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DIPARTIMENTO DI SCIENZE AGRARIE E AMBIENTALI - PRODUZIONE, TERRITORIO, AGROENERGIA

Milan, June 18th, 2020

Agriculture, Environment and Bioenergy PhD Course

Virtual workshop on Microsoft Teams: «Sustainability in animal production»

Sustainable livestock systems in developing countries

G. Matteo Crovetto

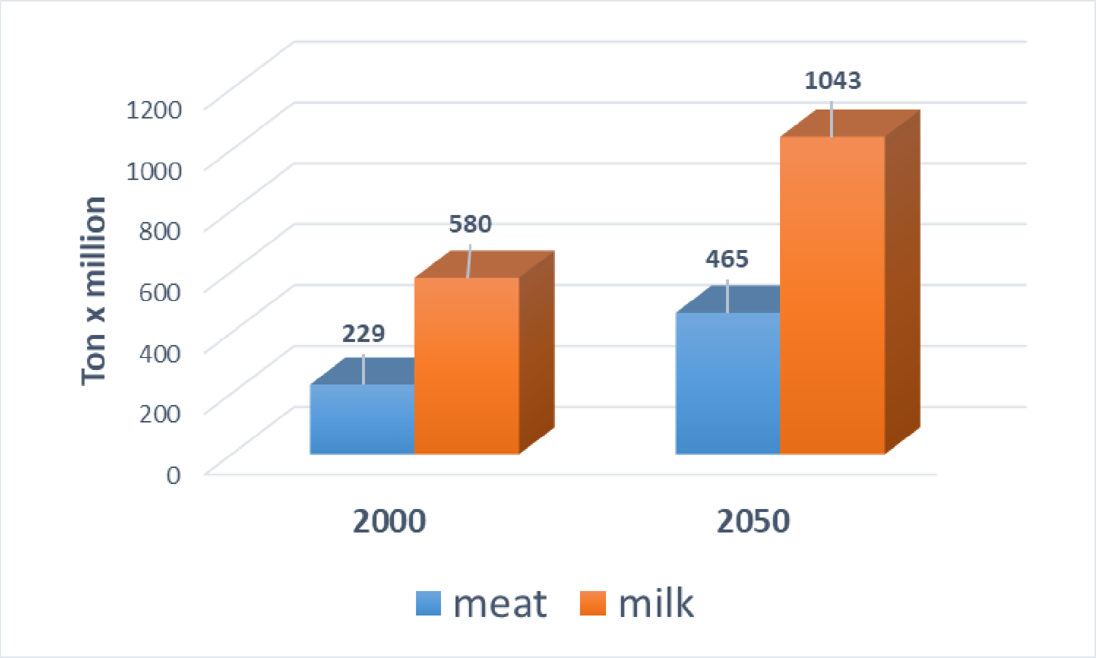
Why sustainability?

Farming has always been environmentally sustainable. However, nowadays…

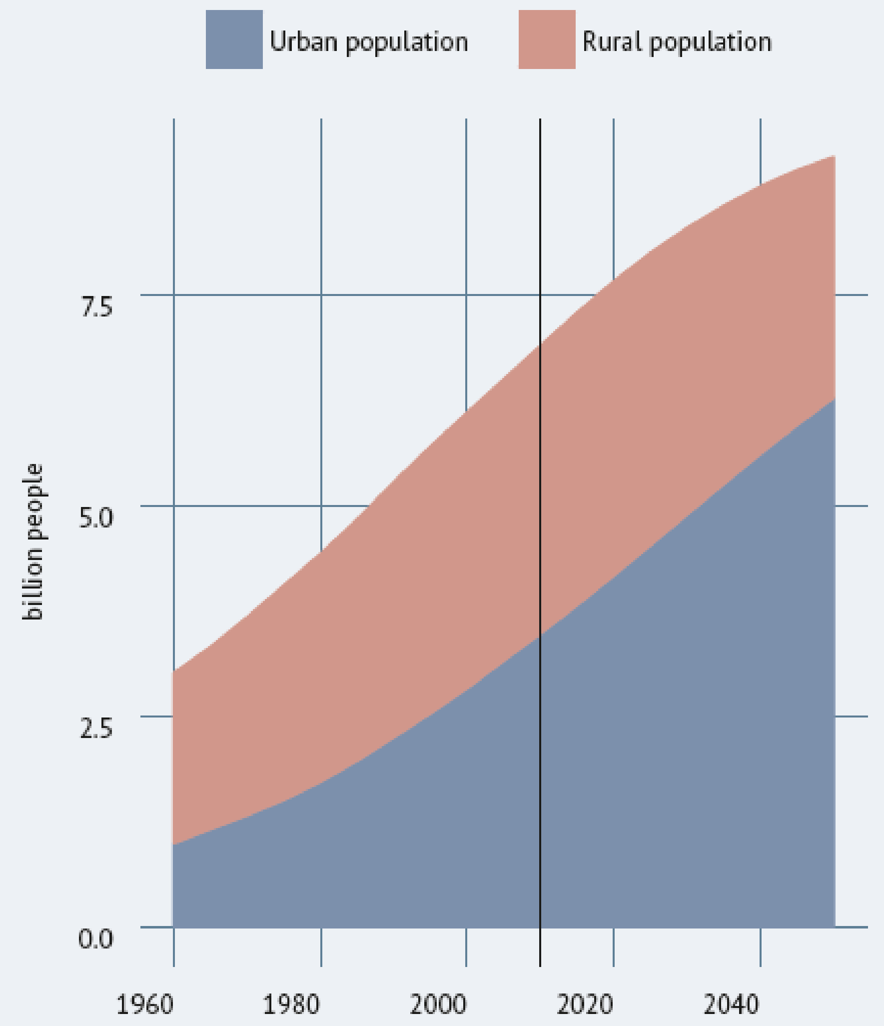
- World population growth(from 3.5 a 9.5 billion people from 1960 to 2050)
- Urbanism (people living in towns: in 1960 30%, in 2050 70%)
- Human activities (industry, transport, heating, fossil fuel plants, agriculture) are changing the world and challenging Nature resilience.

Higher and higher demand for food of animal origin in the world (+100% in 2050)

Environmental impact per unit of product must halve to avoid increasing today's risks



World rural and urban population (1960-2050) (FAO, 2013)



Source: United Nations Population Division.
Data after 2011 are projections.

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Mission of agriculture and livestock systems

1° Supply food.

2° Preserve the environment.

For thousands of years man has been cultivating fields and rearing animals for food.

Livestock systems transform vegetable protein and fibre into animal protein of high nutritional value.

Animal kingdom: no fibre → food of very high digestibility.

Food of animal origin: high nutritive value.

Assets of food of animal origin

Meat, fish, eggs, milk and cheese supply man with essential nutrients hard to get from only vegetable-based diets. Among these:

- essential amino acids (lysine, methionine, threonine, tryptophan, leucine, isoleucine, phenylalanine, histidine and valine)
- essential fatty acids (e.g. ω_3 and CLA)
- minerals (e.g. Ca, P, Mg) and vitamins (e.g. B_{12})

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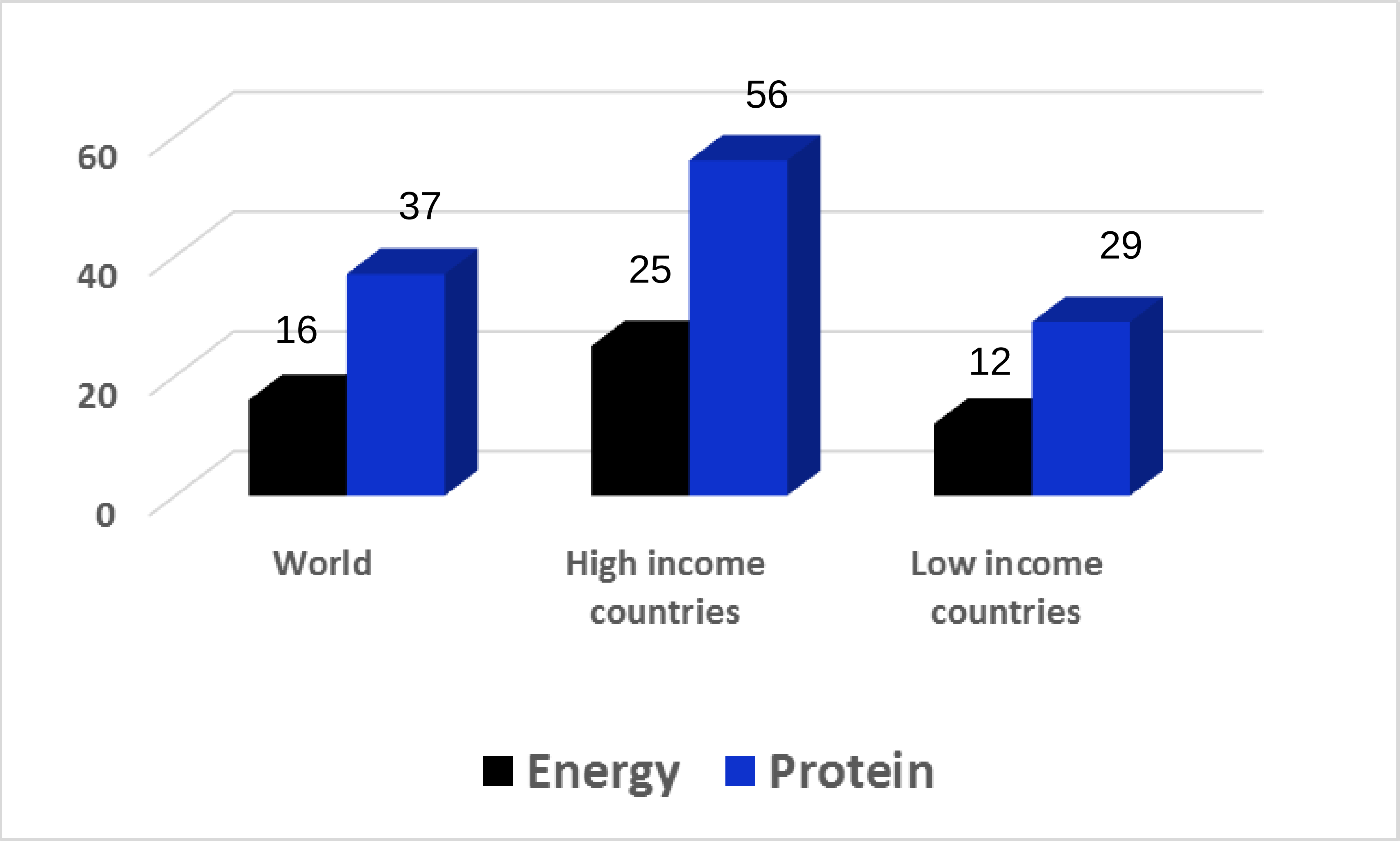
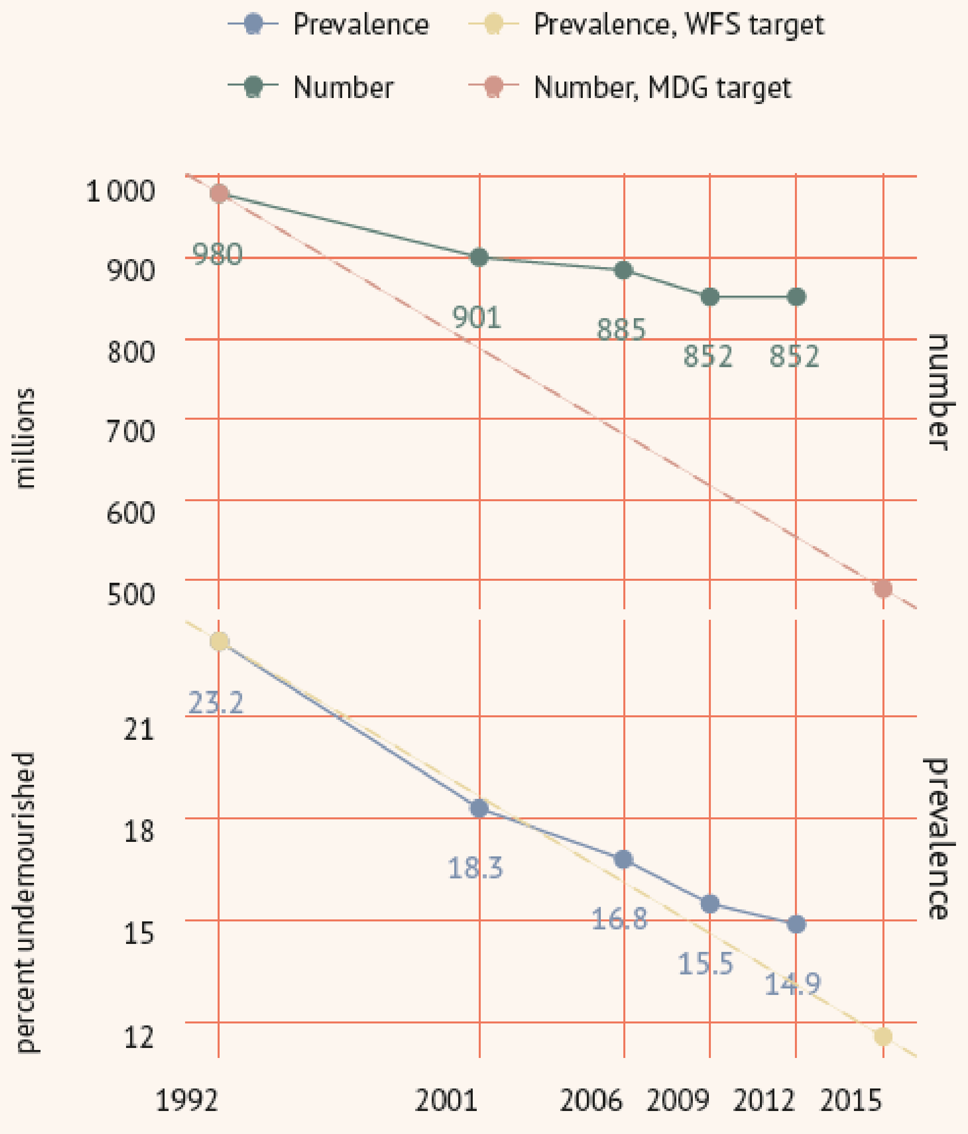
Contribute (%) of food of animal origin to human diet



Population, population growth, and child malnutrition in the world and in its different income shares (from The World Bank, 2014)

	WORLD	WORLD INCOME SHARES			
		LOW	LOWER MIDDLE	UPPER MIDDLE	HIGH
Population (millions)	7,043.9	846.5	2507.0	2390.6	1299.8
Population growth (%)	1.1	2.3	1.5	0.8	0.3
Under-five mortality rate (per 1,000 live births), 1990 - 2012	90 - 48	166 - 82	118 - 61	54 - 20	15 - 6
Child malnutrition, underweight (% of under age 5) 1990 - 2012	24.9 - 15.1	39.9 - 21.8	38.7 - 24.1	12.6 - 2.8	1.4 - 1.4

Undernourishment in the world (1992-2012) (FAO, 2013)



Source: FAO, Statistics Division.

WFS: World Food Summit

MDG: Millennium Development Goals

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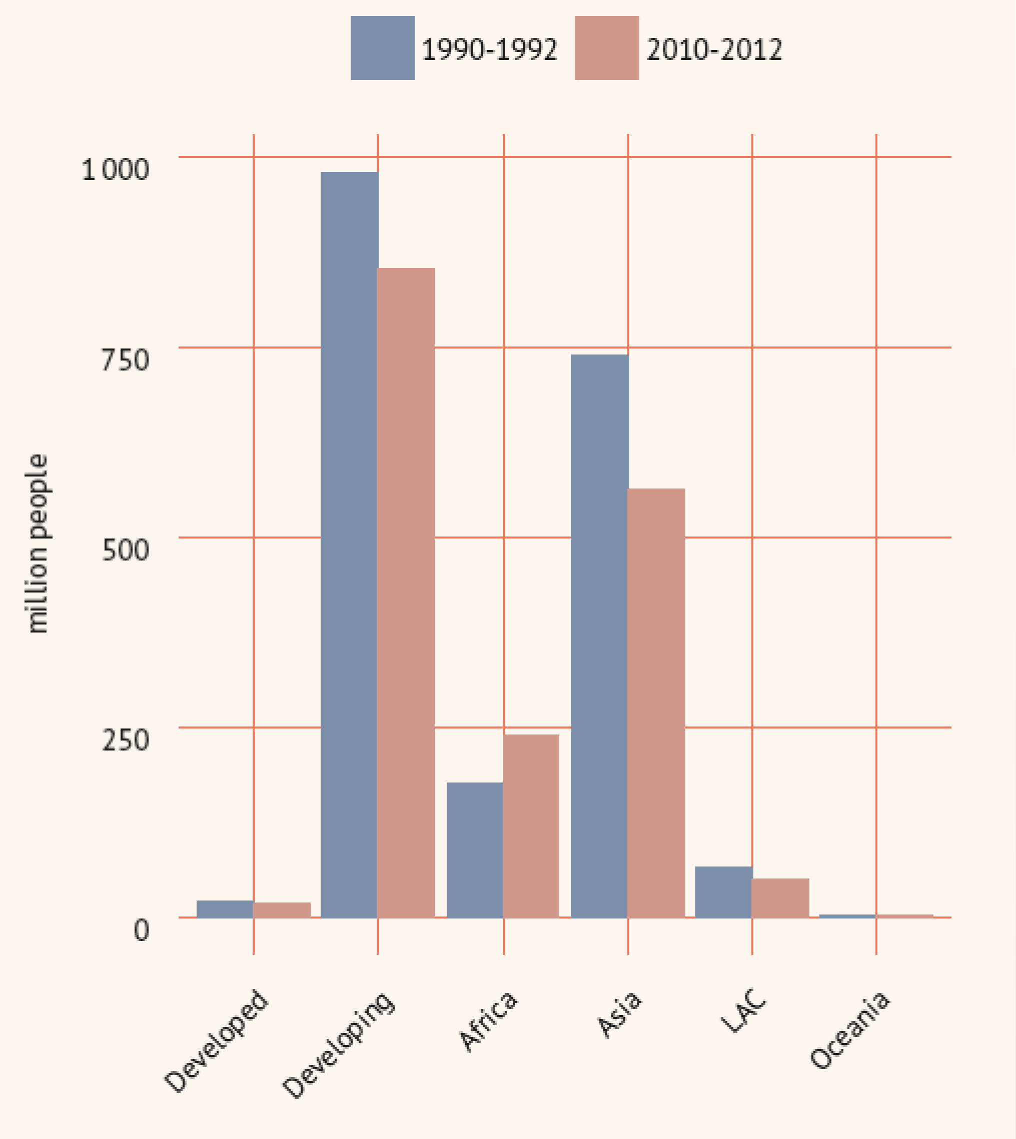
Number of people undernourished (1990-1992 and 2010-2012)
(FAO, 2013)



Source: FAO, Statistics Division.

