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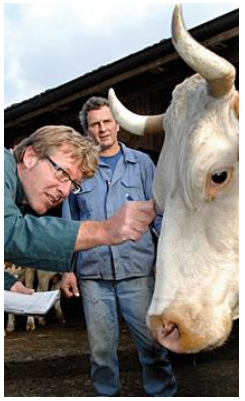
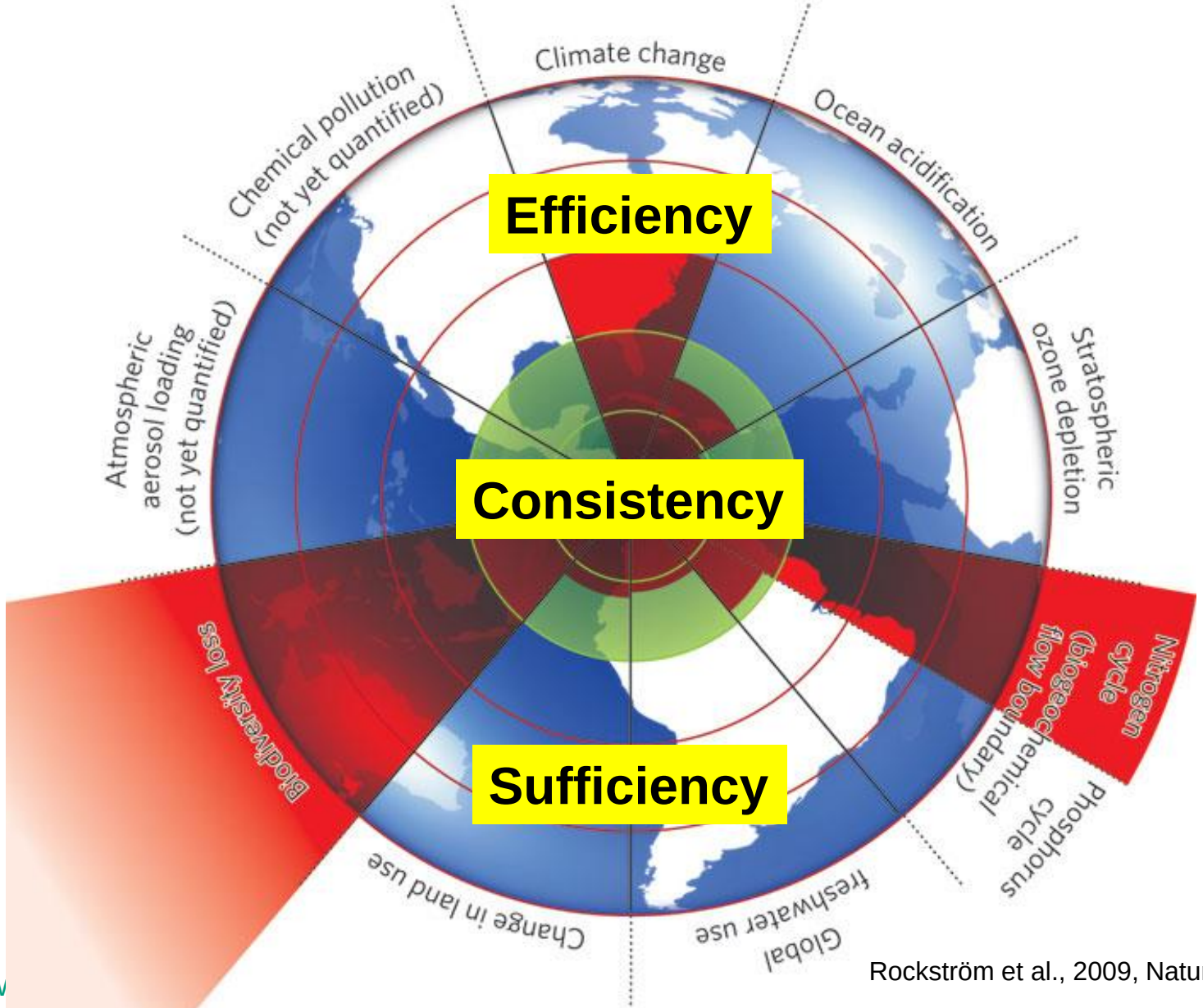



The role of human-edible components in livestock feed for future food availability, the environment and human diets

