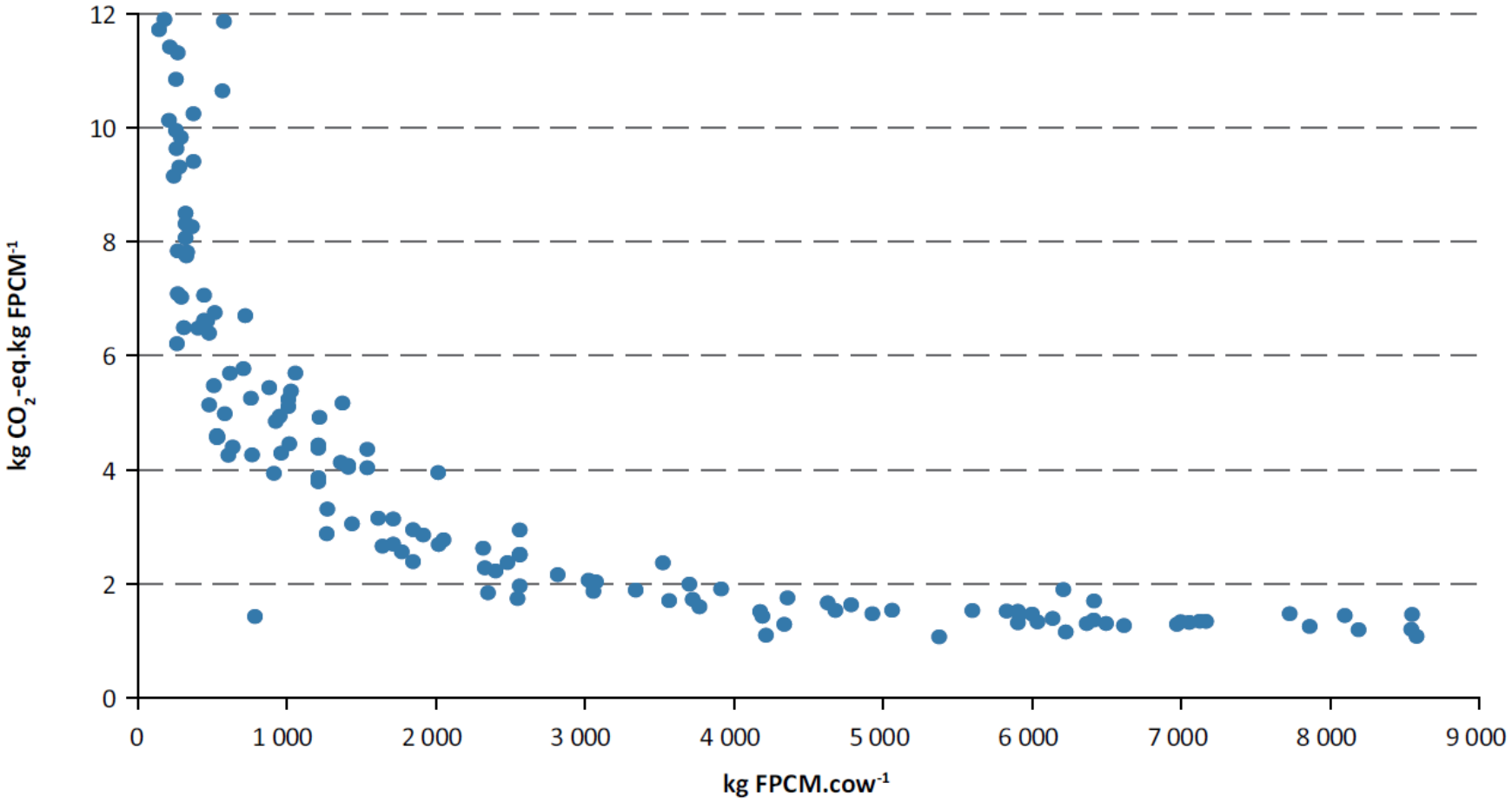
Result-oriented policy rationale:
Monitoring/Payment based on achievement of results