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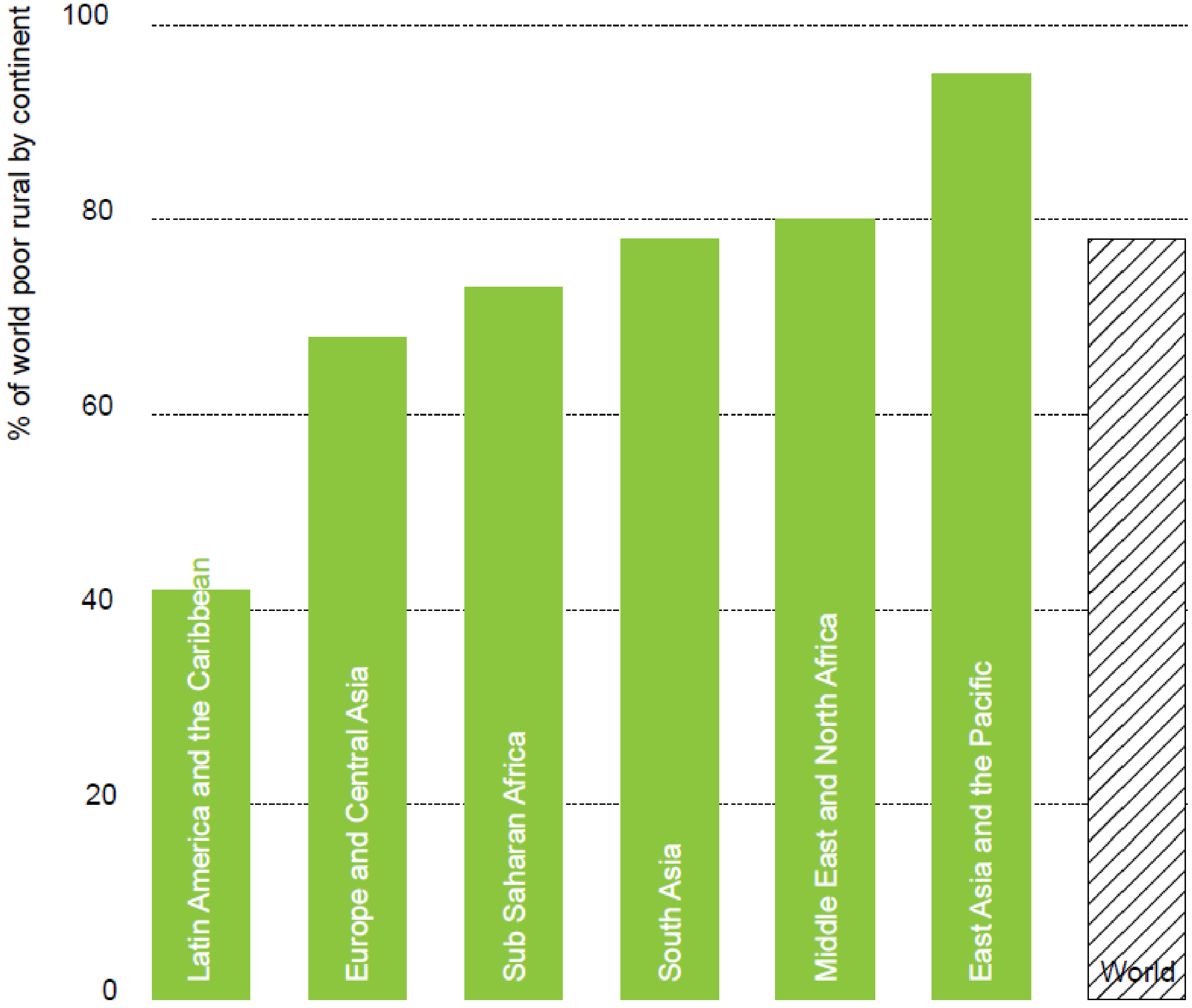
Figure 5: Seventy-five per cent of the world's poor people live in rural areas



Source: based on presentation by Alain de Janvry at the 2050 FAO High-Level Forum, October 2009

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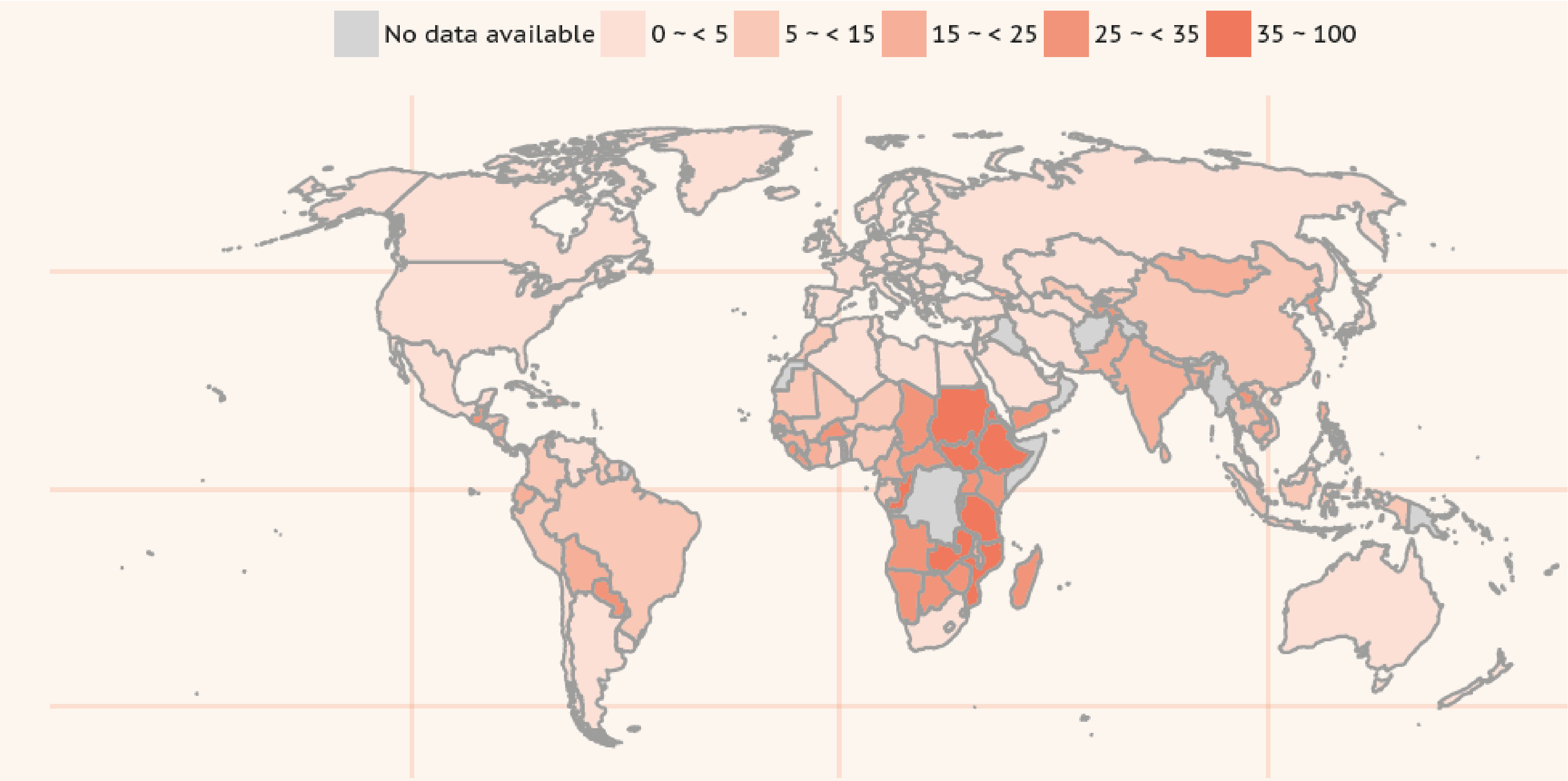
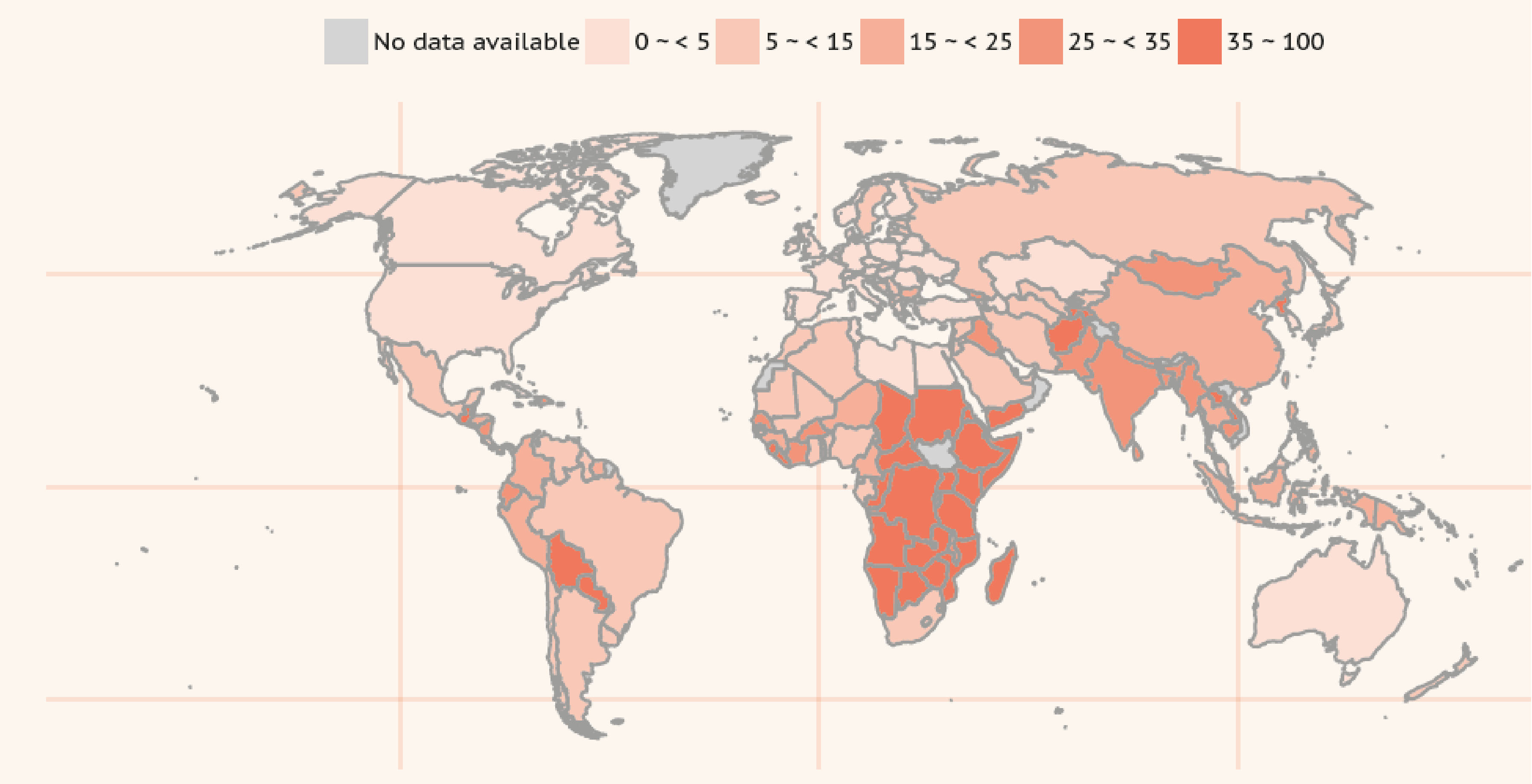
Map of hunger (% prevalence of undernourishment, 2012)

(FAO 2013)



Source: FAO, Statistics Division.

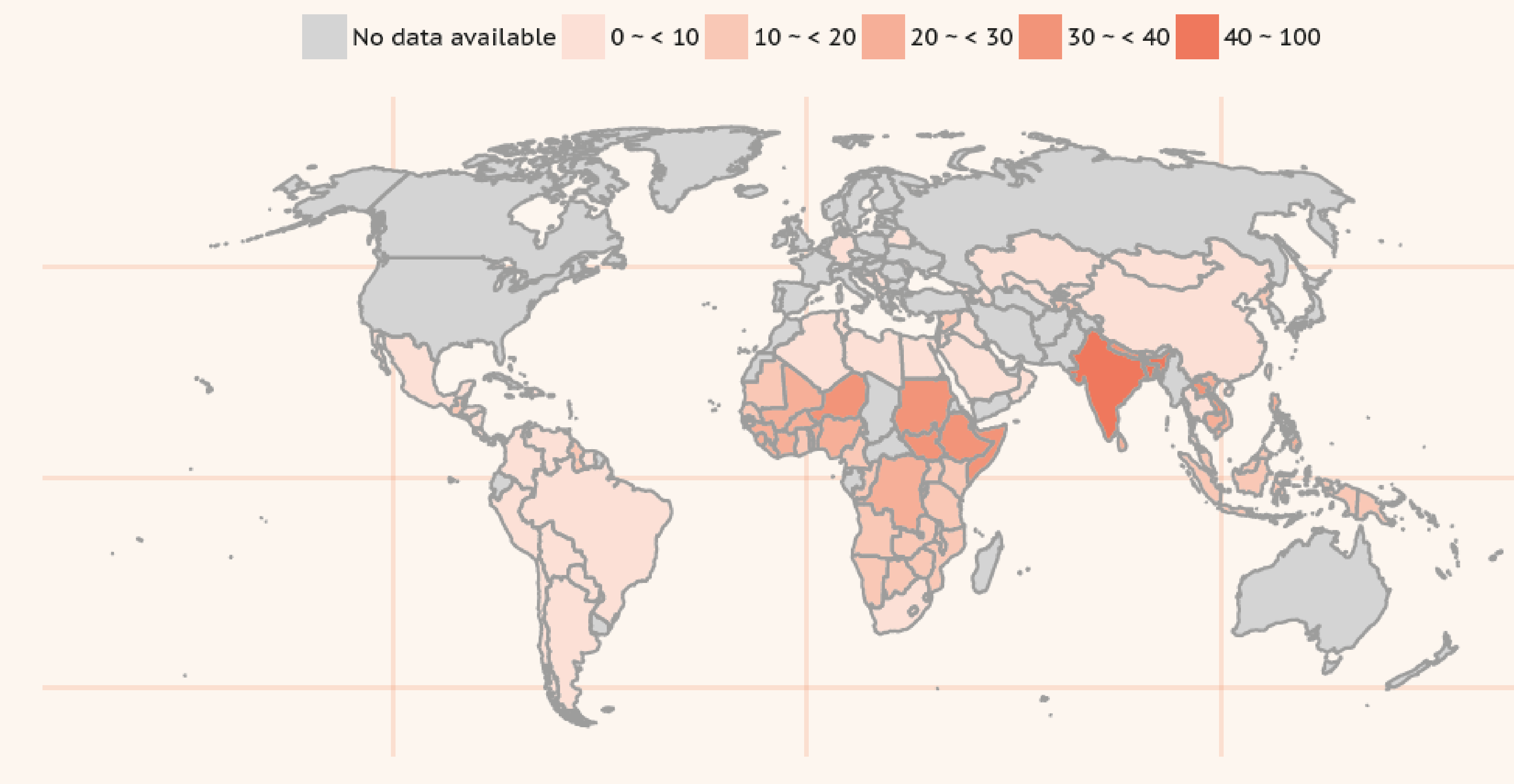
Prevalence of food inadequacy (%, 2012) (FAO 2013)



Source: FAO, Statistics Division.

Children under 5 years of age who are underweight (%, 2005-2011)

(FAO 2013)



Source: FAO, Statistics Division.

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Which type of crop and animal production systems?

Basically 3 main systems:

- ❑ **Extensive** (normally small-scale, family farming)
- ❑ **Semi-intensive** (medium scale, group farming)
- ❑ **Intensive** (large-scale, industrial farming)

Extensive systems rely on pasture (for ruminants) and scavenging and kitchen waste for monogastrics. Crop by-products can be fed both to ruminants and monogastrics.

Intensive systems have high stocking rates and supply feeds heavily or totally ➡ risk for the environment.

Strengths and weaknesses of animal production systems

Extensive systems: very low costs and normally low levels of production. About 2 billion people rely on these systems for their food supply.

Intensive systems: high inputs and costs, and high production levels. The majority of the world population depends on these food supply systems. However: risk of negative environmental impact.

