Mitigation strategies of environmental impact of animal production

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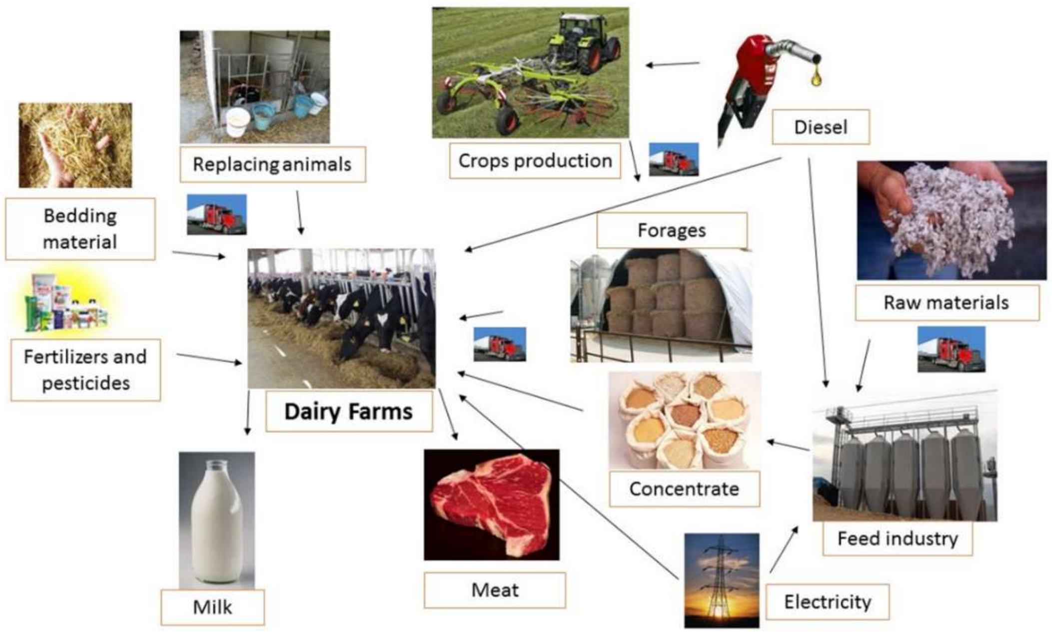
DIPARTIMENTO DI SCIENZE AGRARIE
E AMBIENTALI - PRODUZIONE,
TERRITORIO, AGROENERGIA