FiBL Proposal for a New Farm Payment System based on Sustainability Assessment



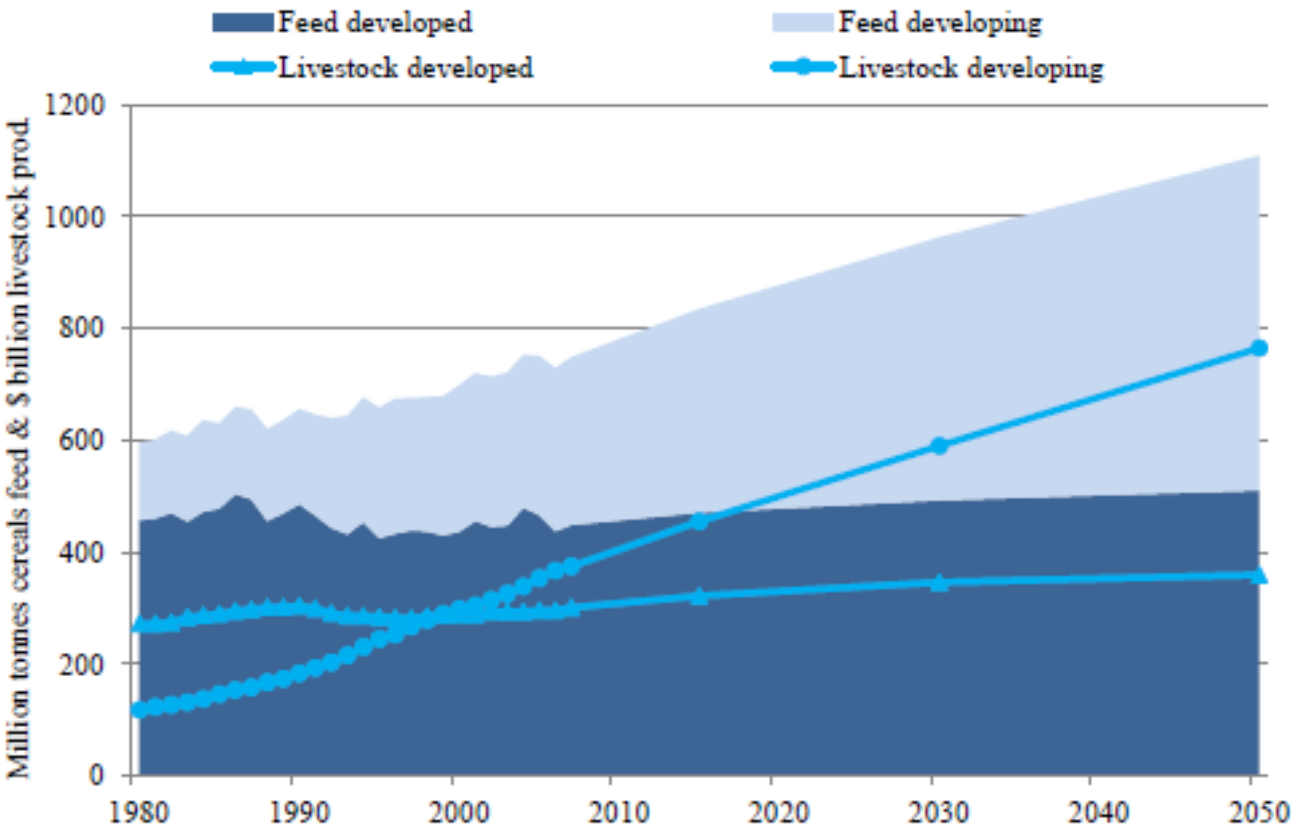

Sustainablity assessment
LCA
Water foot-print
RISE
SMART
Economic and mass-flow models
Product level
Farm or company level
Sector level

Relationship between productivity and emission intensity of milk (country averages)



Source: Gerber *et al.*, 2011.