Christian Schader

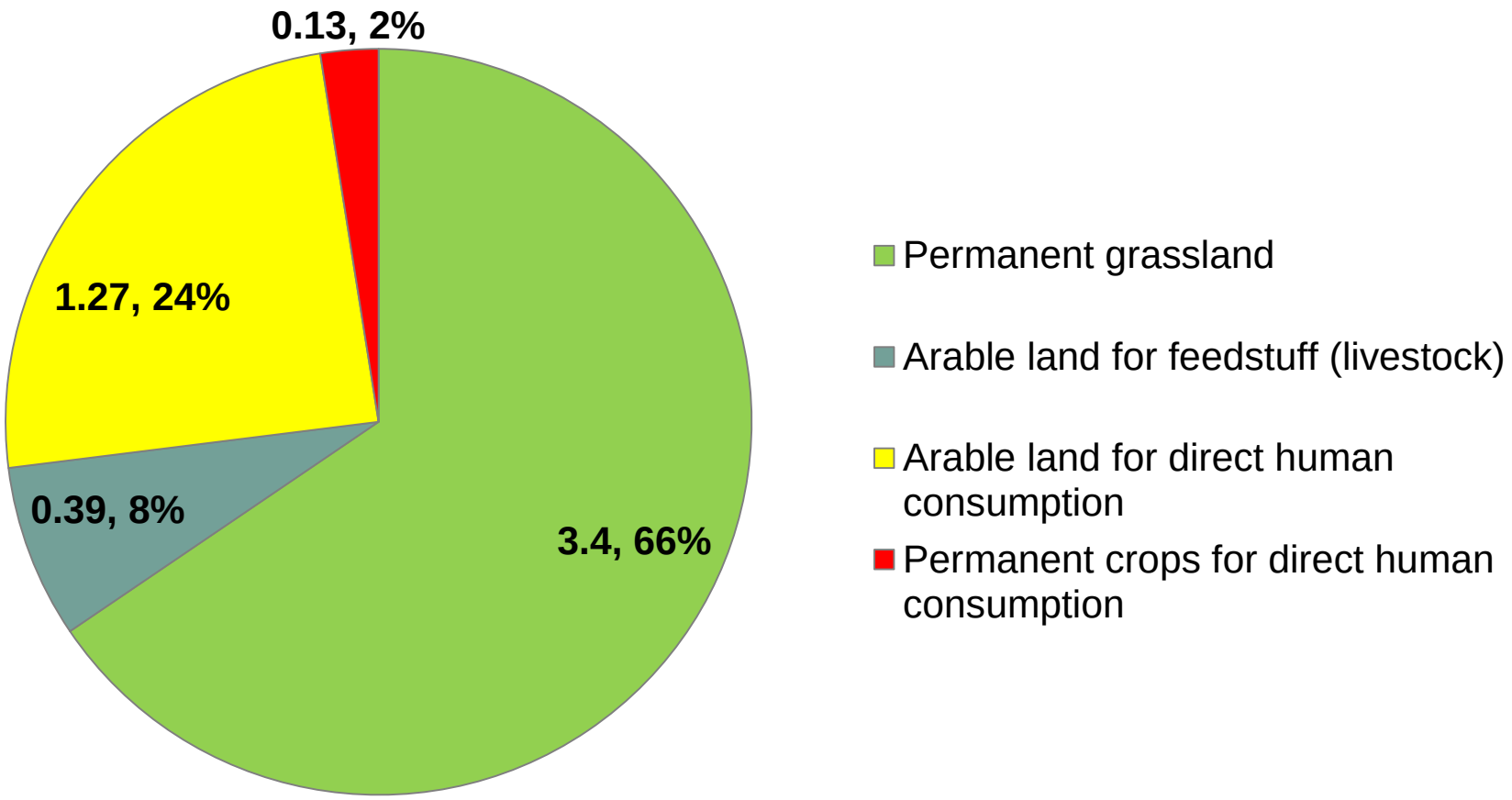
Adrian Muller, Nadia El-Hage Scialabba, Judith Hecht, Anne Isensee, Karl-Heinz Erb, Pete Smith, Harinder Makkar, Peter Klocke, Florian Leiber, Patrizia Schwegler, Matthias Stolze, Urs Niggli

Planetary boundaries



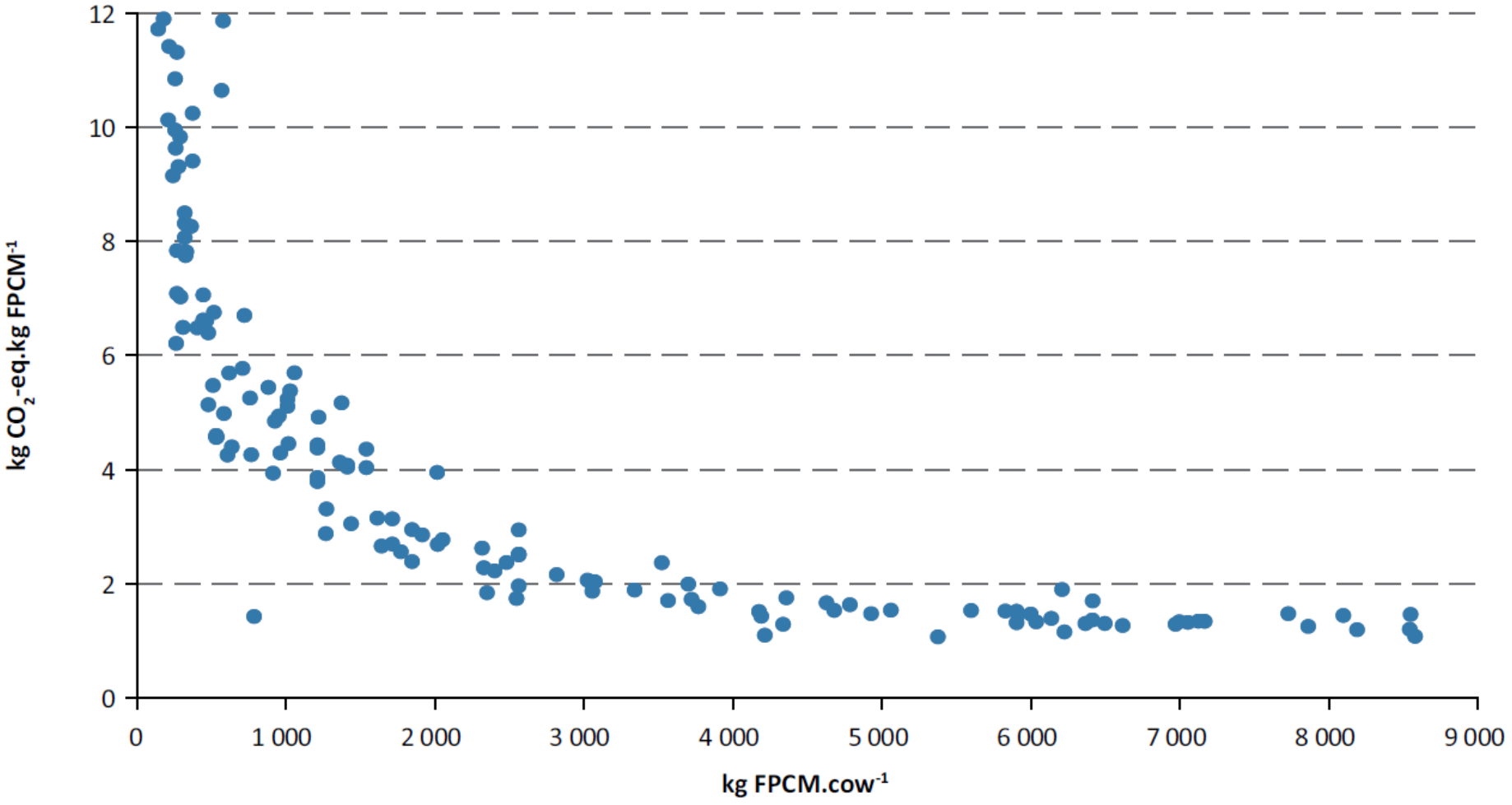
Rockström et al., 2009, Nature 461

World-wide agricultural land use (in billion ha and percentage)