DiSAA
ZOOTECNIA

Topics on mitigation

Mitigation actions in farming system on

- Climate Change and global warming (methane)
- Eutrophication
- Acidification



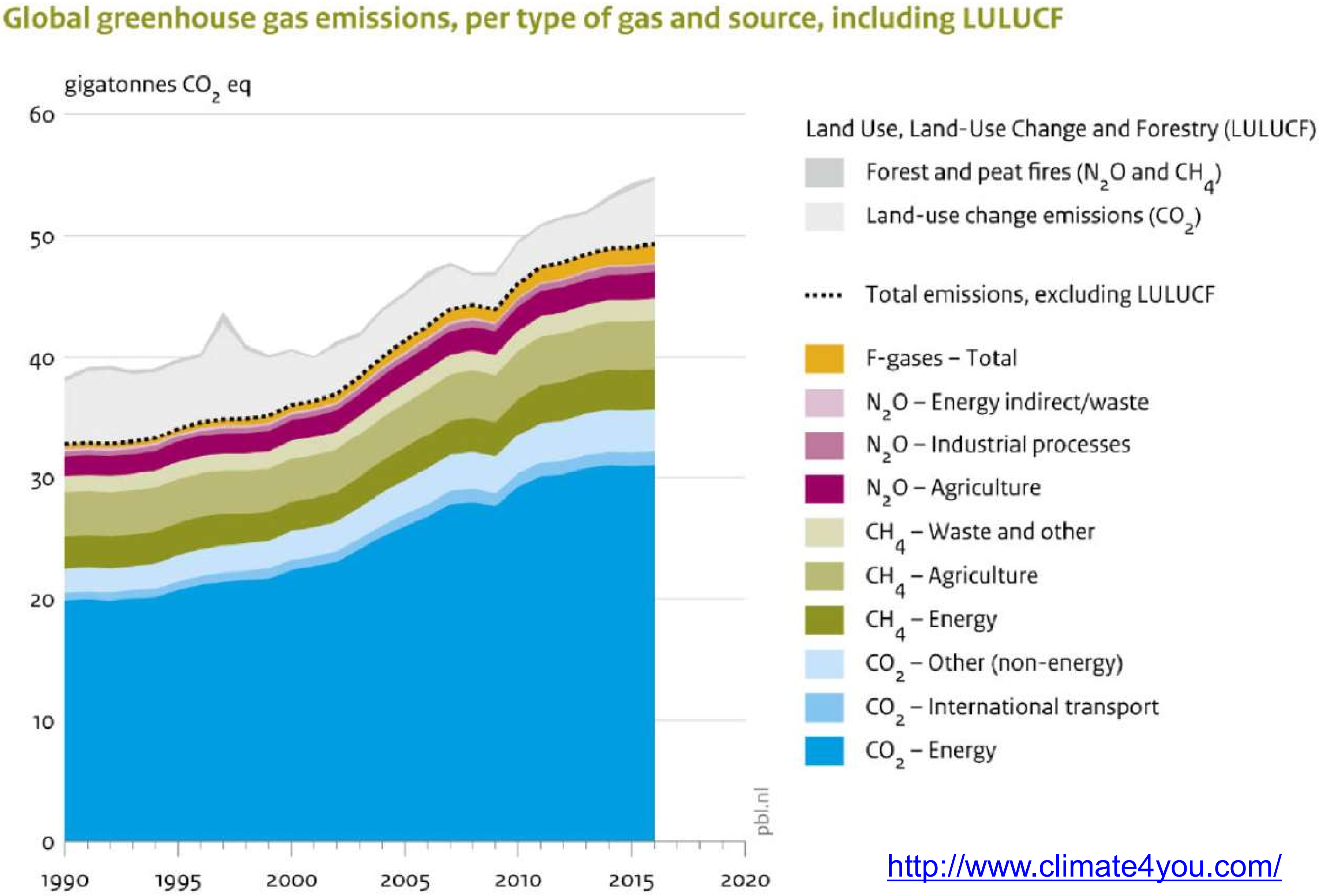
Climate Change and Global Warming GHG

Agriculture and Climate Change

Agriculture is and will be:

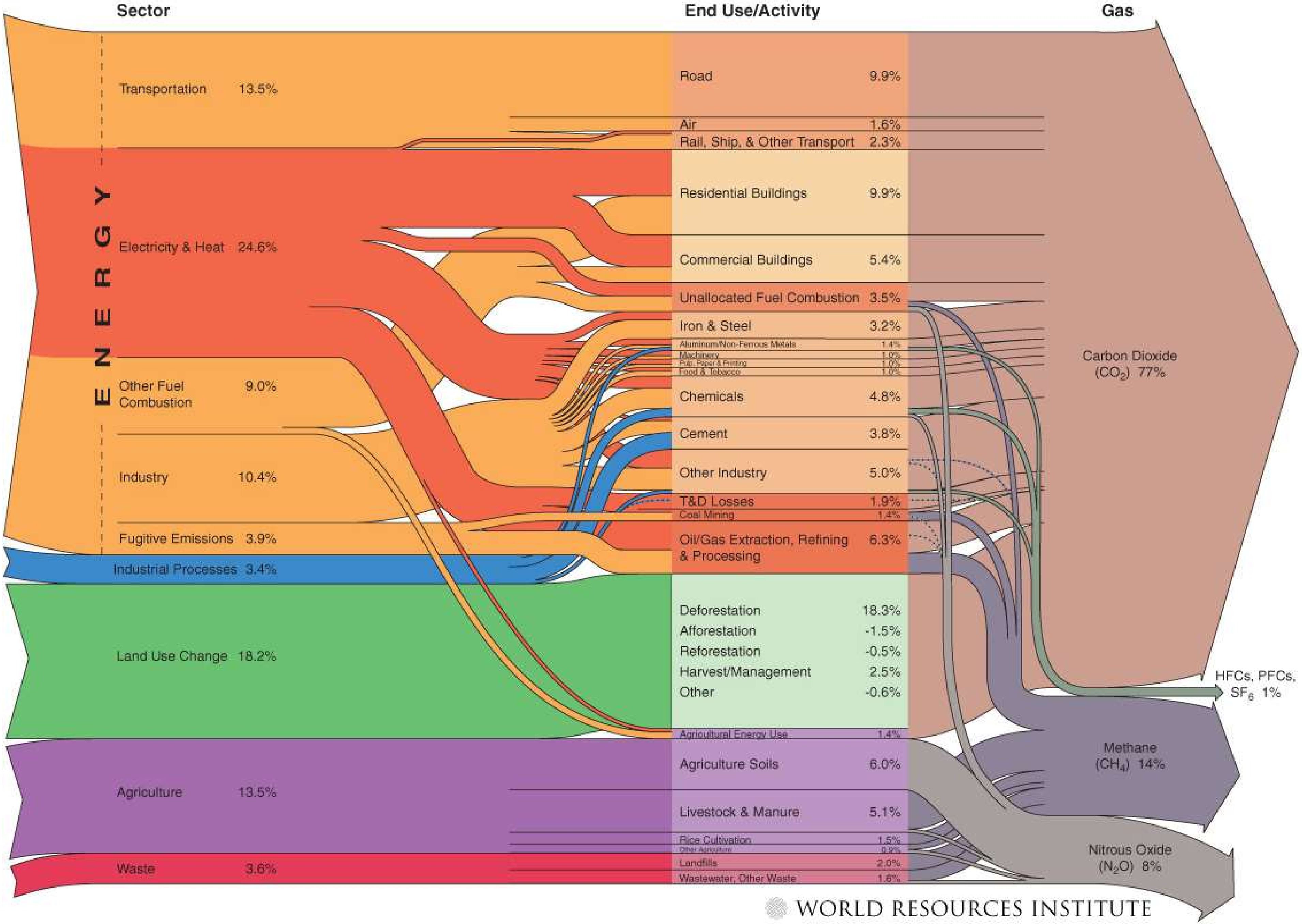
- **cause** of climate change (?!)
- But it is also among the sectors most **affected** by global warming
- And it is creator of **mitigation actions**