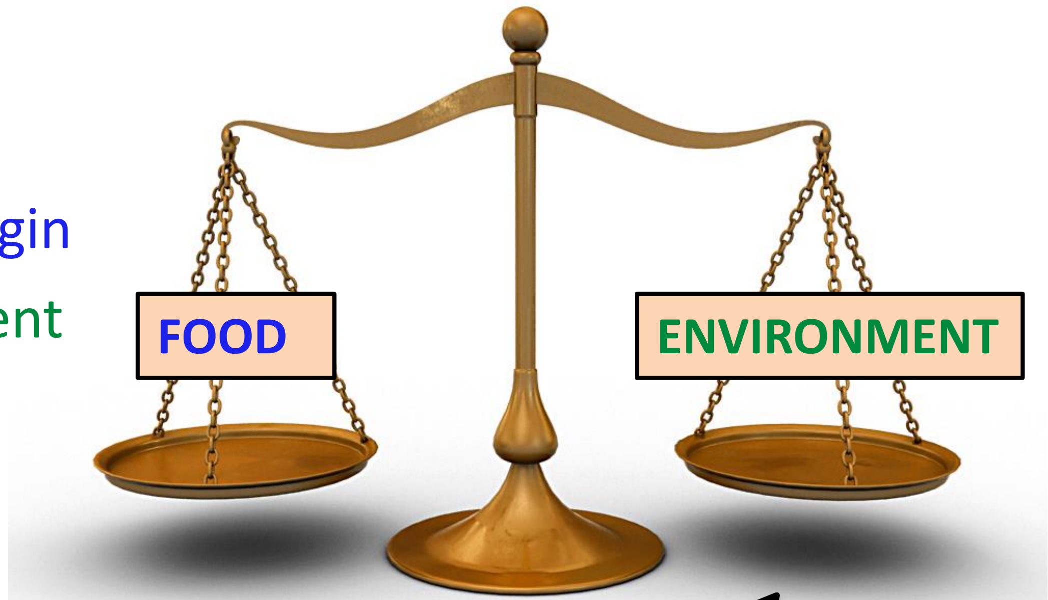
Efficiency must be improved in both systems to attain economic and environmental sustainability.

Environmental impact should be assessed per kg product (meat, milk, eggs, fish) more than in absolute values.

Food supply and environment protection

A balance must be found between the two needs:

- Supply enough food of vegetable and animal origin
- Safeguard the environment



Extensive and small-scale farms are important both environmentally and socially, but they are more and more insufficient for food supply worldwide.

Soil and water:
limited and diminishing resources

Animal production, nitrates, ammonia, and N_2O

Organic nitrogen excreted by livestock is partly (28-30%) released into atmosphere as **ammonia** or incorporated into the soil where it undergoes several reactions among which **urea** is nitrified to **nitrate** (NO_3), one of the main N sources for plants. Nitrates, if not absorbed by plant roots, can pollute ground water (>50 mg/litre).

Atmospheric ammonia contributes to acid rains and to the formation of particulate matter (PM_{10} and $PM_{2.5}$).

A little part of N from slurries can also be broken down to **Nitrous oxide** (N_2O) which is emitted into the atmosphere where it acts as a powerful and persistent GHG (1 N_2O = 300 CO_2, and after 100 years it is still there!).

Productivity and emission intensity

In the period 1960-2000 emissions intensities have decreased by

38% for **milk** **45%** for **pig meat** **57%** for **eggs** **76%** for **chicken**

This means that

- A large potential to mitigate emissions exists in low-yield animal production systems.
- Improved productivity at the animal and herd level can lead to a reduction of emission intensities while at the same time increasing milk or meat output.

Since the 50s feedstuffs, together with genetics, buildings, management, hygiene and health made it possible an extraordinary boost in animal productions. **Concentrate feeds and feedstuffs must be seen as allies, not enemies, of the environment.**

Table 1: Mean farm sizes worldwide: predominance of small-scale farmers

Region	Mean size (ha)	% < 2 ha
Central America	10.7	63
East Asia	1	79
Europe	32.3	30
South America	111.7	36
South Asia	1.4	78
South-east Asia	1.8	57
Sub-Saharan Africa	2.4	69
United States	178.4	4
West Asia & North Africa	4.9	65

Source: based on World Bank 2010

Table 2: Small-scale versus large-scale agriculture

Objective	Detailed info	Small scale agriculture	Large scale agriculture
Production efficiency	Land and Capital productivity	+	−
	Labour productivity	−	+
Marketing efficiency	Economies of scale	−	+
Use of technology	*e.g. fertilisers, agrochemicals, irrigations*	−	+
Access to Markets and information		−	+
Poverty reduction	Employment provider	+	⊘
	Food Price reduction		+
	Gender impact	+	−
Access to modern risk management tools	e.g. insurance, and finance to cope with weather and price risks	−	+
Maintain biodiversity		+	−
Environmental cost	*e.g. water contamination, soil degradation*	⊘	+
GHG emissions Reduction		+	−
Resilience to climate change		+	−

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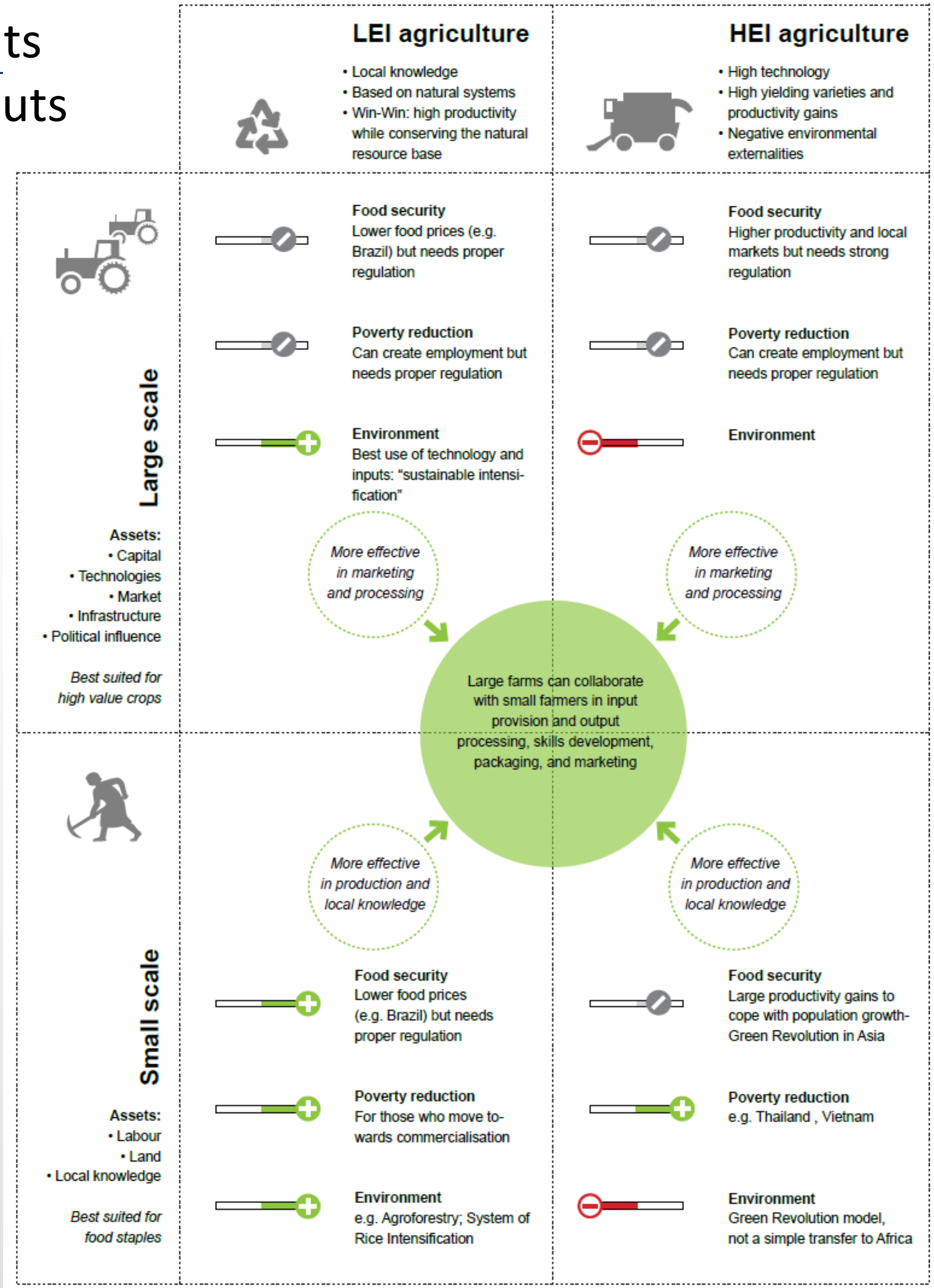
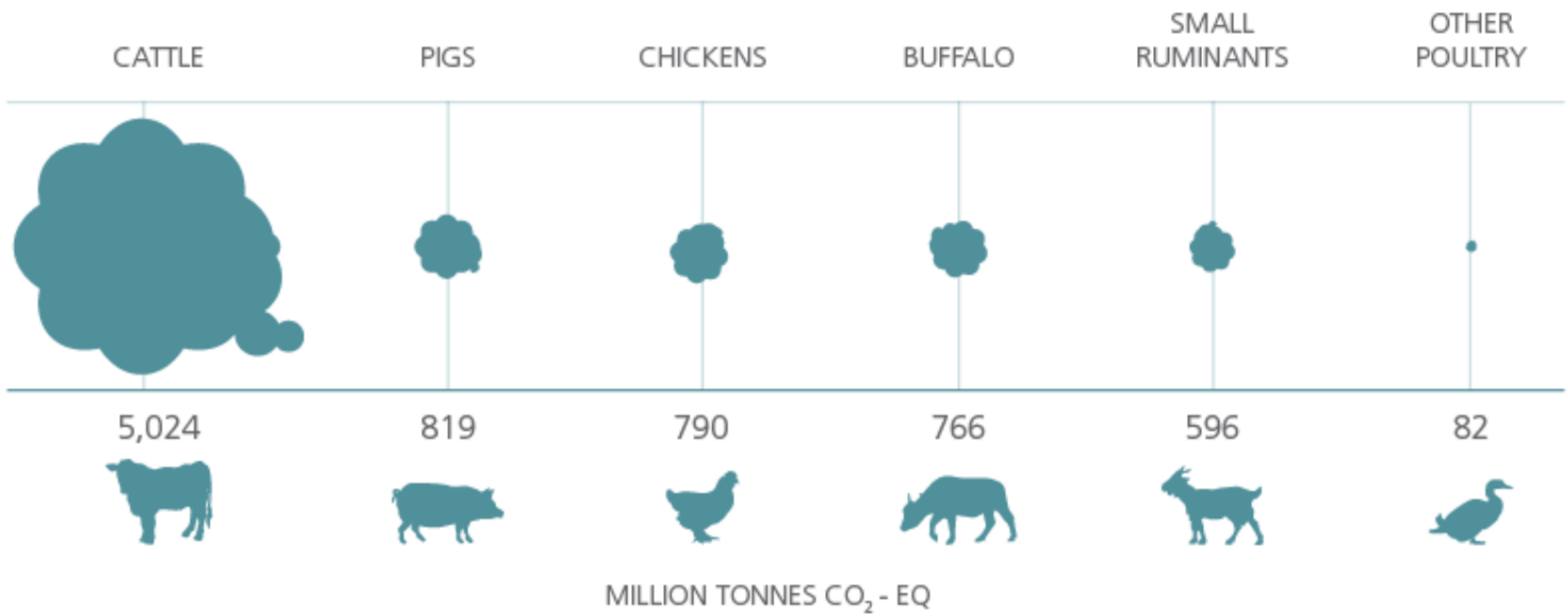
Figure 10: Who will feed the world?

LEI=low external inputs

HEI=high external inputs



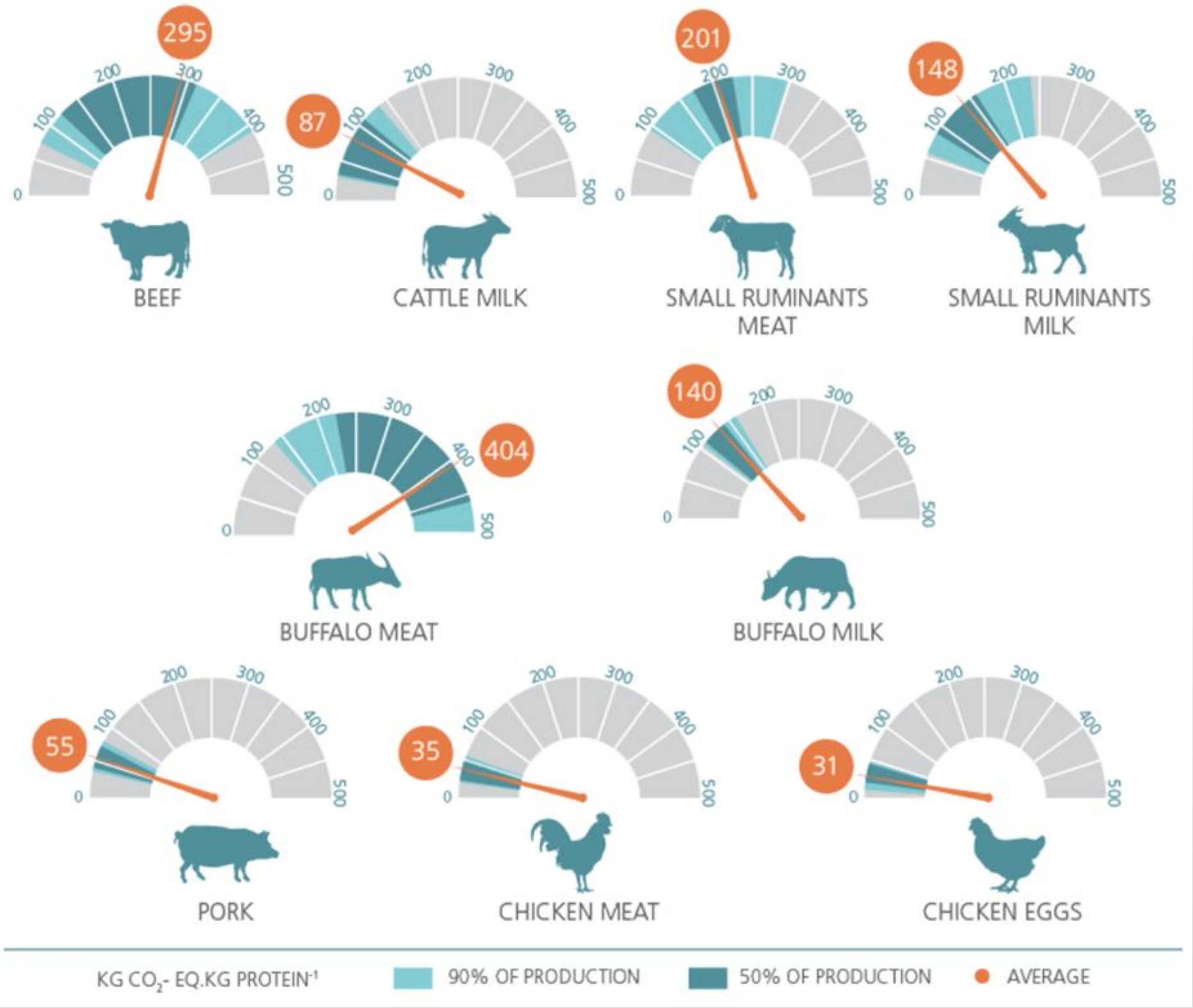
Global estimates of emissions by species (GLEAM 2.0, 2010)



Global Livestock Environmental Assessment Model (GLEAM)

GLEAM is a GIS framework that simulates the bio-physical processes and activities along livestock supply chains under a life cycle assessment approach. The aim of GLEAM is to quantify production and use of natural resources in the livestock sector and to identify environmental impacts of livestock in order to contribute to the assessment of adaptation and mitigation scenarios to move towards a more sustainable livestock sector.