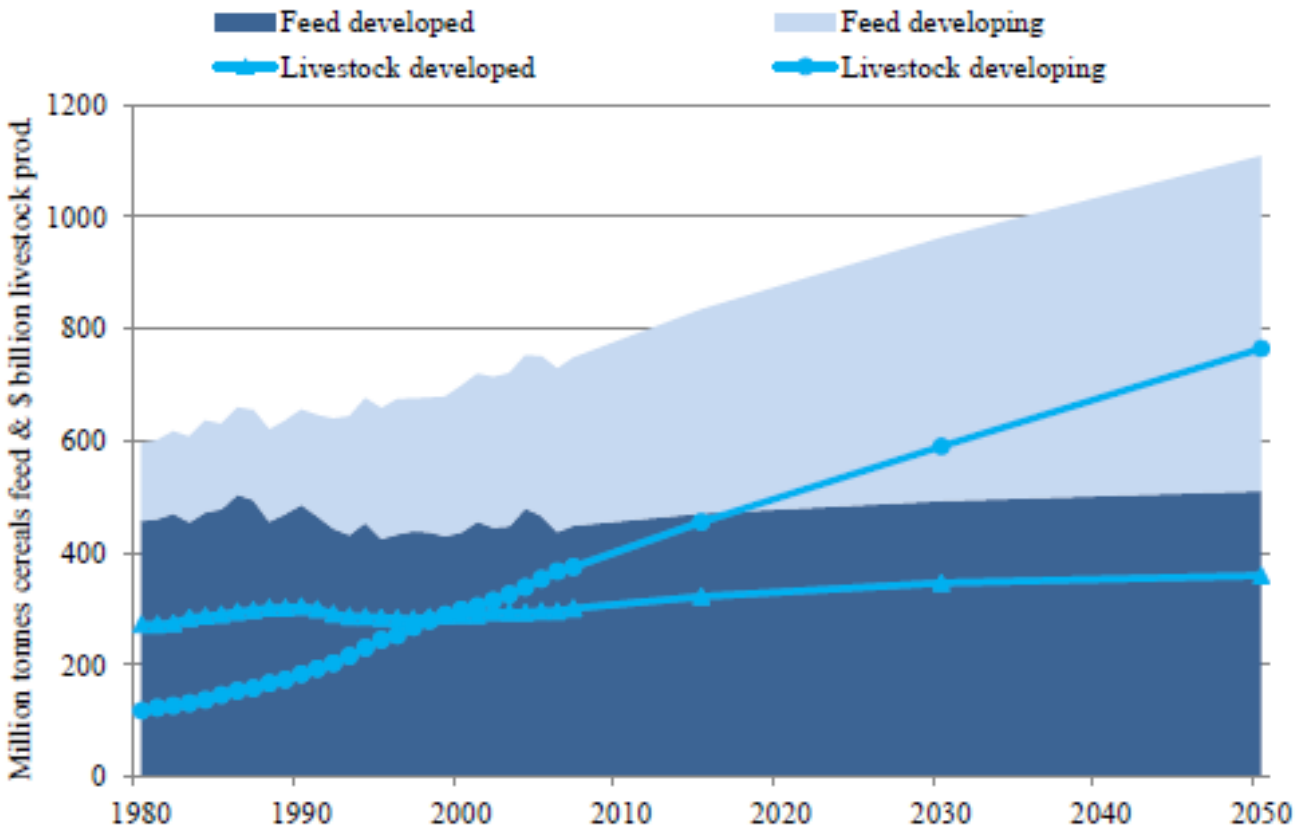
FAOSTAT, 2011

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



Source: Gerber *et al.*, 2011.