Cereal feed and livestock production

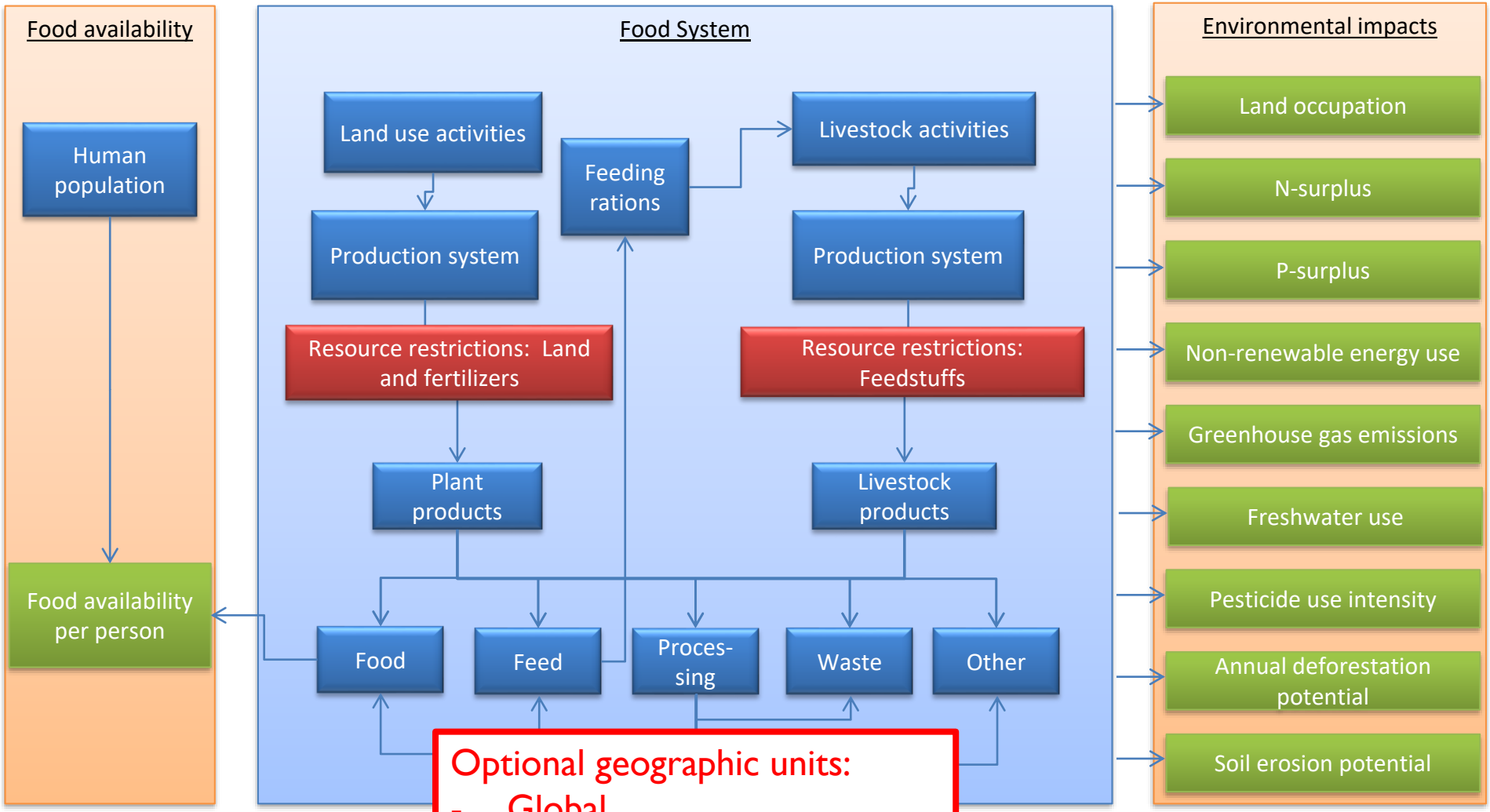


36% of world cereal production goes to feed: developing countries account 42% of world total and will increase to 56% in 2050

FiBL www.fibl.org

Source: FAO, 2012. World agriculture towards 2030/2050

Model overview



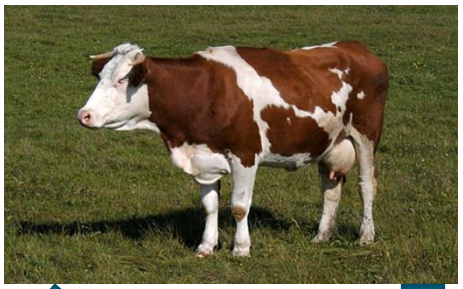
External Inputs:

- Grass-based fodder
- Fodder from forage crops
- Concentrates
- Electicity and fuel use
- Buildings and infrastructure

- NH3 losses from manure management
- NO3 losses from manure management
- N2O losses from manure management
- CH4 losses from manure management
- CH4 losses from enteric fermentation