Global emission intensities by commodity expressed as kg CO_2-eq/kg protein (GLEAM 2.0, 2010)



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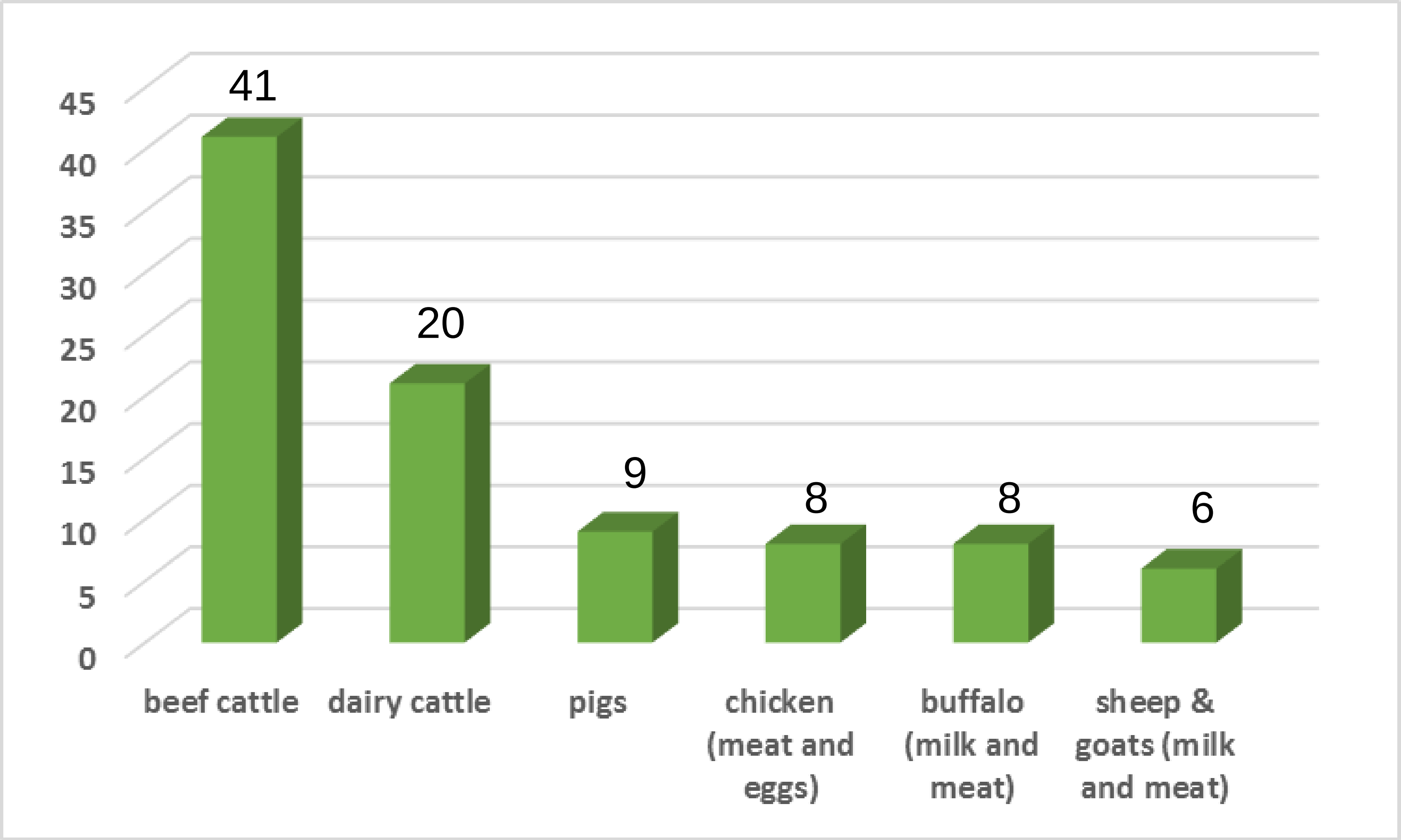
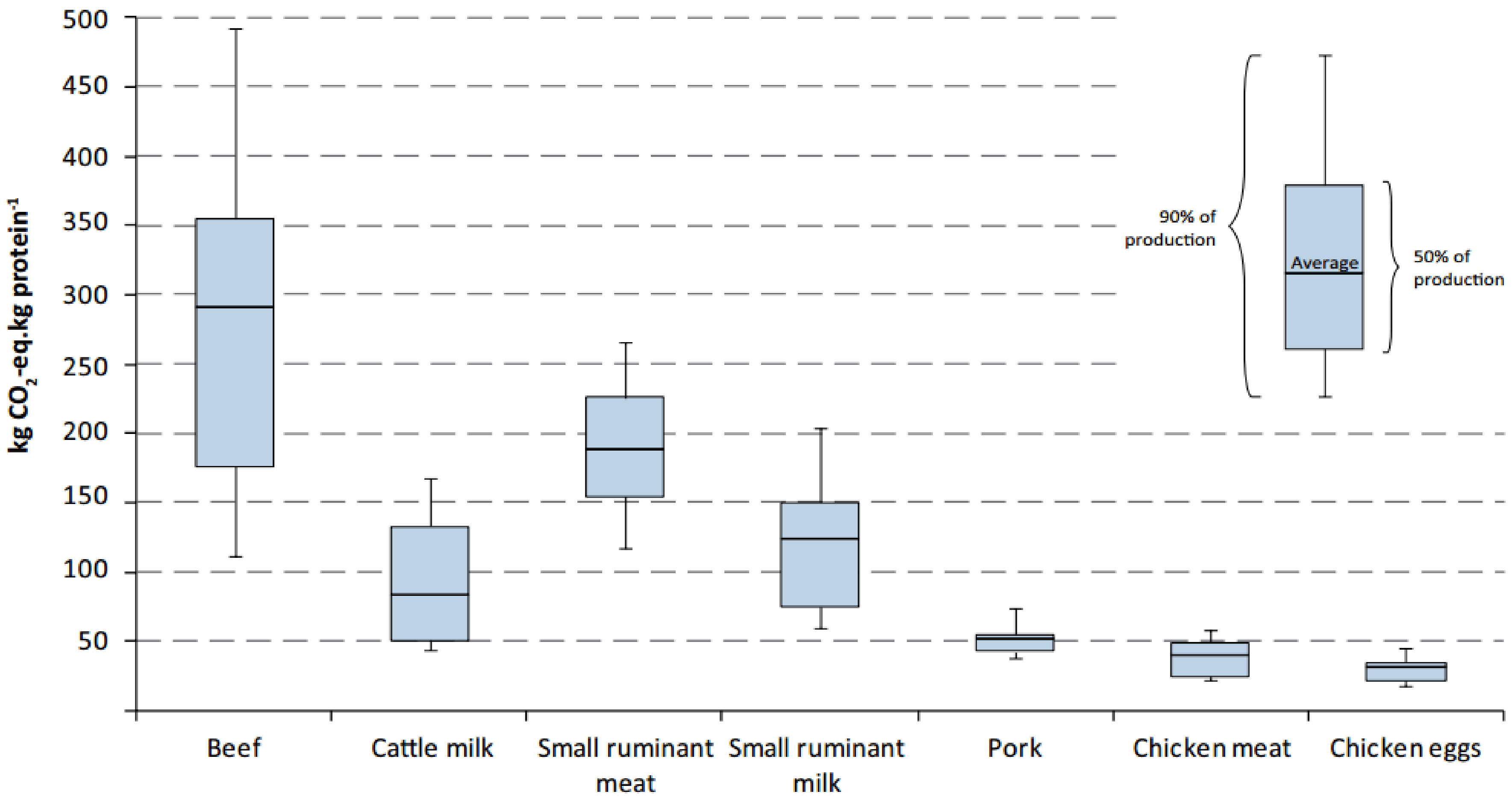
Contribute (%) of different species to global CO_2 equivalents emissions from livestock (FAO 2013)

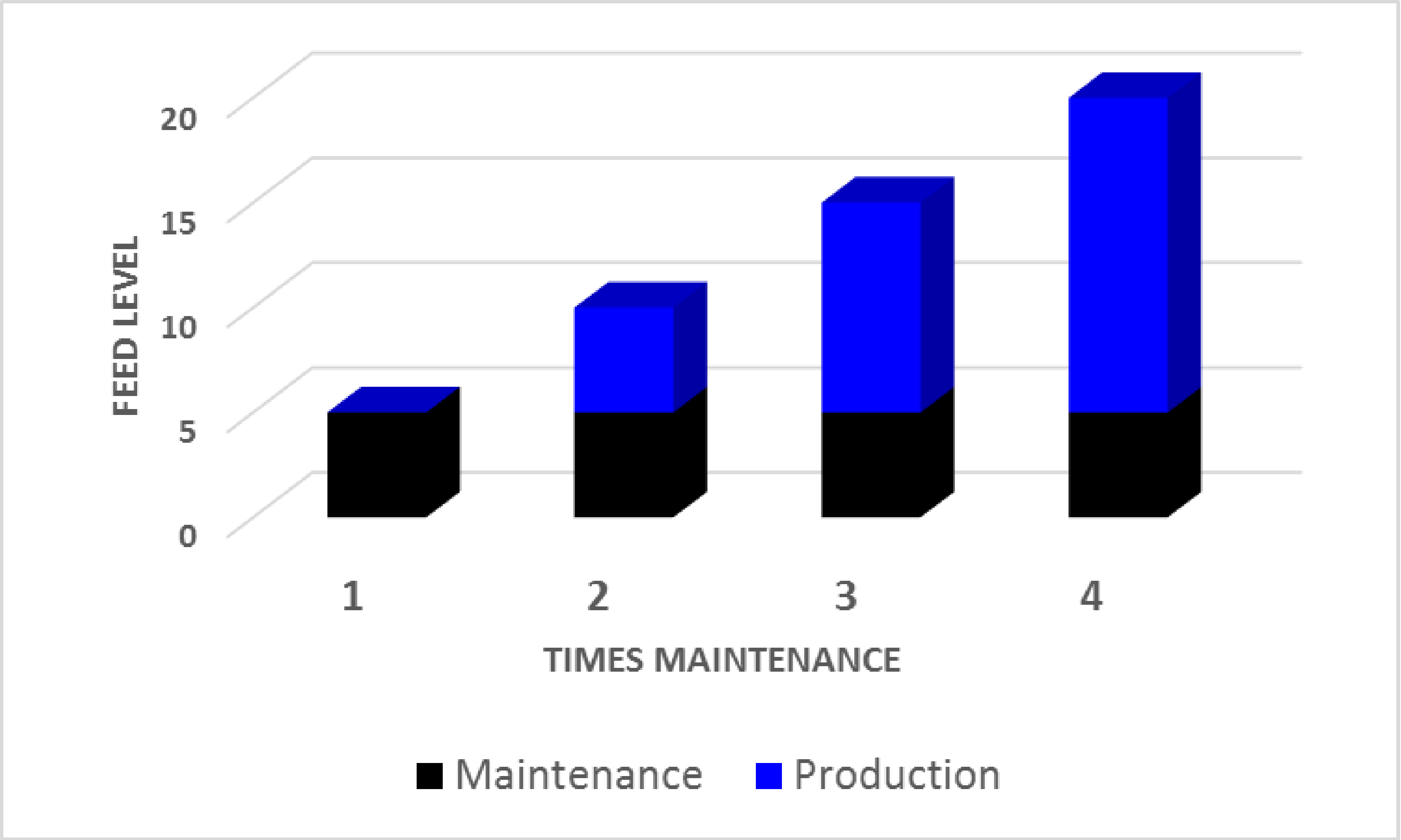


Global emission of CO_2 equivalents per kg of protein from different sources (FAO 2013)

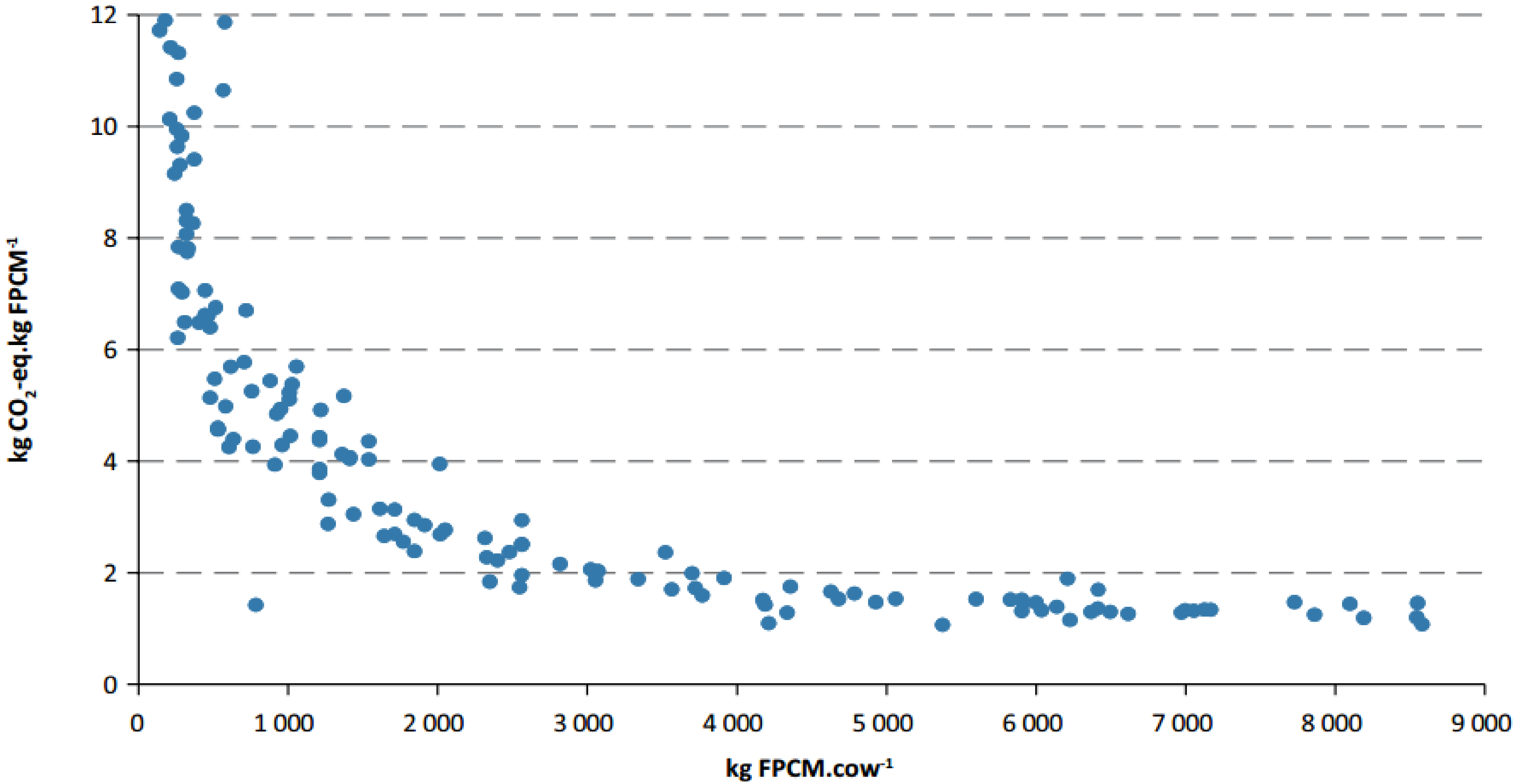


From poultry and pigs less GHG/kg protein than from ruminants

Maintenance, a fixed cost to be amortized



Milk productivity and emission intensity (FAO 2013)



Source: Gerber *et al.*, 2011.

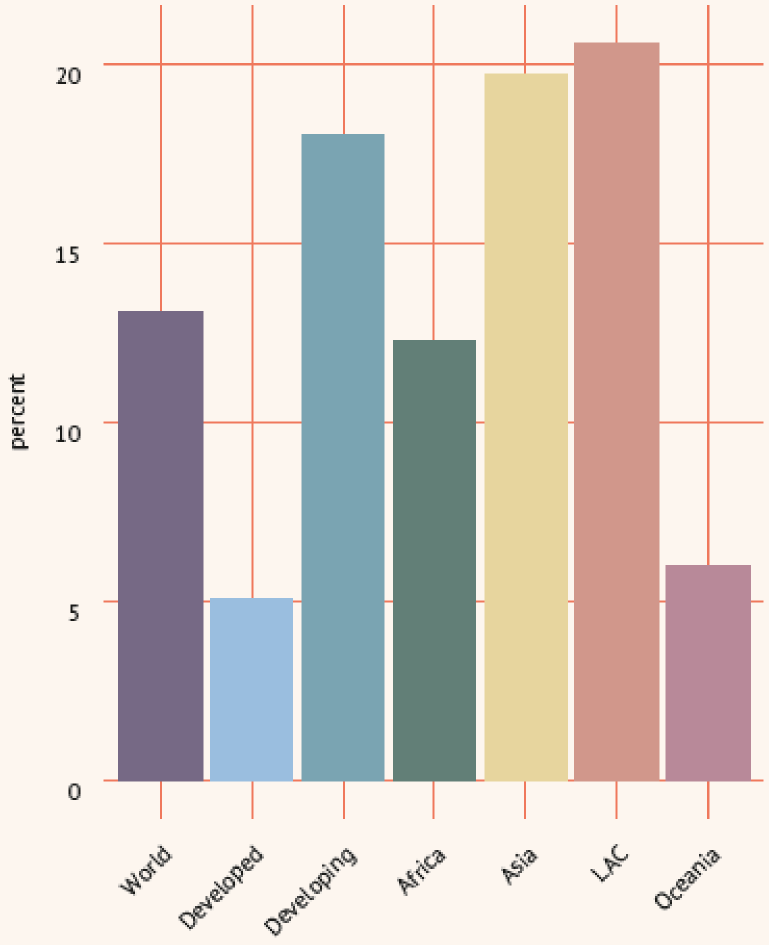
Enteric methane emissions per animal and milk yield

FAO and GDP. 2018. Climate change and the global dairy cattle sector – The role of the dairy sector in a low-carbon future.

Region	kg of CH_4 per animal per year		Average milk yield (kg per animal/year)		g CH_4/kg milk (2015)
	2005	2015	2005	2015	
North America	111.0	116.6	8,899	9,867	12
Russian Federation	64.2	71.8	3,000	4,146	17
Western Europe	76.3	80.9	6,287	6,957	12
Eastern Europe	71.2	81.7	3,921	5,005	16
West Asia & Northern Africa	68.2	72.8	1,240	1,830	40
East Asia	69.5	69.1	2,915	2,907	24
Oceania	72.3	81.4	4,274	4,659	18
South Asia	60.8	62.1	979	1,388	45
Central & South America	82.2	84.6	1,668	1,947	44
Sub-Saharan Africa	46.1	46.4	464	457	102

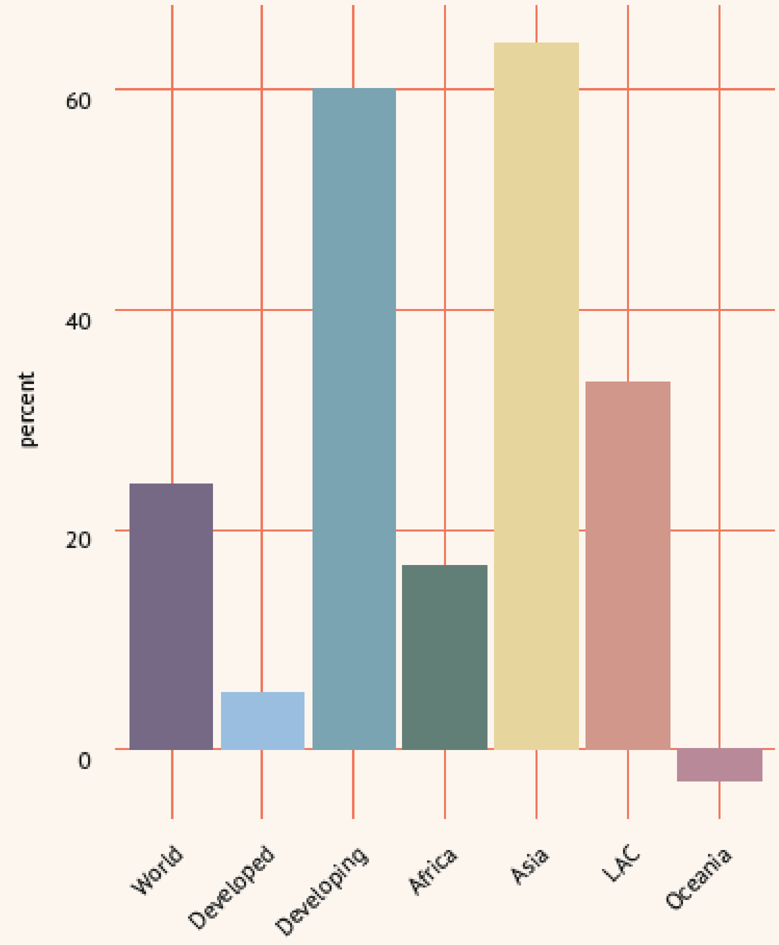
Available protein and animal protein supply in the period 1990-2009 (FAO, 2013)

CHART 32: **Relative change in average protein supply (between 1990-1992 and 2007-2009)**



Source: FAO, Statistics Division.