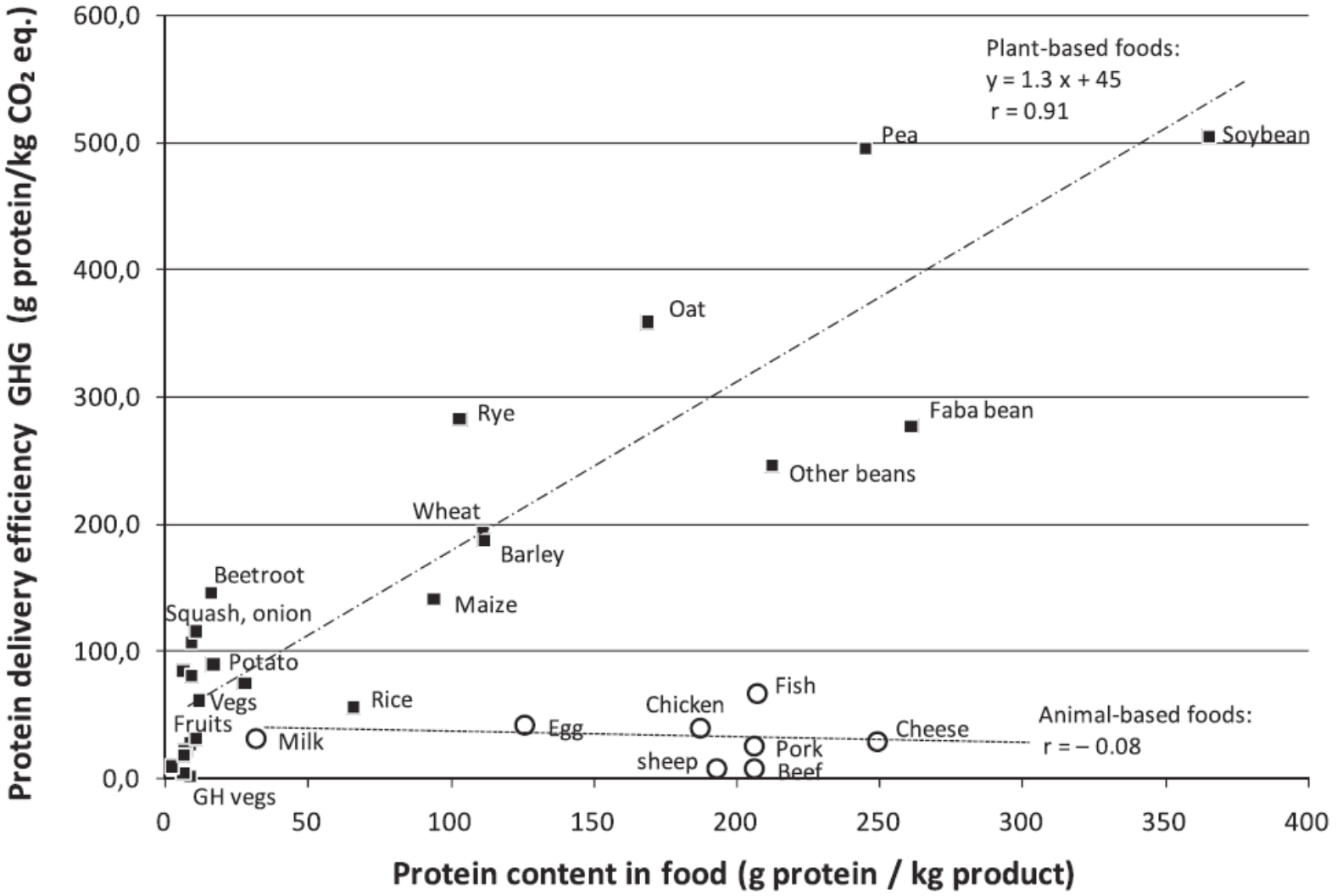
Cereal feed and livestock production



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

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

Protein delivery efficiency



Gonzalez et al. 2011

Research question

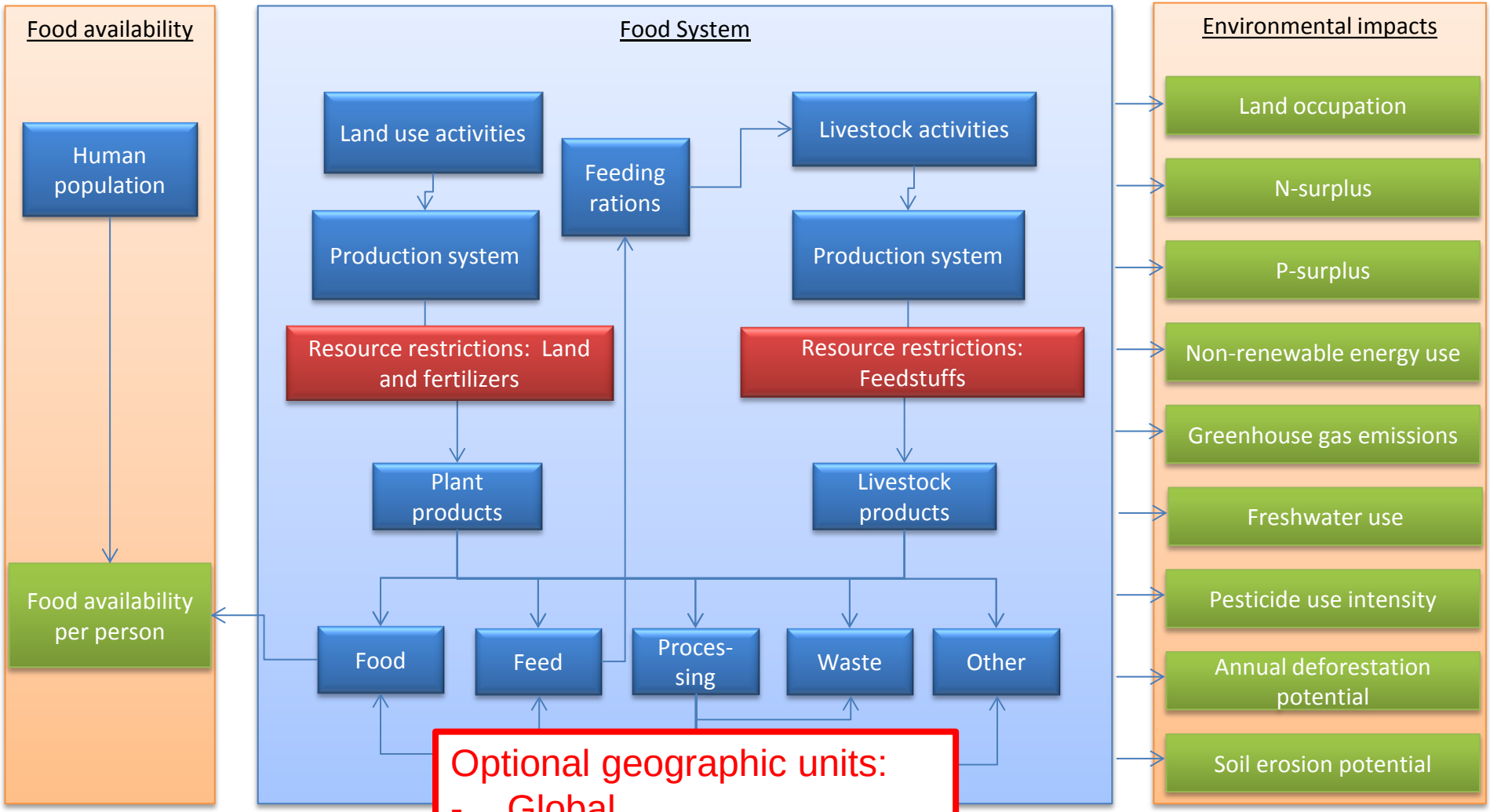
What impacts does feeding less human-edible feedstuffs to livestock have on

a. Agricultural production patterns
b. Food availability
c. Human diets
d. Environmental impacts