Outputs:

- Meat yield
- Milk yield
- Eggs yield
- Hides yield
- Wool yield
- Manure



- Purchased animals

- Grass-based feed
- Feed from forage crops
- Concentrate feed

- Manure

- Crop residues

Outputs:

- Crop yield

www.fibl.org

- NH3 losses from fertiliser application
- NO3 losses from fertiliser application
- N2O losses from fertiliser application
- CH4 losses from flooding

External Inputs:

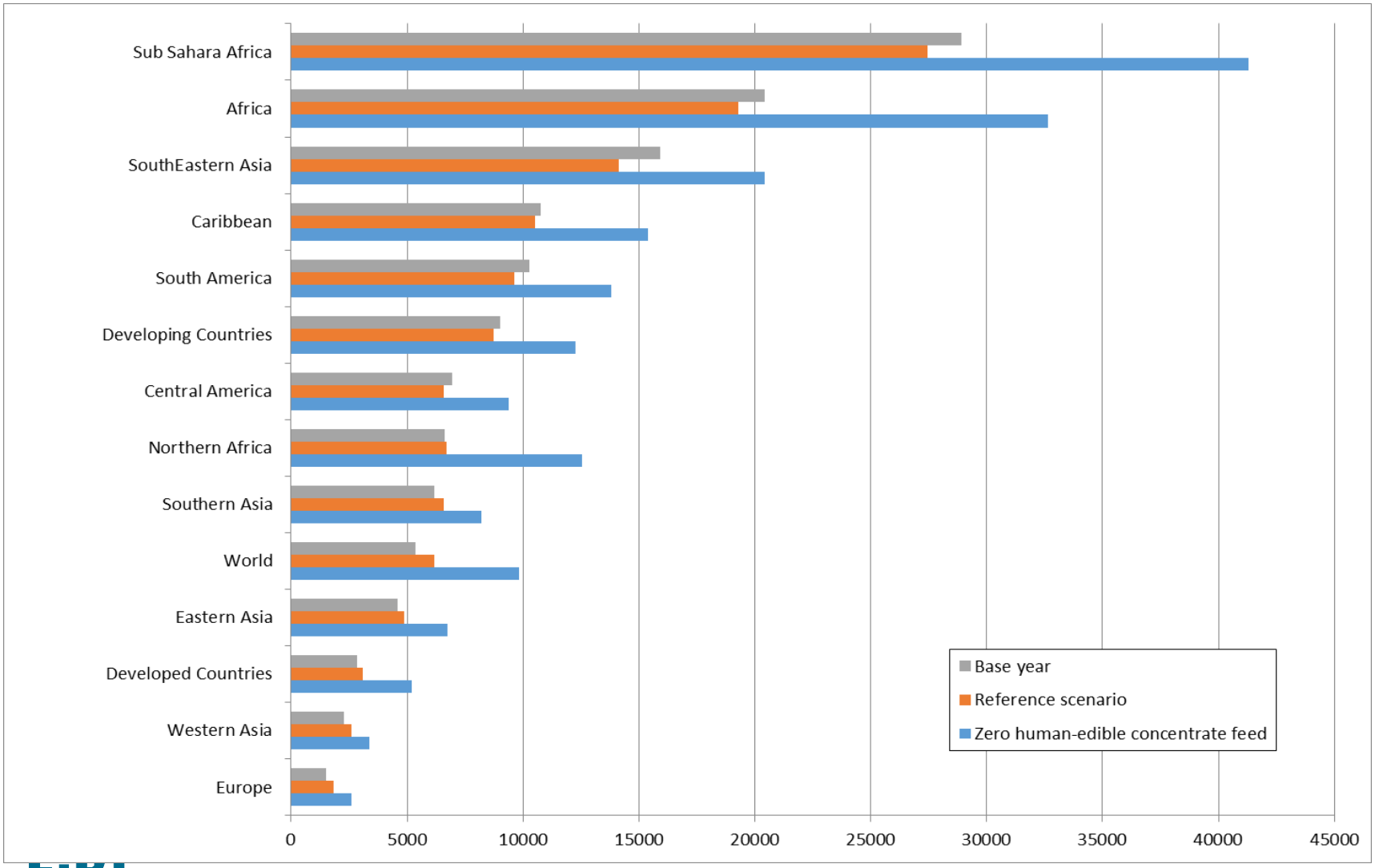
- Mineral fertiliser
- N-fixation
- Seeds
- Pesticides
- Water
- Electricity and fuel use
- Buildings and infrastructure