CHART 33: **Relative change in average protein supply from animal origin (between 1990-1992 and 2007-2009)**



Source: FAO, Statistics Division.

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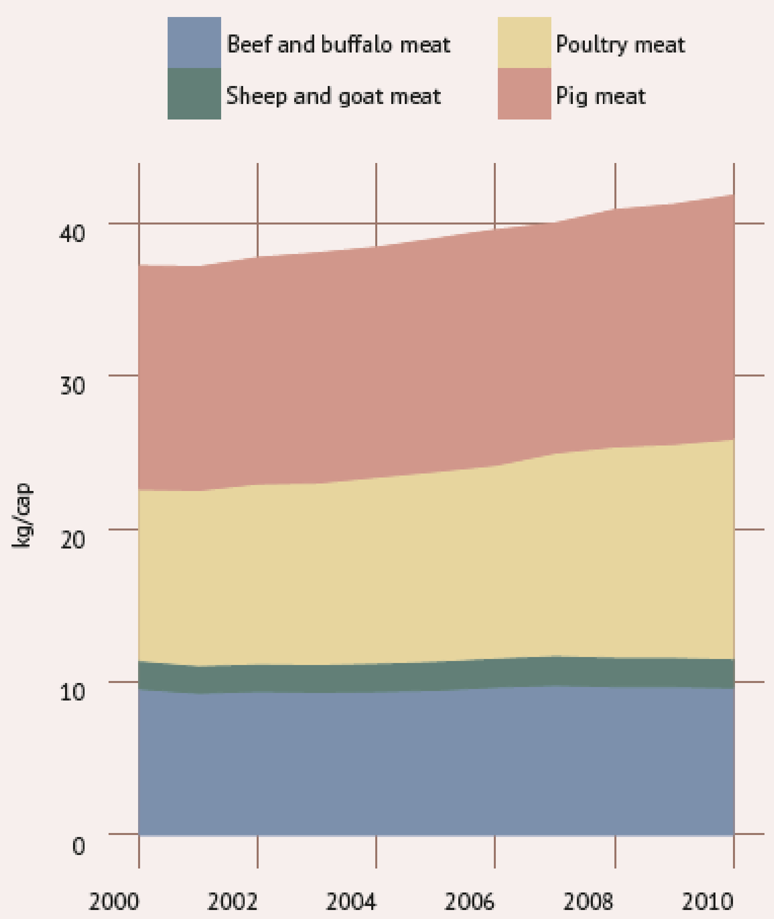
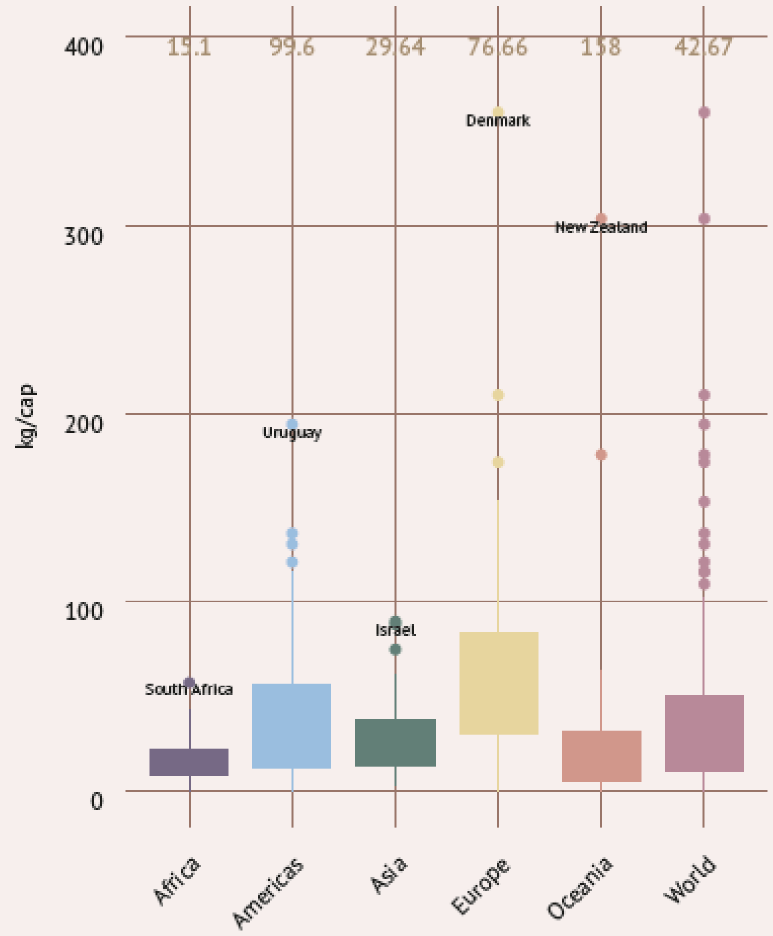
Per capita meat production in the world (2000-2010) and in the different continents (2010) (FAO, 2013)

CHART 71: **Per capita meat production (2000-2010)**



Source: FAO, Statistics Division (FAOSTAT).

CHART 72: **Per capita meat production (2010)**



Source: FAO, Statistics Division (FAOSTAT).

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GLOBAL LIVESTOCK PRODUCTION AVERAGE BY PRODUCTION SYSTEM 2001 TO 2003

	LIVESTOCK PRODUCTION SYSTEM				
	GRAZING	RAINFED MIXED	IRRIGATED MIXED	LANDLESS/ INDUSTRIAL	TOTAL
			(Million head)		
POPULATION					
Cattle and buffaloes	406	641	450	29	1 526
Sheep and goats	590	632	546	9	1,777
			(Million tonnes)		
PRODUCTION					
Beef	14.6	29.3	12.9	3.9	60.7
Mutton	3.8	4.0	4.0	0.1	11.9
Pork	0.8	12.5	29.1	52.8	95.2
Poultry meat	1.2	8.0	11.7	52.8	73.7
Milk	71.5	319.2	203.7	-	594.4
Eggs	0.5	5.6	17.1	35.7	58.9

Source: Steinfeld *et al.*, 2006

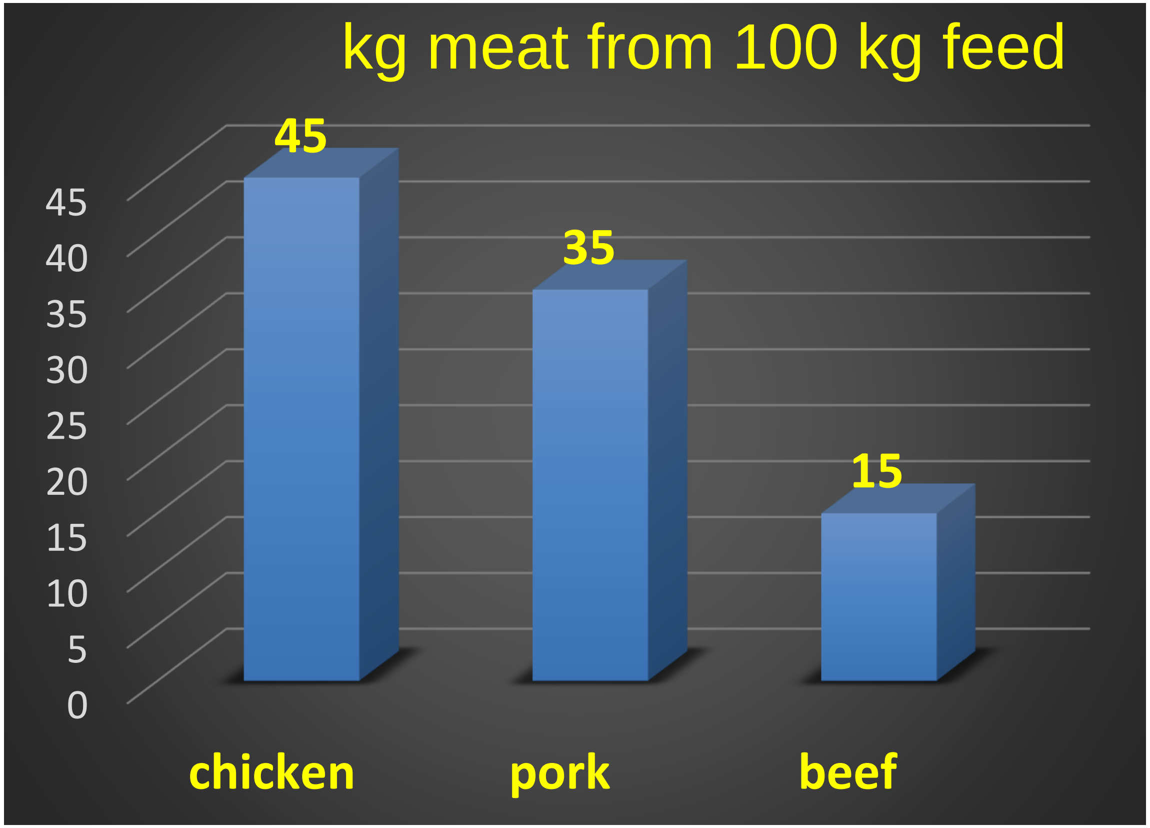
Which are the most efficient animals?

For fibre: ruminants (cattle, sheep and goats, buffaloes, camels).

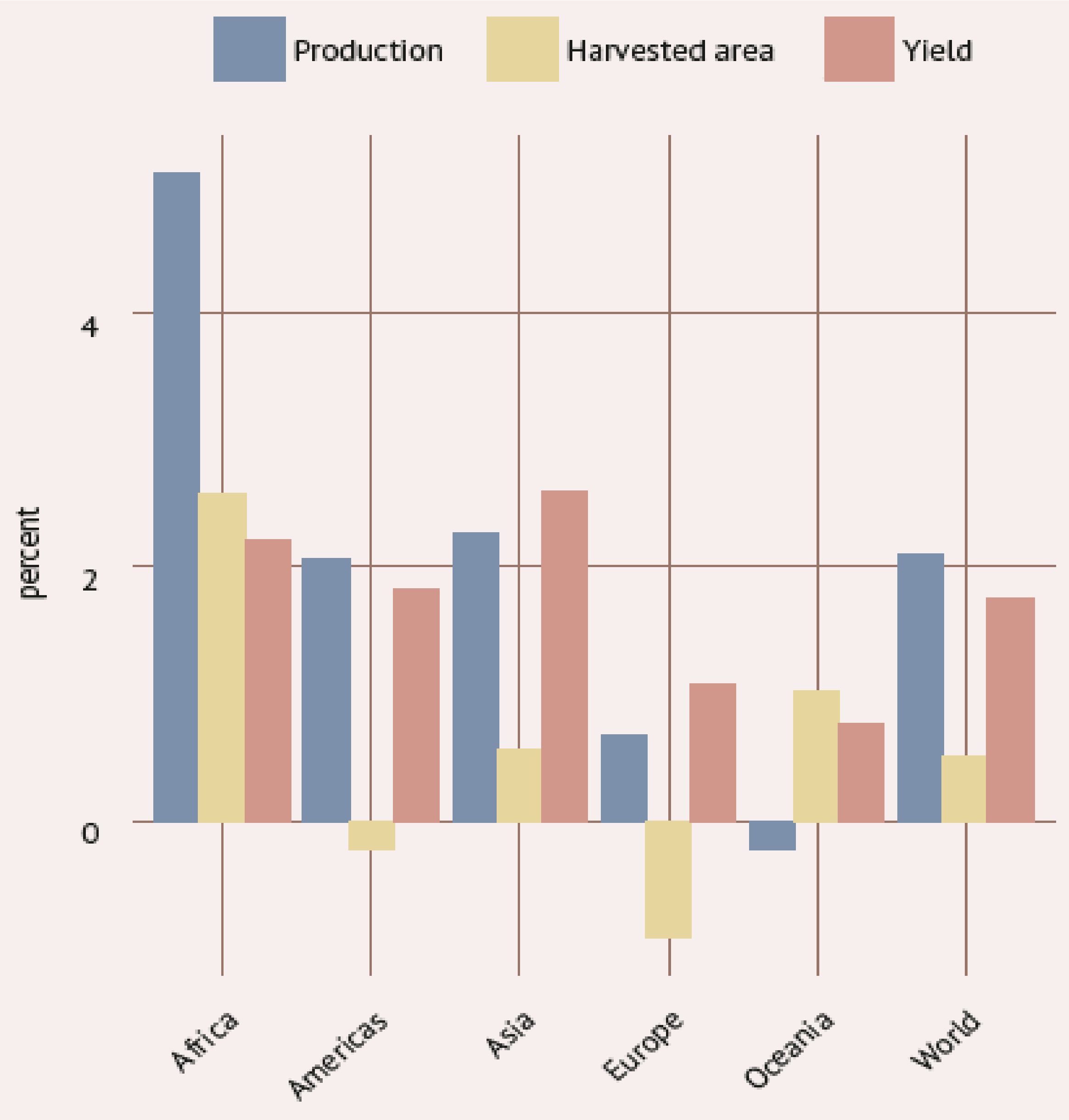
For starchy feeds: monogastrics (pigs and poultry).

100 kg feed (made by 80% cereal grain and 20% protein suppl.) can produce about:

- 45 kg chicken meat
- 35 kg pork
- 15 kg beef



Growth in cereal production in the decade 2000-2010 in the world and in the different continents (FAO, 2013)



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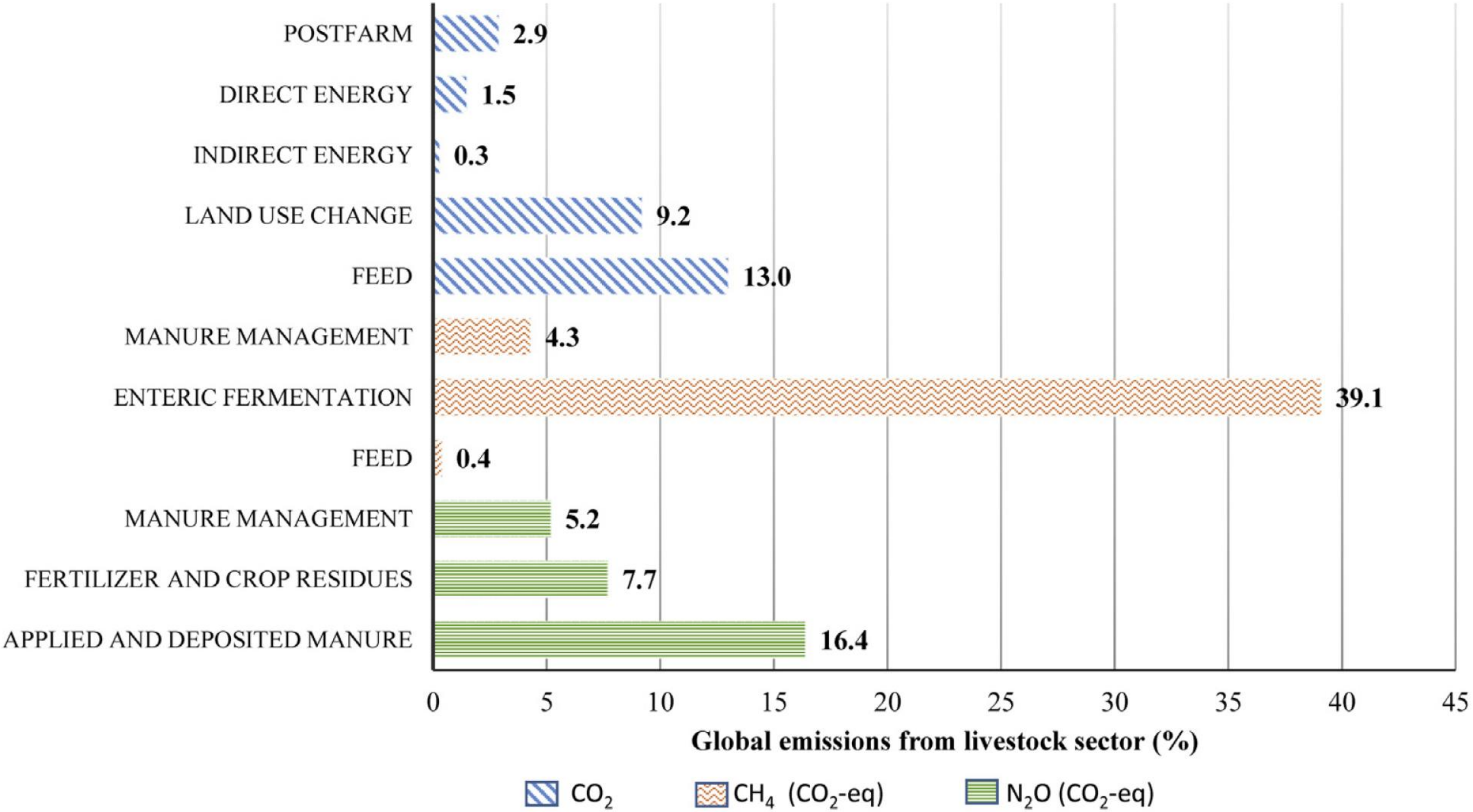
Global GHG emissions from the livestock sector