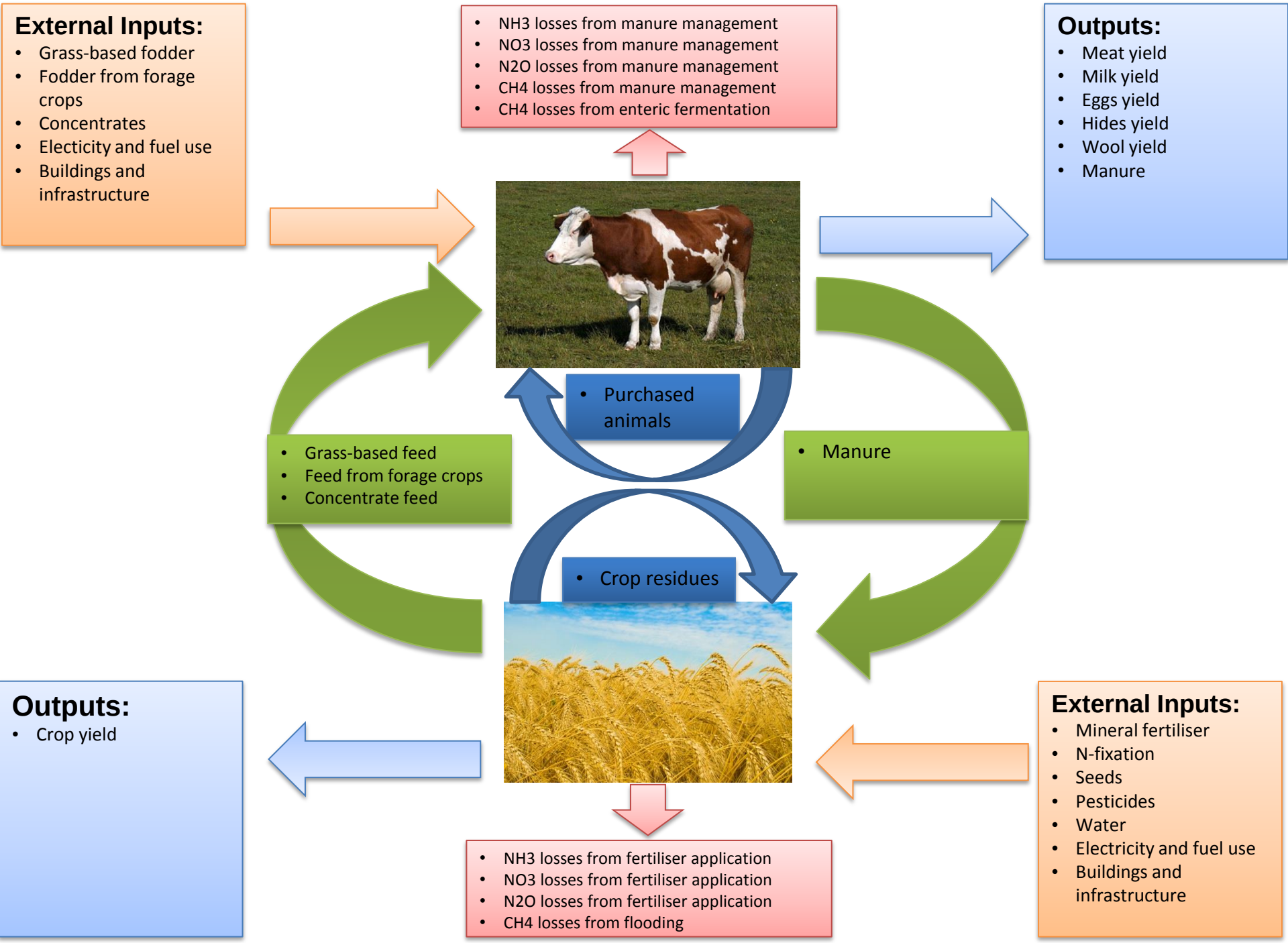
Modelling System

- Global mass flow model => Multi-objective optimization model
- General Algebraic Modelling System (GAMS)
- 229 countries, 185 crop production activities, 30 livestock production activities, 230 main products, ca. 700 sub-products
- FAOSTAT working system, including food balance sheets, tradestat, fertistat, etc.
- Herd structure models using the maximum entropy approach for calculating the most likely herd structure composition in a country
- Further data: e.g. IPCC Guidelines 2006, GLC2000, Erb et al. 2007

Model overview



Optional geographic units:
- Global
- Regional
- Country


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
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

Methods for modelling environmental impacts

Environmental impact	Indicator	Unit
Land occupation	Land occupation by arable and grassland	ha
Soil erosion potential	Crop-specific factor covering the erosion susceptibility of crops combined with country-specific or regional average soil erosion rates	t soil lost/year
Non-renewable energy use	Cumulative energy use (CED) 1.05-1.08	GJ/year
Greenhouse gas emissions	Global Warming Potential (GWP) IPCC100a	t CO2-eq/year
Nitrogen surplus	Nitrogen surplus	N-surplus/year
Phosphorus surplus	P_2O_5 surplus	P_2O_5-surplus/year
Pesticide use intensity	Classification of pesticide use per ha by intensity and by crop, legislation by country and access to pesticides by farmers	semi quantitative indicator
Annual deforestation potential	Additional crop land required annually	ha/year
Freshwater use	Water used for irrigation of crops	m3/year