Environmental impacts covered in SOL-m

Environmental impact	Indicator
Land occupation	Land occupation in terms of arable, permanent crops and grassland
Soil erosion potential	Crop-specific factor covering the erosion susceptibility of crops
Use of fossil energy resources	Cumulative energy use (CED) 1.05-1.08
Greenhouse gases	GWP IPCC100a
Nitrogen surplus	Nitrogen surplus and losses
Phosphorus surplus	P_2O_5 surplus
Pesticide use	Pesticide intensity of crops, legislation in the countries and access of farmers to pesticides
Annual deforestation potential	Additionally required crop land
Grassland exploitation	Ratio between ruminants fed on grassland and ruminants that could be fed on grassland in a country

Schader et al.

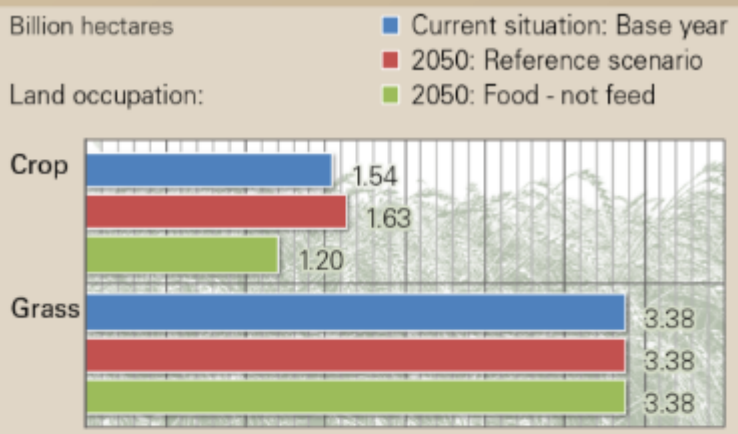
Comparison of average global warming potential in different regions per t milk delivered by dairy cattle



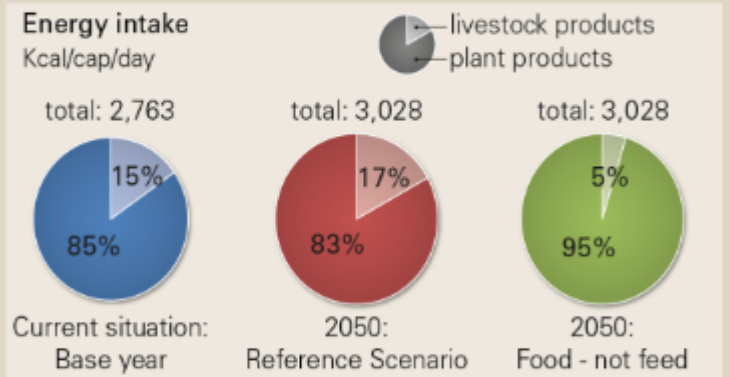
Schader et al. 2014

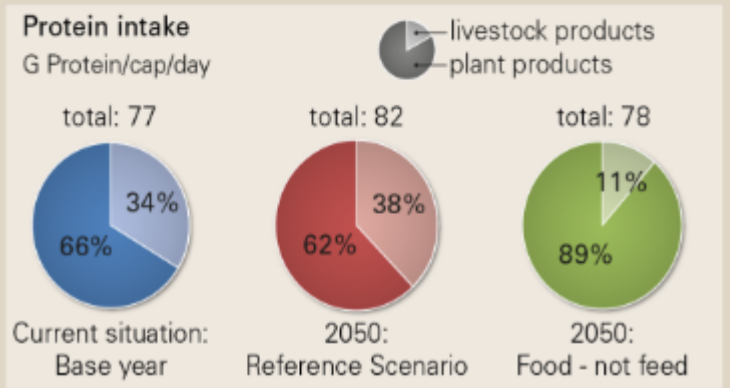
Schader et al. 2015, Journal of the Royal Society Interface