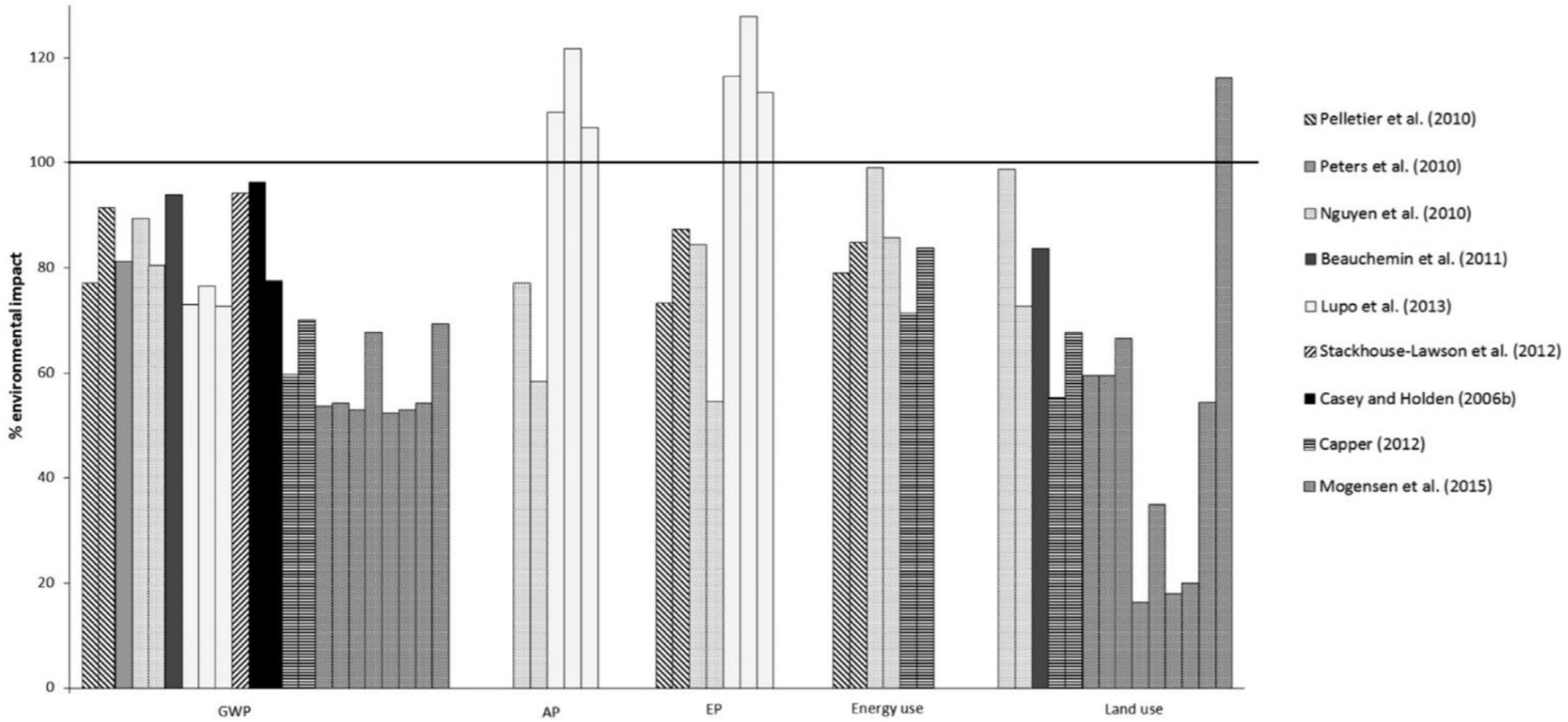
(Rojas-Downing M.M. et al., 2017)



Productivity and emission intensity

- A large potential to mitigate emissions exists in low-yield ruminant production systems.
- Improved productivity at the animal and herd level can lead to a reduction of emission intensities while at the same time increasing milk output.

Environmental impacts (%) per unit of product of concentrate-based relative to roughage-based beef production systems (de Vries et al., 2015)



GWP=global warming potential; AP=acidification potential; EP=eutrophication potential.

Environmental impact of broiler production, expressed per kg of live weight (LW) at fattening farm gate (Cesari et al., 2017)

Impact categories		Broiler production Light 1.6 kg LW	Medium 2.5 kg LW	Heavy 3.8 kg LW
Global warming	kg CO_2-eq	3.03	3.25	3.84
Acidification	g SO_2 eq	14.3	15.8	19.2
Eutrophication	g PO_4^{3-} eq	10.0	10.6	12.8
Terrestrial ecotoxicity	g 1.4-DCB eq	4.80	4.69	5.00
Non-renewable fossil energy	MJ	10.2	10.7	12.4

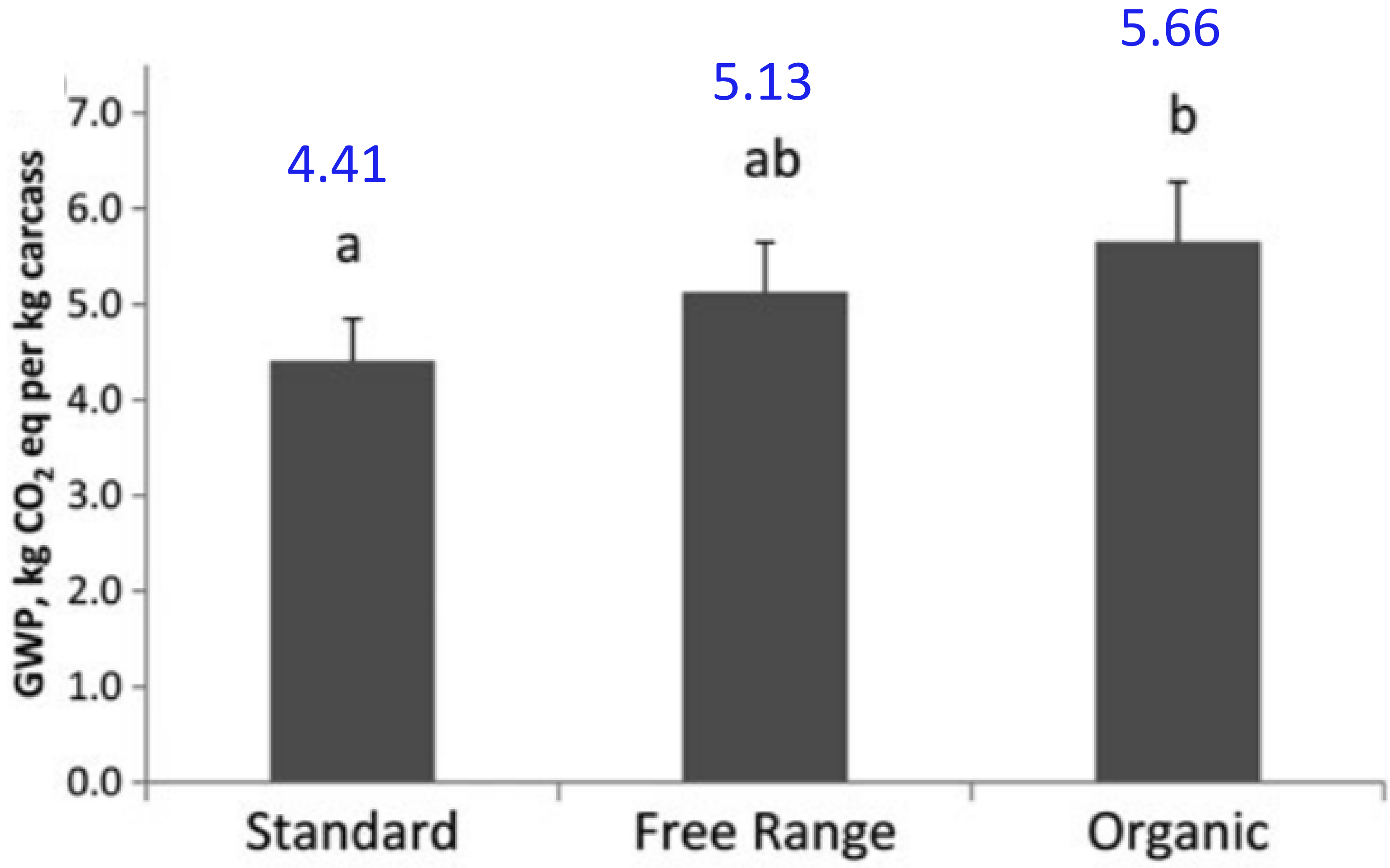
DCB=dichlorobenzene

Light LW at slaughter: 32 days of age (FCR=1.50)

Medium LW at slaughter: 40 days of age (FCR=1.63)

Heavy LW at slaughter: 53 days of age (FCR=1.88)

Global warming potential (GWP) for different broiler production systems (Leinonen and Kyriazakis, 2016)



Daily nitrogen (N) balance of pigs at 152 kg BW

(Galassi et al., 2010)

Diet[a]	C	HF	HFLP
N intake (NI) (g)	54.7[a]	58.2[a]	45.6[b]
N in faeces (g)	7.82[c]	10.82[a]	9.80[ab]
N in faeces (%NI)	14.3[b]	18.6[a]	21.4[a]
N in urine (g)	25.8[a]	23.8[a]	17.8[b]
N in urine (%NI)	47.1	40.8	38.9
N excreted (g)	33.6[a]	34.6[a]	27.6[b]
N excreted (%NI)	61.5	59.4	60.5
N retained (g)	21.1	23.6	18.0
N retained (%NI)	38.6	40.5	39.5

C=control; HF=high fibre; HFLP=high fibre-low protein.

Protein content (g/kg as-fed basis): C 120, HF 122, HFLP 98

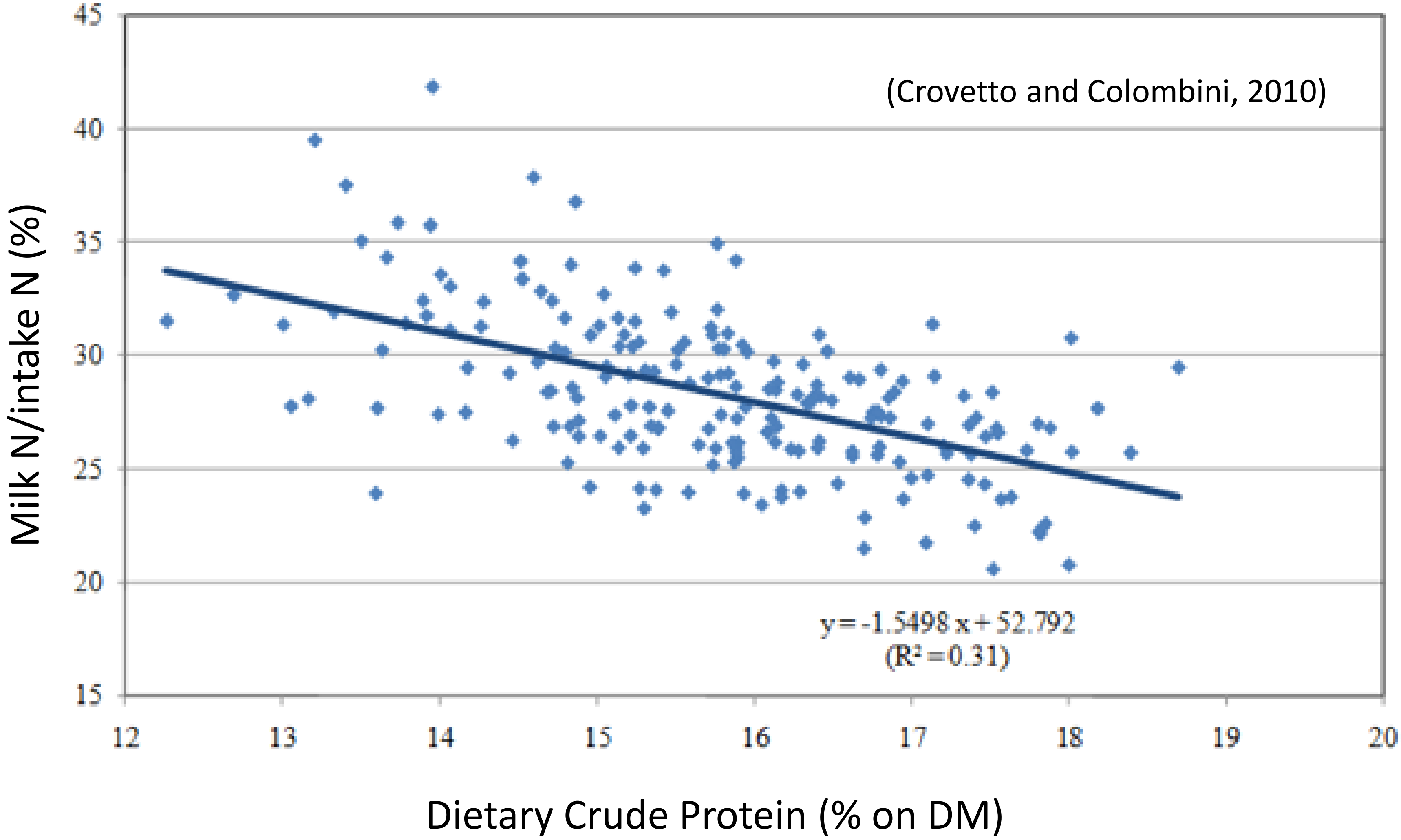
Effects of dietary protein and essential amino acid content on N balance in pigs of 129 kg BW (Galassi et al., 2015)

	Diet				
	CONV	LP1	LP2	SEM	P
NI, g/d	62.8[a]	49.0[b]	45.0[c]	0.31	<0.001
Faecal N					
g/d	9.30	8.89	7.69	0.607	0.269
% NI	15.1	18.2	17.1	1.24	0.139
Urinary N					
g/d	32.6[a]	24.3[b]	21.0[b]	1.93	0.006
% NI	52.0	49.2	46.0	3.58	0.623
Excreted N					
g/d	41.3[a]	33.4[b]	29.0[b]	2.19	0.009
% NI	66.2	67.7	63.7	4.20	0.738
Retained N					
g/d	21.6	15.6	15.8	2.33	0.135
% NI	33.8	32.3	36.3	4.20	0.738

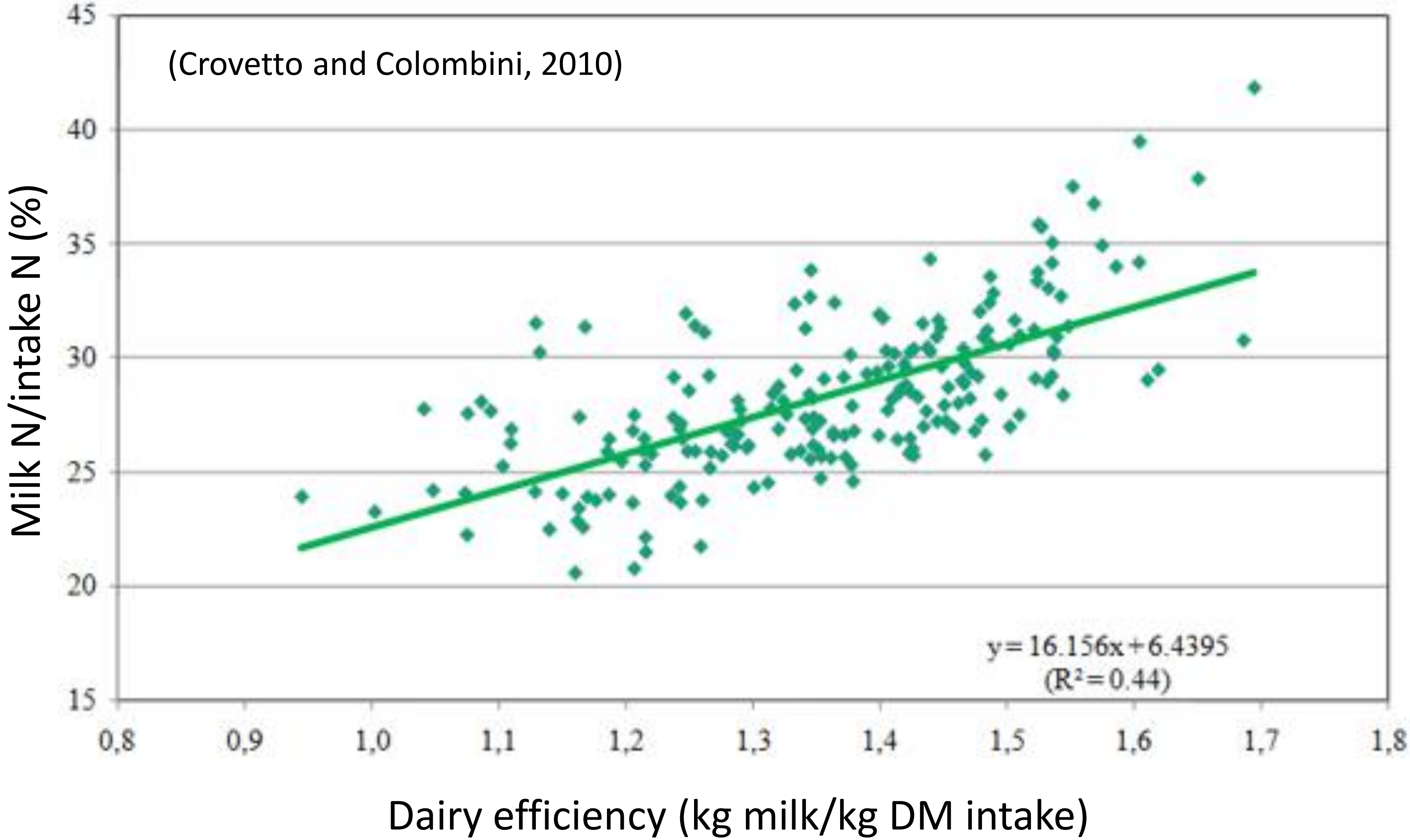
CONV=conventional diet; LP1=low protein and low essential amino acids diet; LP2=low protein and conventional essential amino acids diet.