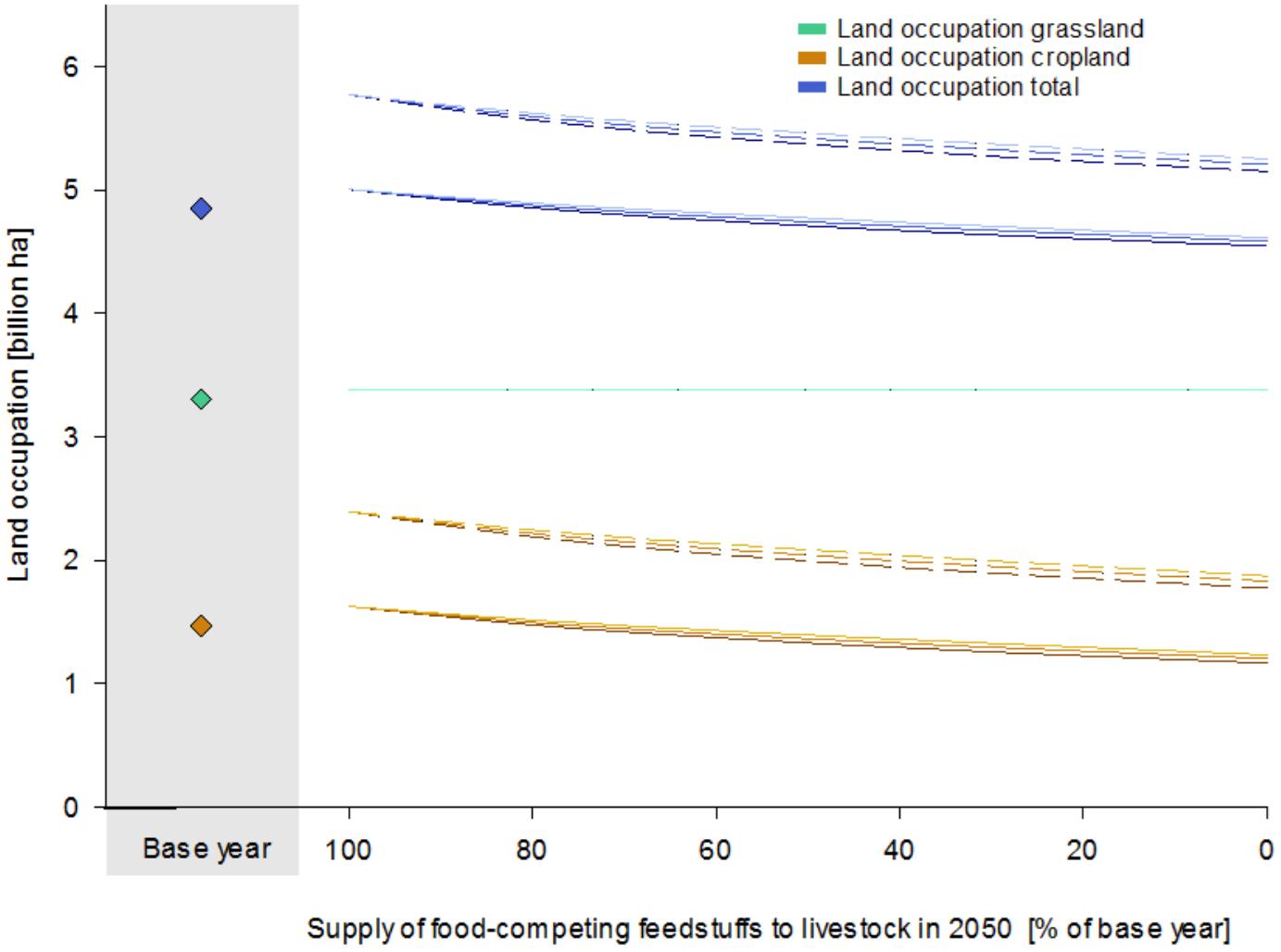
Scenarios

1. **Base year:**
   - Current situation 2005-2009, 2763 kcal/cap/day

2. **Reference scenario:**
   - Situation in 2050 based on FAO calculations (Alexandratos and Bruinsma 2012)
   - Activity-specific yield increases
   - 9.2 billion people
   - Food demand patterns, 3027 kcal/cap/day
   - Permanent grassland areas constant at global level

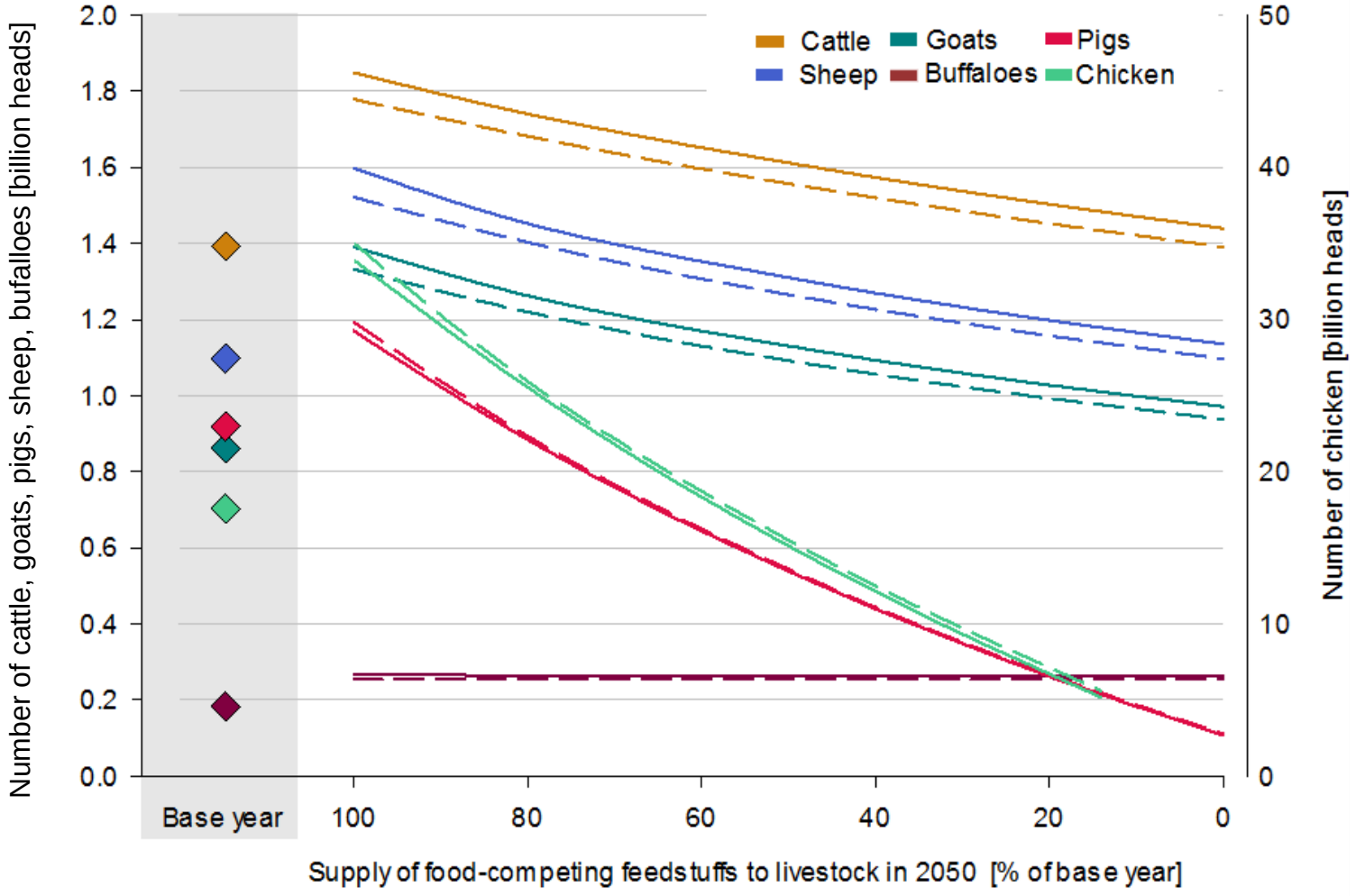
3. **Food – Not Feed: Reduced human-edible feeds scenario:**
   - Same assumptions as for reference scenario (e.g. same energy provision per person as in reference scenario). Plus:
     - Reduction of human-edible feedstuffs in livestock rations
       - Ruminants grassfed
       - Monogastrics fed on by-products
     - Livestock yield reduction 0-40%
     - Substitution of nutrients in manure and proteins in human consumption by increased legume shares in rotations