Is it whose fault?

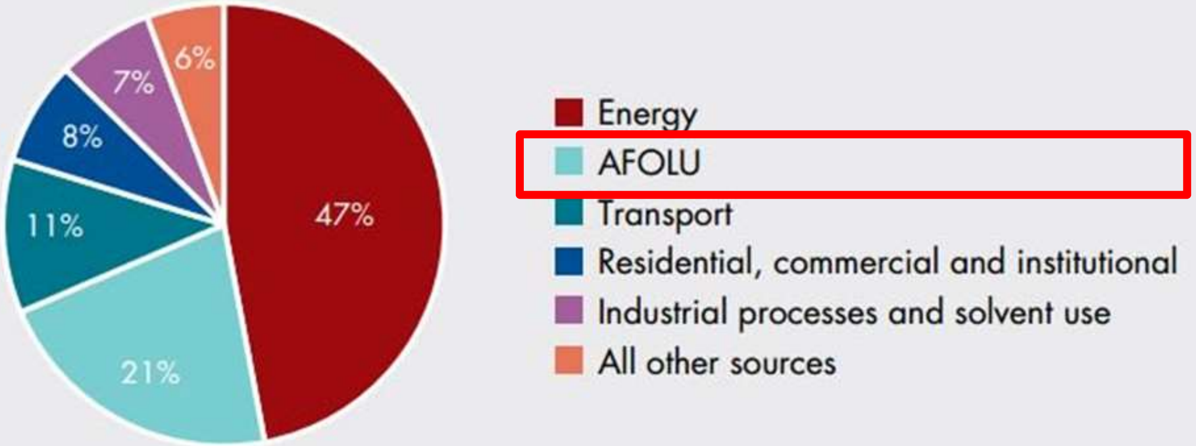


http://www.climate4you.com/

World GHG Emissions Flow Chart



Agriculture and Climate Change



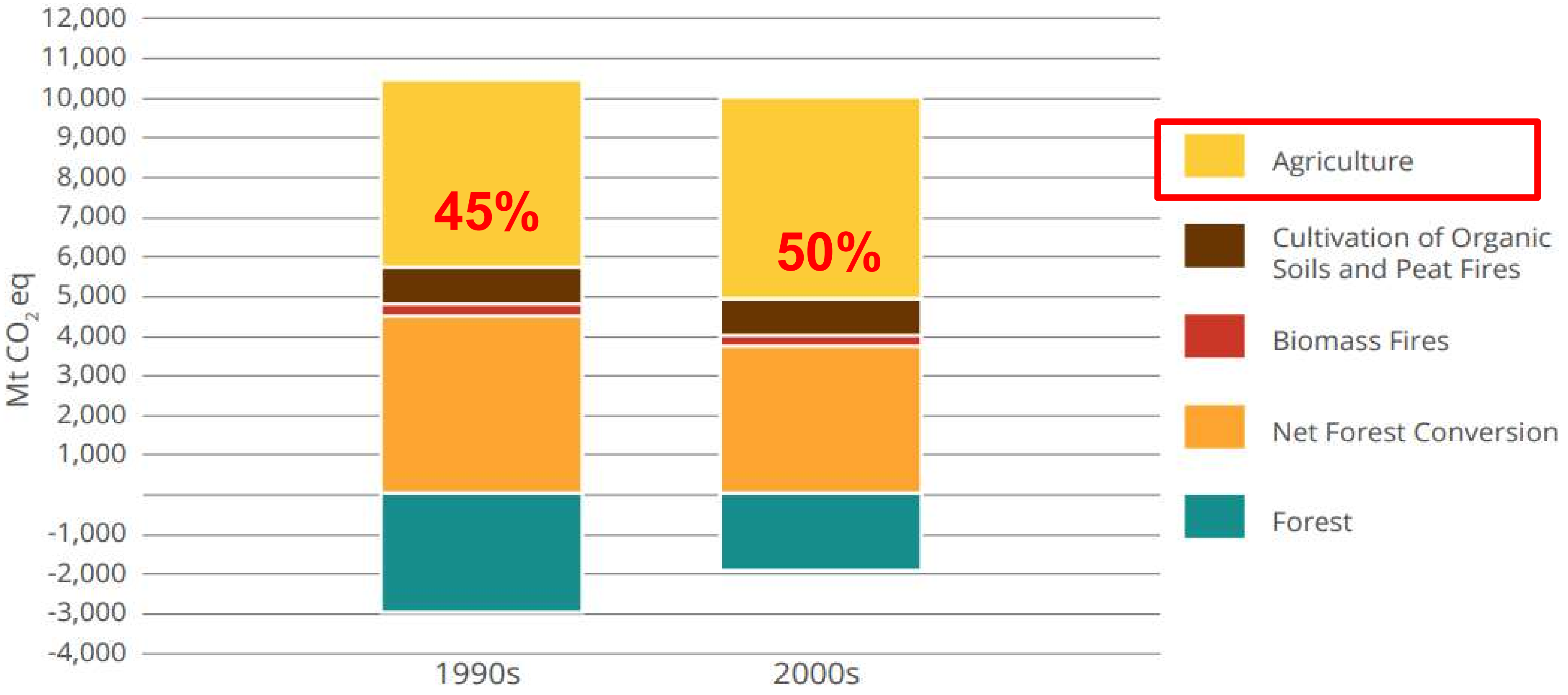
Notes: Emissions from energy include industries, manufacturing and fugitive emissions. AFOLU means "Agriculture, forestry and other land use". "All other sources" includes international bunkers, waste and other sources.