CP and Lys (g/kg as-fed basis): CONV: 132-5.5; LP1: 104-4.3; LP2: 97-5.1

Nitrogen in milk and protein content of the diet

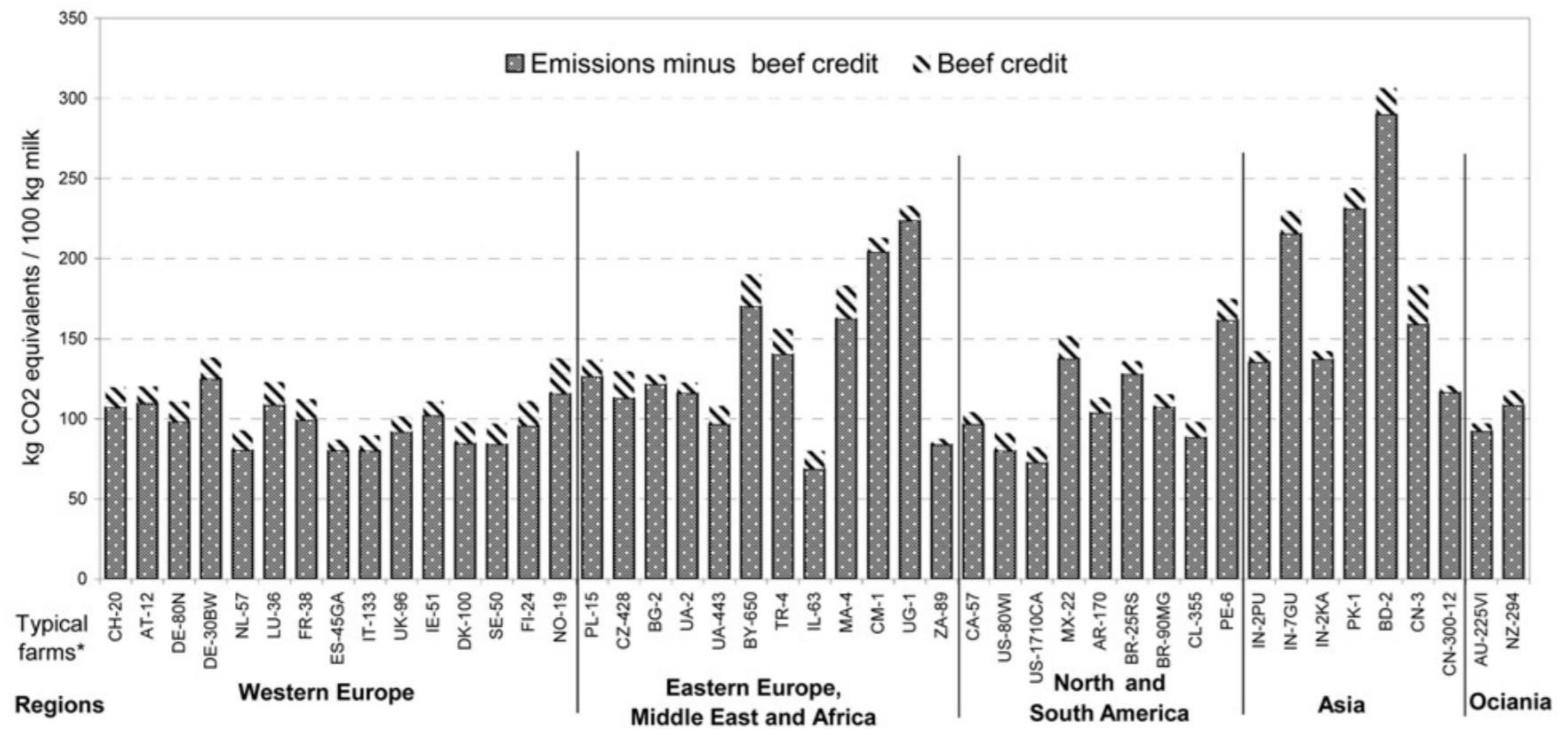


Nitrogen in milk and dairy efficiency



Cradle-to-farm-gate emissions of 45 typical farms

(Hagemann et al., 2011)



*Example farm code DE-80N: DE = Germany, 80 = 80 cows, N = North (see Annex 1)

Statistics (kg CO2 equ.)	**total emissions**		**beef credit**	
Mean (St. dev.)	135	(49)	11	(5)
Min. (Max. value)	80	(307)	3	(24)

Numbers of studies showing positive, negative or mixed/no difference when species abundance and/or richness where compared in organic versus conventional farming (Tuomisto et al., 2012)

Taxon	Positive			Negative			Mixed/no difference		
	1981–2003	2004–2009	Total	1981–2003	2004–2009	Total	1981–2003	2004–2009	Total
Birds	7	3	10			0	2	2	4
Mammals	2	1	3			0			0
Butterflies	1	3	4			0	1	2	3
Spiders	7	1	8			0	3		3
Earthworms	7	1	8			0	4	2	6
Beetles	13	3	16	2		2	3	2	5
Other arthropods	7	3	10	5		5	2	2	4
Plants	13	10	23	1		1	2	1	3
Soil microbes	9	9	18		1	1	8	3	11
Total	66	34	100	8	1	9	25	14	39

The key challenges in conventional farming are to improve soil quality (by versatile crop rotations and additions of organic material), recycle nutrients and enhance and protect biodiversity.

In organic farming, the main challenges are to improve the nutrient management and increase yields.

Food waste in the developing countries…

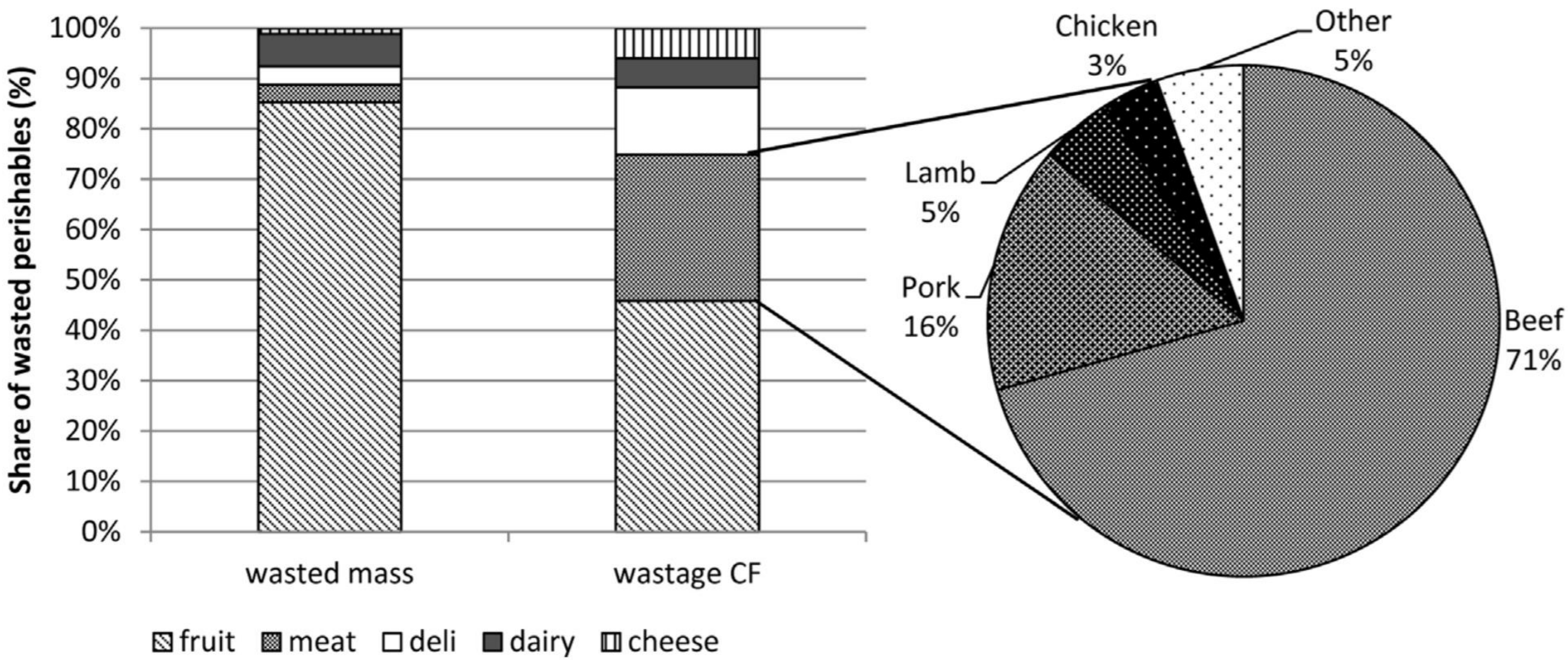
Most of the losses are in the fields, during the harvest and later on, during storage (parasites, rodents, insects, fungi, etc.)

… and in the developed ones

Most of the losses are in the market chain (processing, remains and food waste,…) and particularly at home. How much? About 30%.

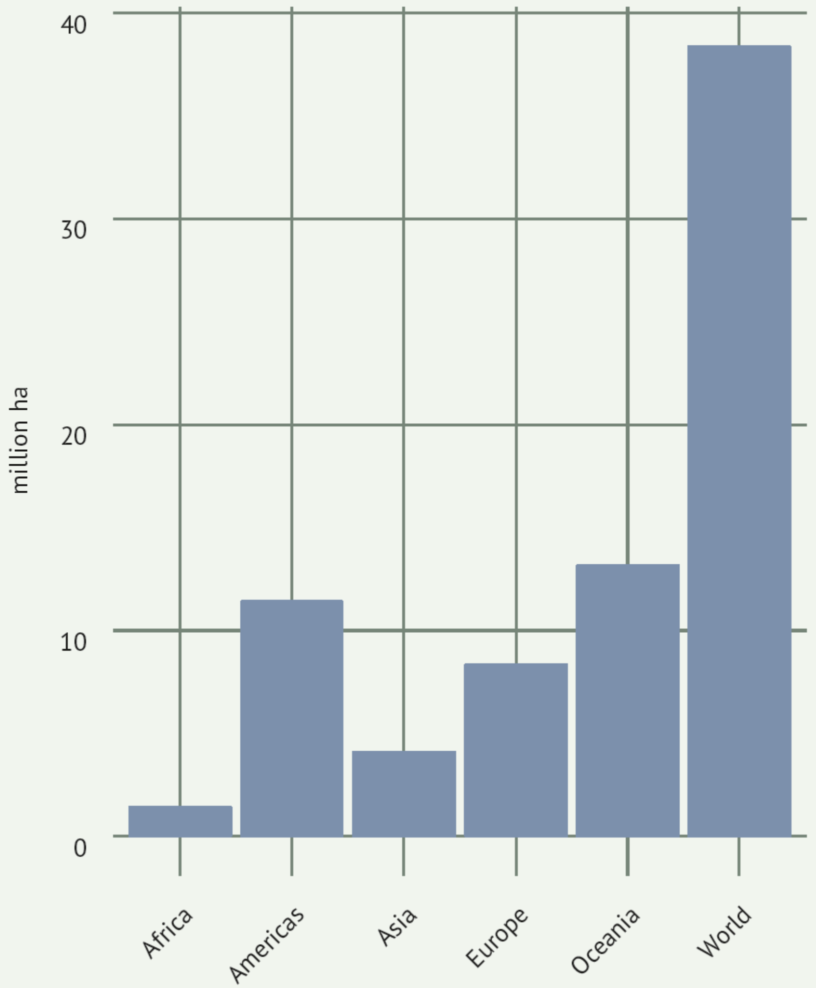
Which kind of food?

Relative distribution of wasted mass and wastage carbon footprint (CF) for five supermarket departments studied (Scholz et al., 2015)



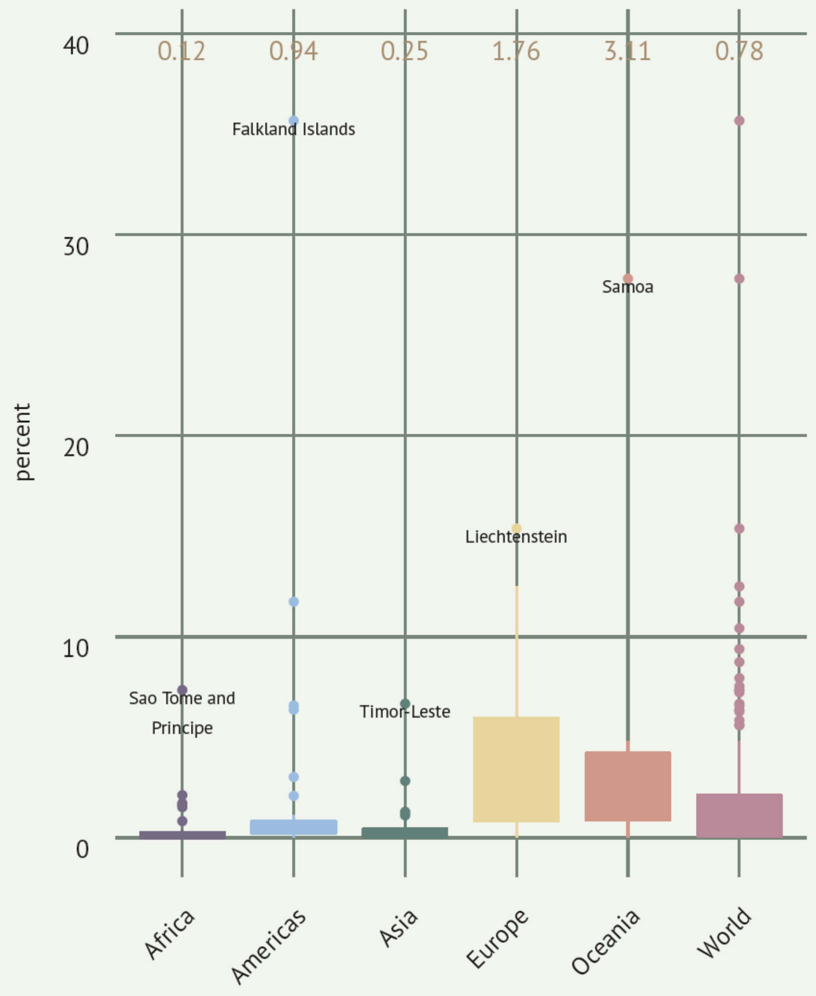
Over a three-year period, 1570 t of fresh food (excluding bread) were wasted in the supermarkets. The associated total wastage CF was 2500 t CO_2eq.

CHART 105: **Organic agriculture area (2009)**



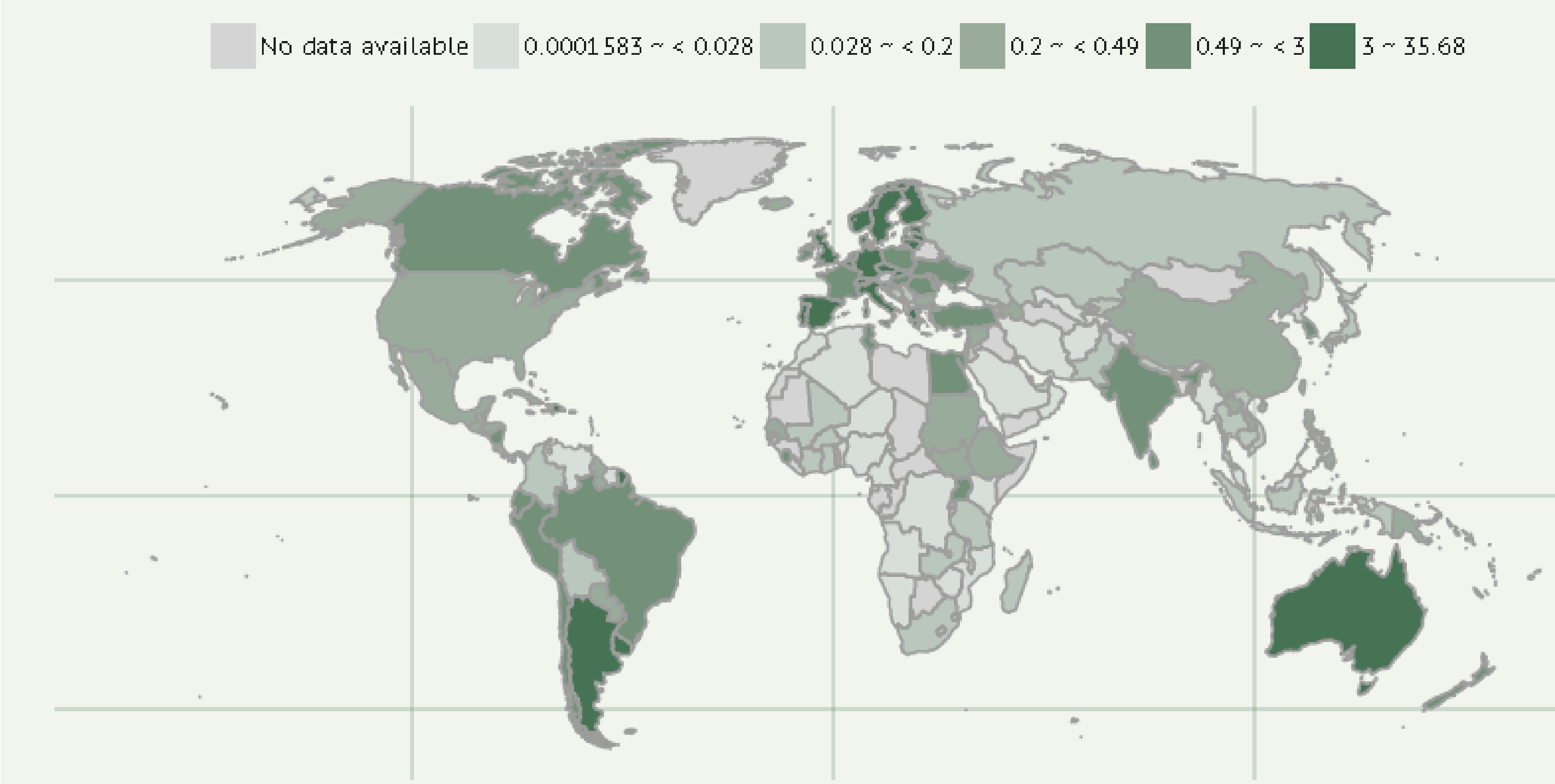
Source: FAO, Statistics Division (FAOSTAT).