Land use

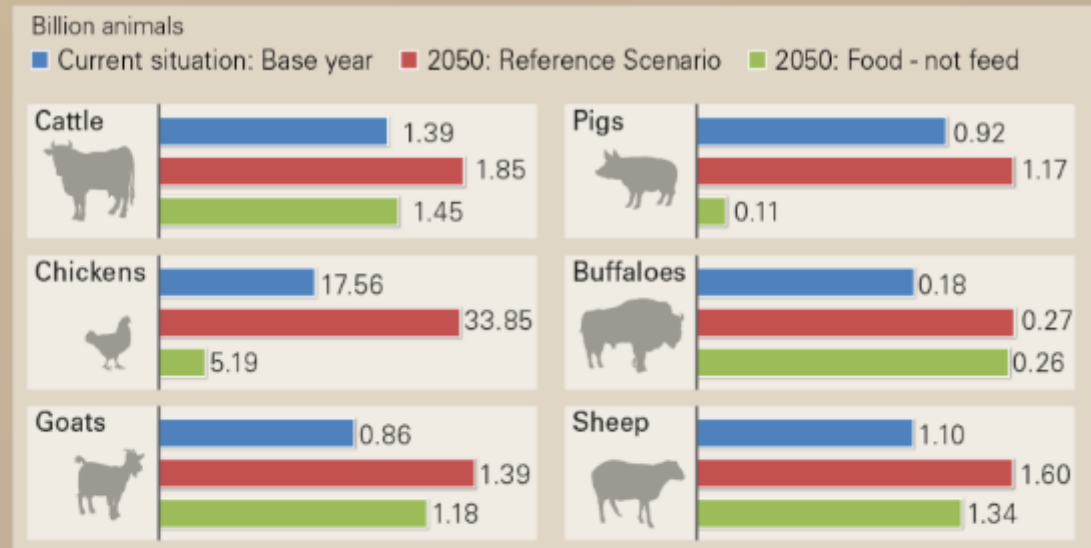


Diets

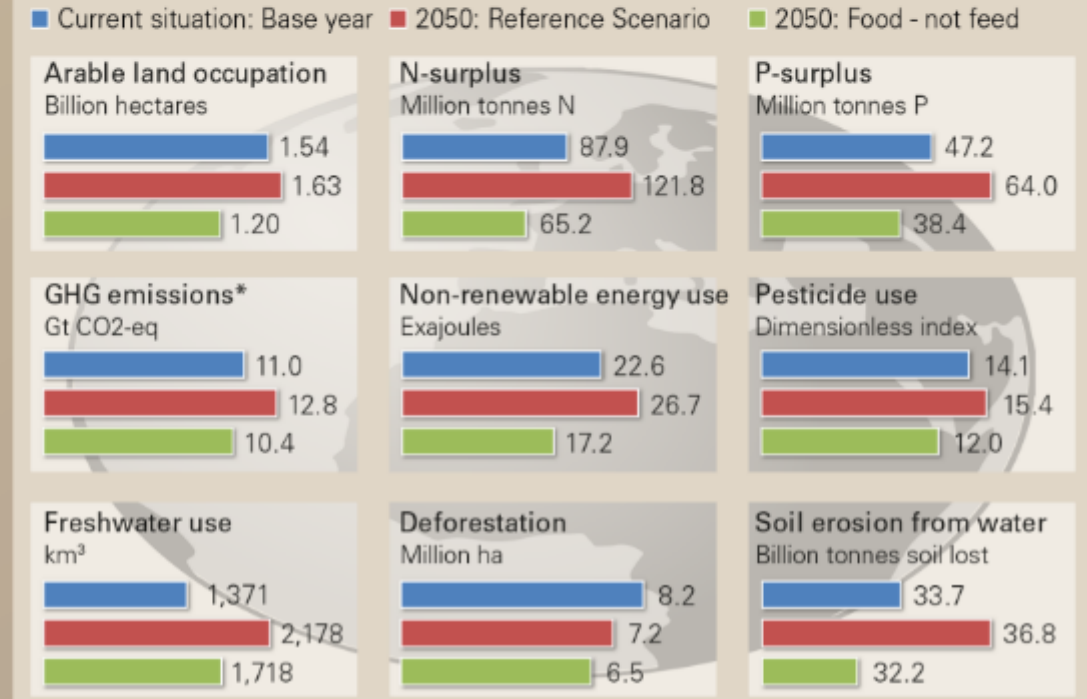




Livestock



Environment



* GHG emissions include emissions from input provision, deforestation and organic soils.