Results:
Land use



Schader et al. 2015 (in review)

Results:
Livestock numbers



Schader et al. 2015 (in review)

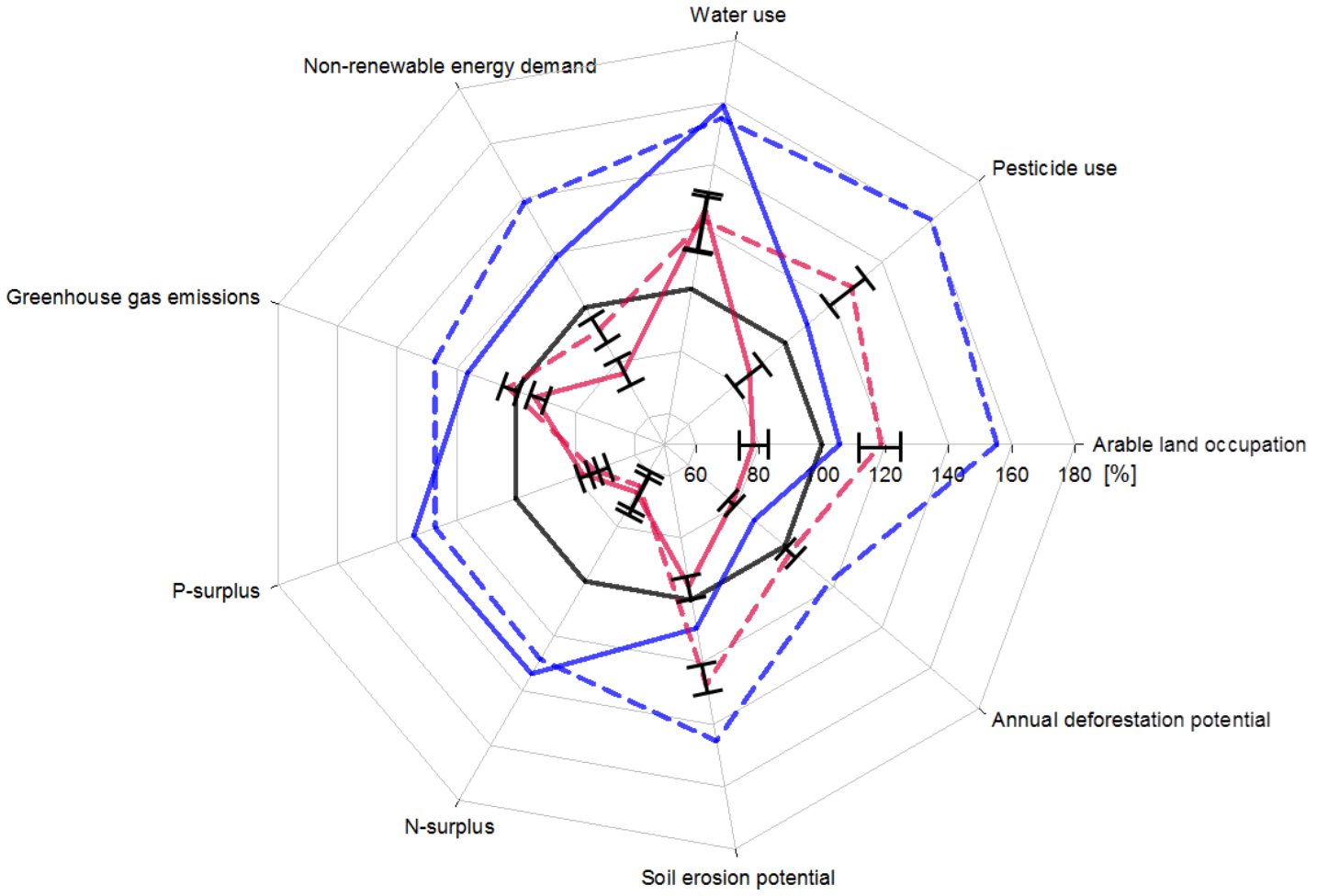
Results:
Daily intake of main food categories per person

Food types (PPE)[x]	Unit[#]	Base year (2005-2009)	Supply of food-competing feedstuffs to livestock in scenarios for 2050 [% of base year] 100%	80%	60%	40%	20%	0%	Difference of 0% food-competing feedstuffs scenario to base year	Difference of 0% to 100% food-competing feedstuffs scenario
Plant products	**g/(cap*day)**	**1442**	**1484**	**1495**	**1507**	**1512**	**1509**	**1499**	***4%***	***1%***
Grains	g/(cap*day)	519	499	531	555	570	577	575	*11%*	*15%*
Starchy roots	g/(cap*day)	185	193	201	207	212	214	212	*15%*	*10%*
Oil crops	g/(cap*day)	74	104	96	90	84	79	73	*-1%*	*-30%*
Legumes	g/(cap*day)	42	52	69	89	112	140	177	*317%*	*242%*
Vegetables	g/(cap*day)	343	295	278	263	248	231	213	*-38%*	*-28%*
Fruits	g/(cap*day)	210	260	243	228	215	201	187	*-11%*	*-28%*
Sugars and sweeteners[+]	g/(cap*day)	65	78	73	70	66	63	60	*-8%*	*-23%*
Others*	g/(cap*day)	5	4	4	4	4	3	3	*-39%*	*-29%*
Livestock products	**g/(cap*day)**	**425**	**484**	**400**	**336**	**283**	**239**	**201**	***-53%***	***-58%***
Milk	g/(cap*day)	242	274	237	207	181	158	138	*-43%*	*-50%*
Meat	g/(cap*day)	110	136	101	75	54	38	26	*-77%*	*-81%*
Non-ruminants meat	g/(cap*day)	77	97	68	46	29	16	7	*-91%*	*-93%*
Ruminants meat	g/(cap*day)	34	39	33	29	25	22	19	*-43%*	*-50%*
Fish	g/(cap*day)	50	48	44	41	39	37	35	*-30%*	*-27%*
Eggs	g/(cap*day)	23	26	19	13	8	5	2	*-90%*	*-91%*
All products	**g/(cap*day)**	**1867**	**1968**	**1896**	**1843**	**1794**	**1747**	**1701**	***-9%***	***-14%***
Total energy availability	*kcal/(cap*day)*	*2763*	*3028*	*3028*	*3028*	*3028*	*3028*	*3028*	*10%*	*0%*
Total protein availability	*CP/(cap*day)*[§]	*77*	*82*	*79*	*78*	*77*	*77*	*78*	*1%*	*-5%*
Animal protein/total protein	*Ratio*	*34%*	*38%*	*31%*	*24%*	*19%*	*15%*	*11%*	*-67%*	*-70%*
energy	*Ratio*	*0.111*	*0.108*	*0.104*	*0.103*	*0.102*	*0.102*	*0.103*	*-8%*	*-5%*

x: PPE: primary product equivalents; #: cap: person; +: raw sugar equivalents; *: mainly treenuts, stimulants and spices; §: CP: crude protein;