CHART 106: **Organic agriculture, share of total agricultural area (2009)**



Source: FAO, Statistics Division (FAOSTAT).

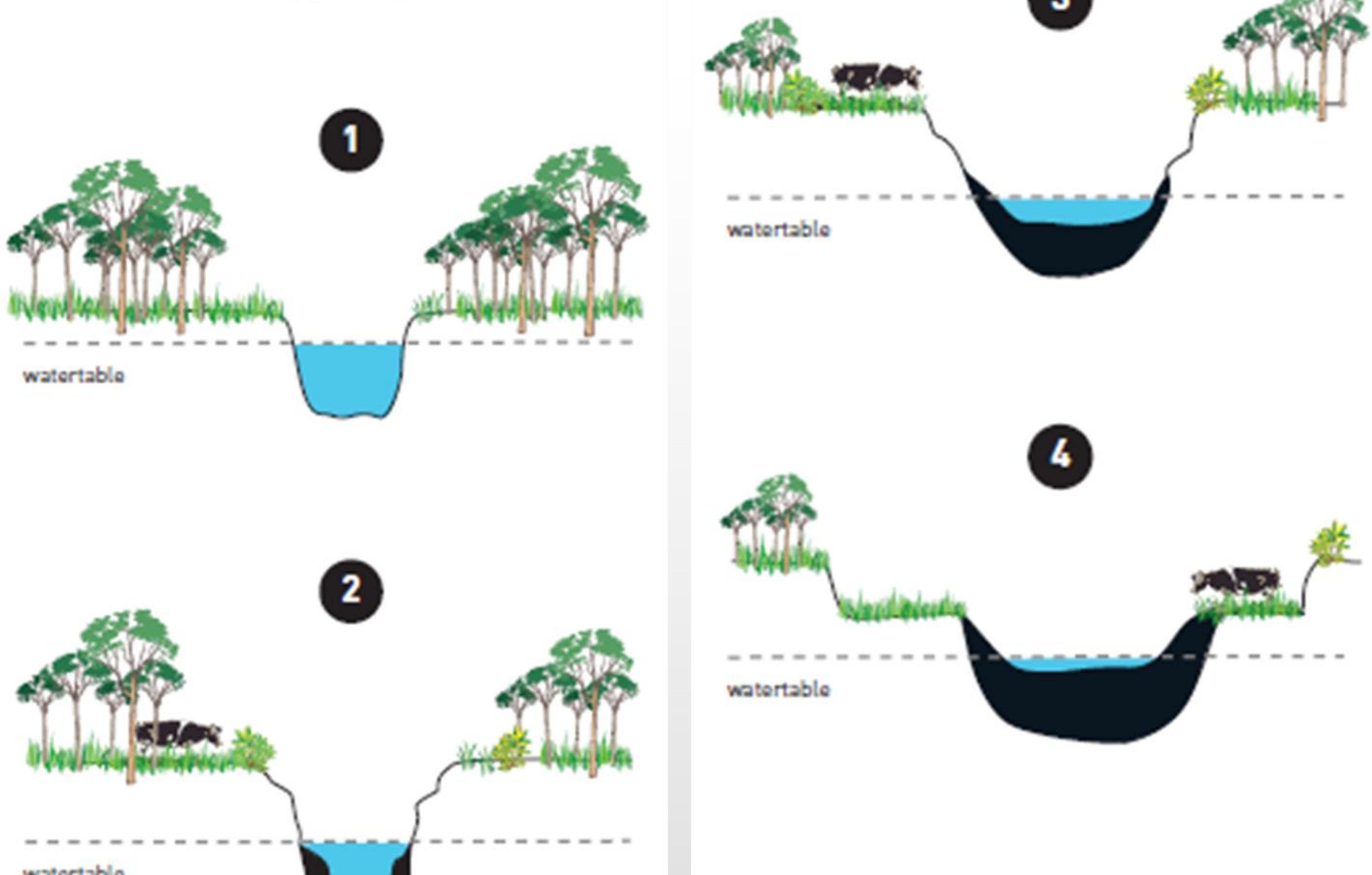
Organic agriculture, share of total agricultural area (%, 2009) (FAO 2013)



Source: FAO, Statistics Division (FAOSTAT).

Enrironmental consequences of overgrazing

Figure 4.2 Process of stream degradation caused by grazing



Source: after English, Wilson and Pinkerton (1999).

G.M. Crovetto,
Milan, 18-6-2020
DiSAA
ZOOTECNIA
UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI SCIENZE AGRARIE
E AMBIENTALI - PRODUZIONE,
TERRITORIO, AGROENERGIA

The mixed farms

Farms where >10% of the dry matter fed to animals derives from agricultural by-products and stubble or where> 10% of the farm income does not derive from livestock (Seré and Steinfeld, 1996).

In many developing countries, mixed farms are small in size, at family level, and livestock make up only a part of their capital, although important in terms of food security.

More than for an increase in income, these small-scale farms are important for the supply of high biological value proteins in the diet.

Mixed farms are estimated to produce most of the meat and milk worldwide. Rain-fed mixed systems produce 33% of sheepmeat, 48% of beef and 53% of milk (Steinfeld et al., 1996).

The mixed farms (*ctd*)

In small-scale mixed farms livestock are reared mostly on grass, browse, and nonfood biomass from maize, millet, rice, and sorghum crops and in their turn supply manure and traction for future crops.

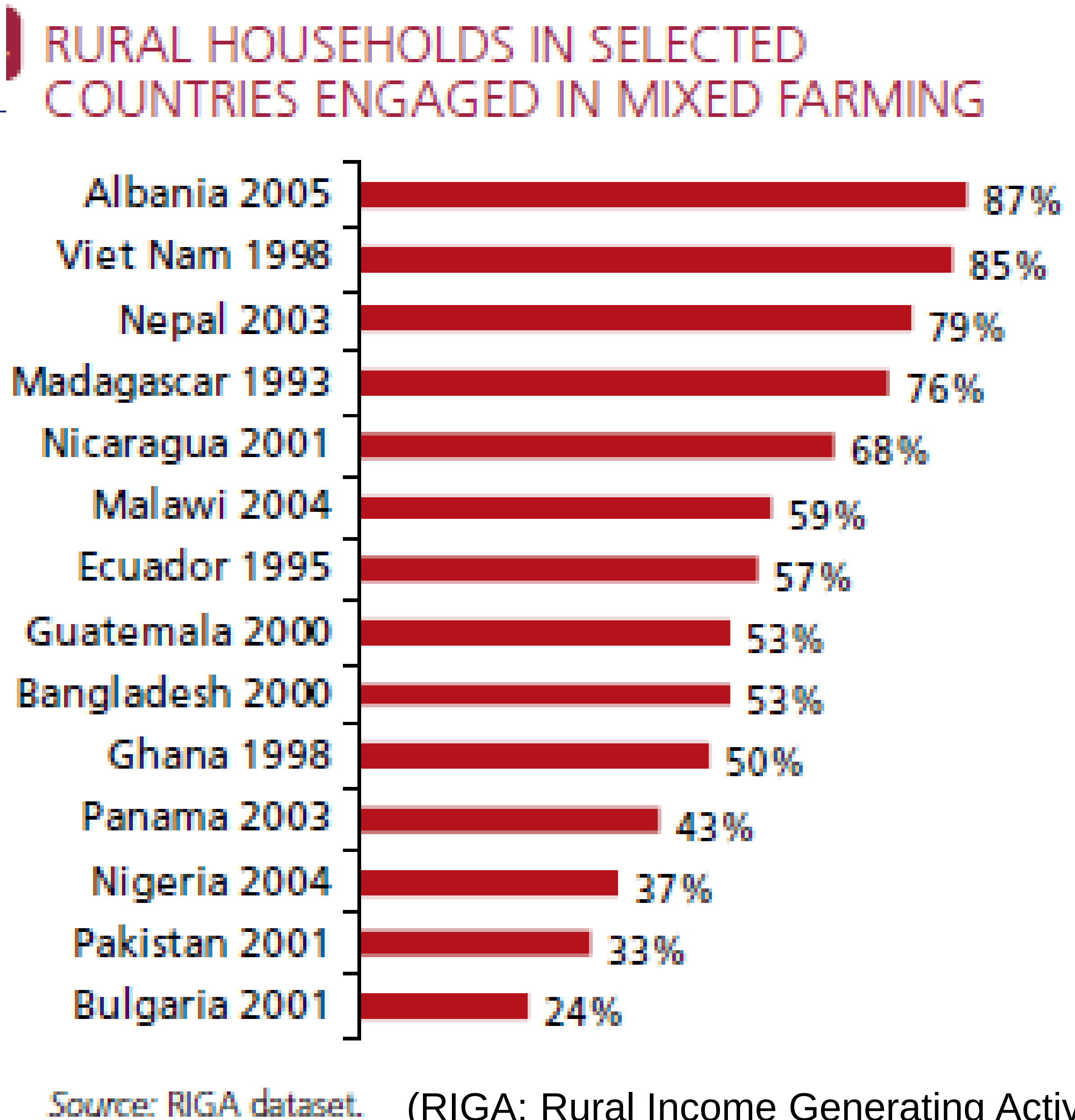
In these farms animals guarantee food, income, labor (traction), manure, and represent social capital and a means of recycling agricultural by-products.

Small-scale mixed farms support families who own them, provide additional food for the local community, but are not economically encouraged to increase their production and certainly cannot provide enough food for the growing urban population.

The mixed farms (*ctd*)

The smaller, rural mixed farms directly consume the milk or poultry they produce. Peri-urban farms generally prefer to sell milk, meat and eggs to make a profit, albeit small.

Animals act as insurance against hard times, and supply farmers with a source of regular income from sales of milk, eggs, and other products. Thus, faced with population growth and climate change, small-holder farmers should be the first target for policies to intensify production by carefully managed inputs of fertilizer, water, and feed to minimize waste and environmental impact, supported by improved access to markets, new varieties, and technologies.



(RIGA: Rural Income Generating Activities)

Pros and cons of the mixed farms

Small-scale mixed farms are more easily able to access credits than animal-free ones.

Small-scale mixed farms make the best use of native cattle, adapted to precarious environmental conditions (food, climate, parasites, diseases ...): they produce little, but at very low cost.

If these companies switch to imported livestock, which needs better environmental conditions to express the genetic potential, they can no longer compete with specialized commercial companies.

Factors to consider if market oriented

Regardless of its dimension, a business enterprise of poultry or pigs should always start from a careful survey and analysis of:

- market demand
- time and cost to reach the market
- availability and cost of feed supply
- health care and veterinary assistance
- appropriate breed to be chosen
- housing and related equipment
- water sources
- access to credit.

Production for self-consumption or for the market

Self-consumption system is almost always extensive.

For market purposes: semi-intensive or intensive production systems. These production units can be at large, medium or even small-scale level.

Biosecurity

Small-scale farms often have several species of livestock raised in a small space, with hygiene problems and even more serious health risks (transmission of infectious diseases).

Under these conditions, it becomes even more difficult for these farms to access the "urban" market which requires products guaranteed from the hygienic/sanitary point of view.

Perspectives for the small-scale mixed farms

Very important since they support many rural families in the world, use and recycle resources effectively and contribute, although to a limited extent, to the supply of food in urban areas.

Main limitations:

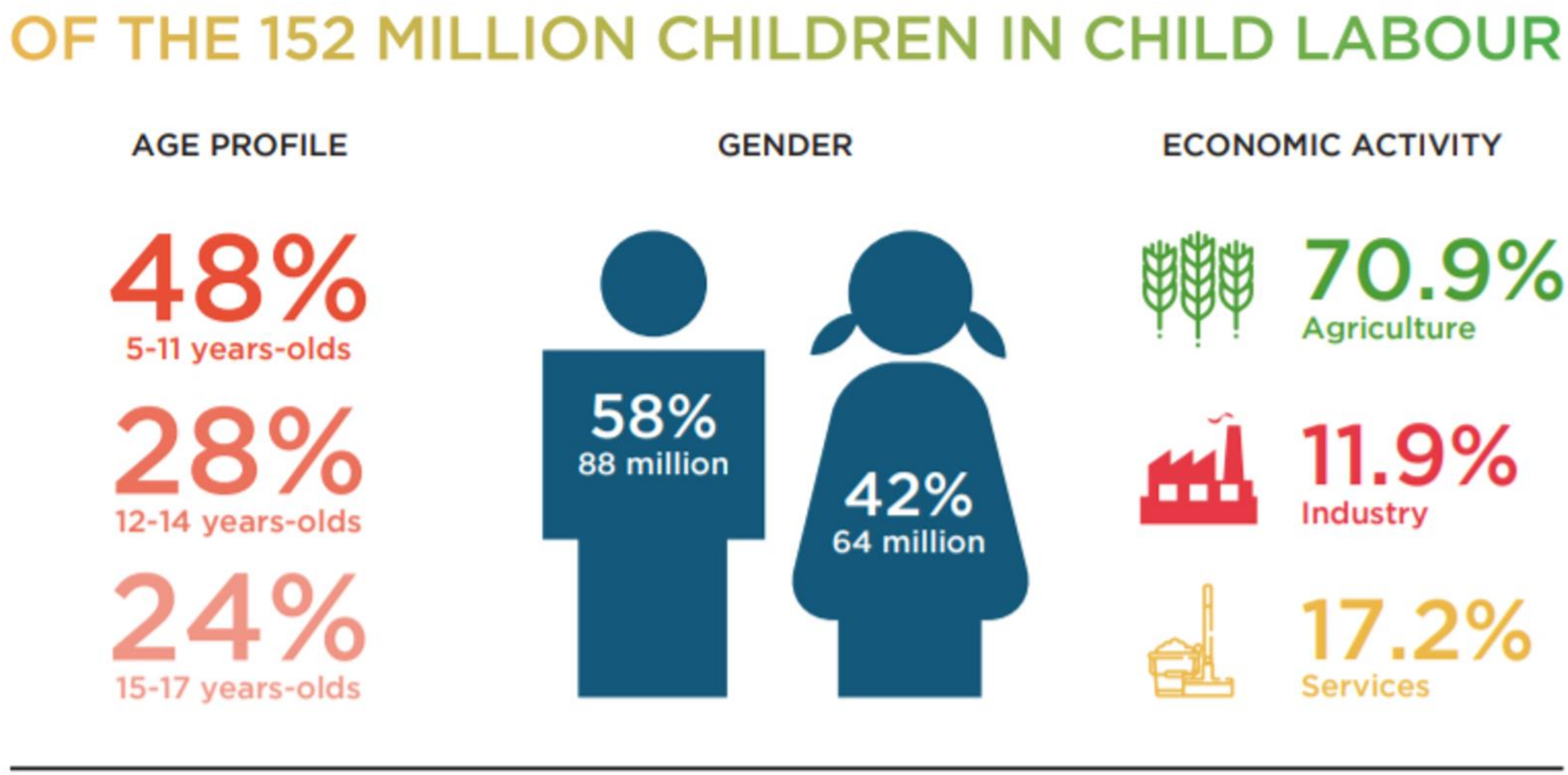
- difficulty getting credits
- limited availability of land and access to common land
- high unit costs of cash products in comparison with large companies
- distance from city markets
- barriers of the quality/safety requirements of city markets.

Main constraints of small-scale farms

- Limited arable land (1-2 ha) with no title deed (property act)
- Limited (if any!) external imputs: machineries, genetically improved seeds, feeds, drugs and chemicals, technical/veterinary assistance, financial credit/microcredit, etc.
- Lack of infrastructures: roads, railway, transportation, clinics, internet communication.
- Distance from city markets
- Lack of vehicles and of a cool chain (→ self-consumption or low-price sale at the village)
- Small amounts of products → poor bargaining power

Environment… but human rights too!

(K. Moore, 2020 - Rainforest Alliance)



Global Estimates of Child Labour
Image: International Labour Organization

The problem is particularly acute in Africa, where nearly half of the child labourers (72.1 million) are found, the majority in agriculture.

Videos links

https://youtu.be/WeoIsjYBQH0	(3 min)	Sustainable food and agriculture
https://youtu.be/Ev6O5T7RKJU	(4,5 min)	Transforming the livestock sector through the SDGs

Conclusions

- Both small-scale and medium/large scale livestock farms must coexist and be implemented in developing countries.
- Mixed small-scale farms are strategic for keeping people in rural areas and avoiding urbanism, but their efficiency must be improved.
- Mixed medium-scale farms (or a cooperative of mixed small-scale farms) are essential for increasing food production and supply, preserving the environment.
- Semi-intensive and intensive livestock production systems are essential for food supply and should not be demonized, but must minimize the environmental impact through genetics, nutrition&feeding, and management.