Can organic agriculture feed the world sustainably?

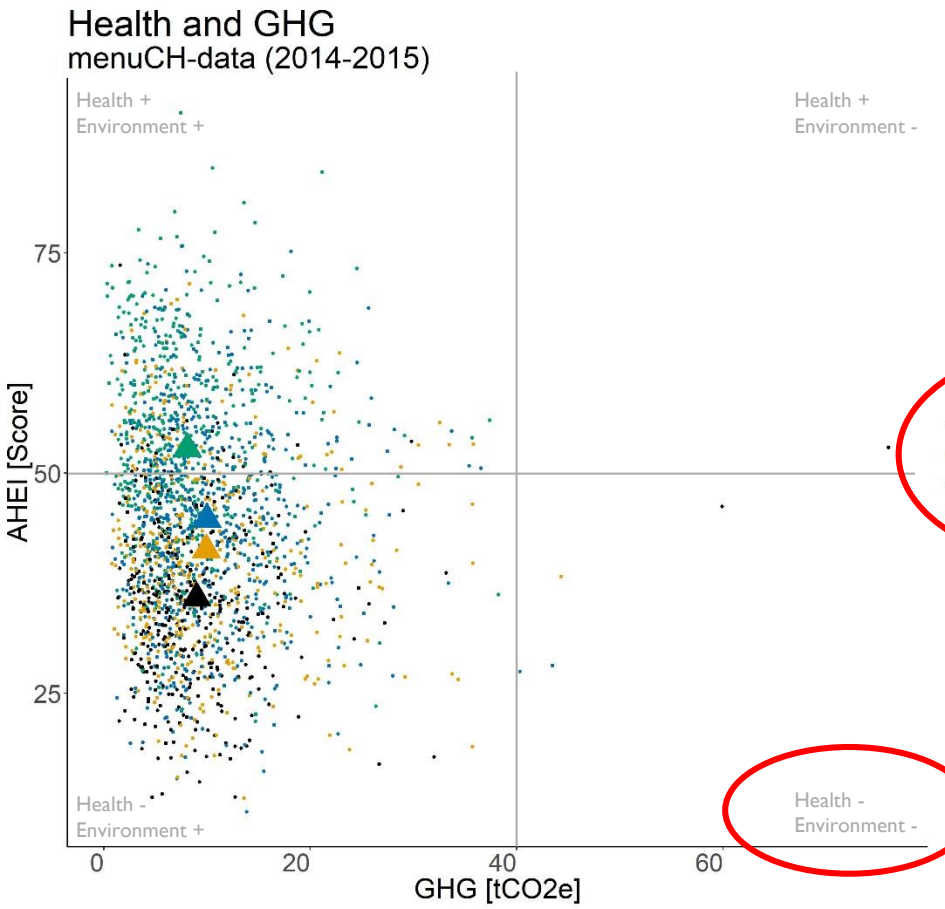
High yield gap between conventional and organic agriculture

Climate change impact on yields	% organic																	
	0	20	40	60	80	100	0	20	40	60	80	100	0	20	40	60	80	100
zero	0	5	10	17	25	33												
medium							21	26	33	40	47	57						
high													46	50	54	58	64	71

Source: Muller et al. 2017

Swiss National Science Foundation NRP69: Healthy and Systainable Diets: Trade-offs and Synergies

Health impacts (AHEI-2010) and greenhouse gas emissions per observation of the menuCH-dataset (points)



Means of the four clusters (Krieger et al. 2018)

Interpretation:
- → poor performance
+ → good performance

Key take-home messages

Overview of principal methodological options for sustainability assessment

Different tools for sustainability assessment can come to different results

There is no «one-size-fits-all solution» => Tools should be chosen depending on the purpose of the assessment

Thank you for your attention!

Thank you for your attention!

Contact details

Dr. Christian Schader
Head Sustainability Assessment
Research Institute of Organic Agriculture (FiBL)
Ackerstrasse 113
5070 Frick
Switzerland

Phone: +41 62 865 0416
Email: christian.schader@fibl.org
http://www.fibl.org/en/themes/sustainability-assessment.html