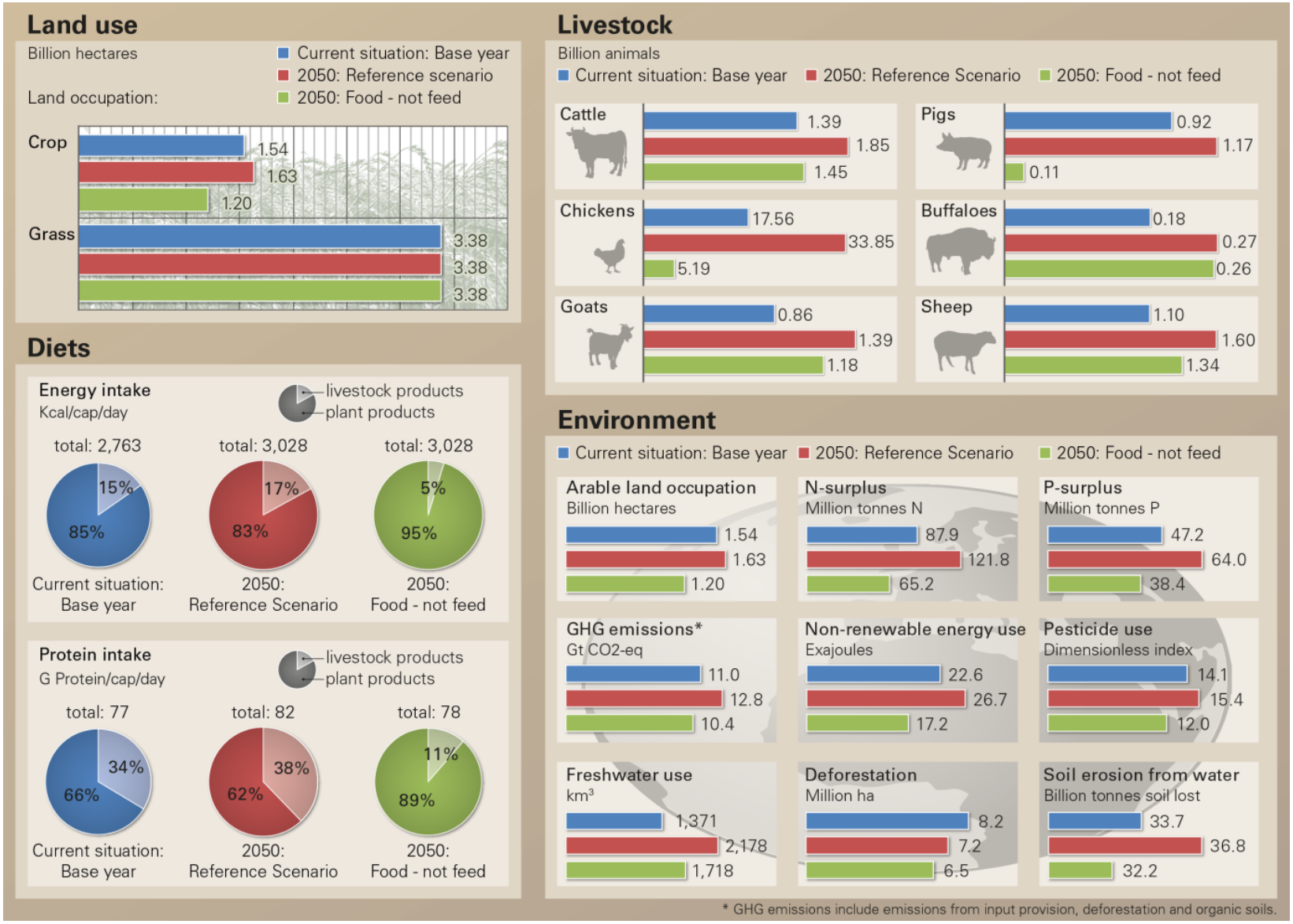
Schader et al. 2015 (in review)

Results:
Environmental impacts



Schader et al. 2015 (in review)

Overview of results



Conclusions

- The standard FAO reference scenario (business as usual) would lead to increased environmental impacts, despite the yield increases and efficiency gains assumed
- Reducing human-edible feedstuffs in livestock feeding would create synergies between food availability and reducing most environmental impacts although efficiency per unit of product goes down for many impacts categories
- Meat, milk and egg consumption needs to be reduced and possibilities for alternative protein sources (e.g. legumes) need to be explored

Conclusions (Methods)

- The model can be used to understand the physical feasibility of fundamental changes in the food system
- The presented approach provides a complementary perspective to product-related LCAs, particularly if fundamental long-term decisions have to be drawn
- A more general functional unit enables to take into account also aspects of the sufficiency strategy
- Regionalisation and product specificity: Improvement of data quality for some countries
- Consideration of other impacts such as animal welfare, economics
- Optimization scenarios can be calculated
- Can be linked to a PE or CGE model
- Further projects: conversion to organic agriculture, land use in Alpine regions, food waste mitigation

30 - 50 % of foods not directly eaten: post harvest losses, processing & householder losses, fed to ruminants for milk and meat, agro-diesel.

Costs of lost production	1.0 trillion US$
Environmental costs	0.7 trillion US$
Social costs	0.9 trillion US$
Total:	**1.6 trillion US$ p.a.**

3-4 % of the global GDP

http://www.fao.org/3/a-i3991e.pdf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Further infos:
http://www.fibl.org/en/themes/sustainability-assessment.html