SOURCE: FAO, forthcoming.

FAO 2014

http://www.fao.org/3/i3671e/i3671e.pdf

Agriculture and Climate Change

Agriculture is responsible for 50 % emission of AFOLU CO_2 eq. **= 10% of total CO_2 emission**



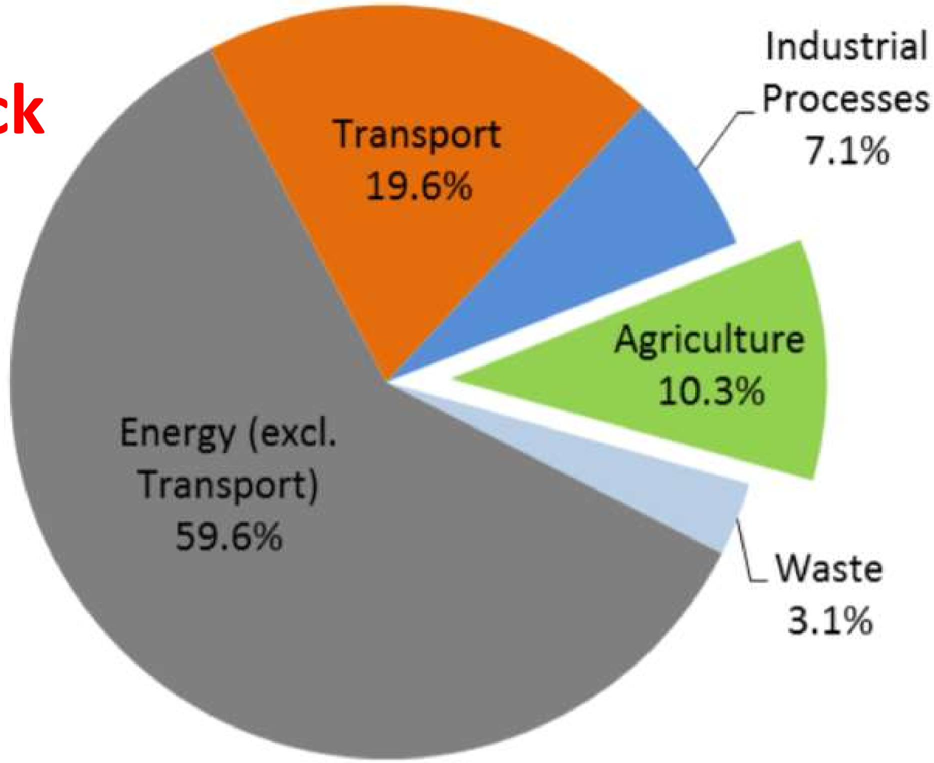
Agriculture and Climate Change

In Europe (UE-28), agriculture is responsible for 10%,

Half for Animal Production

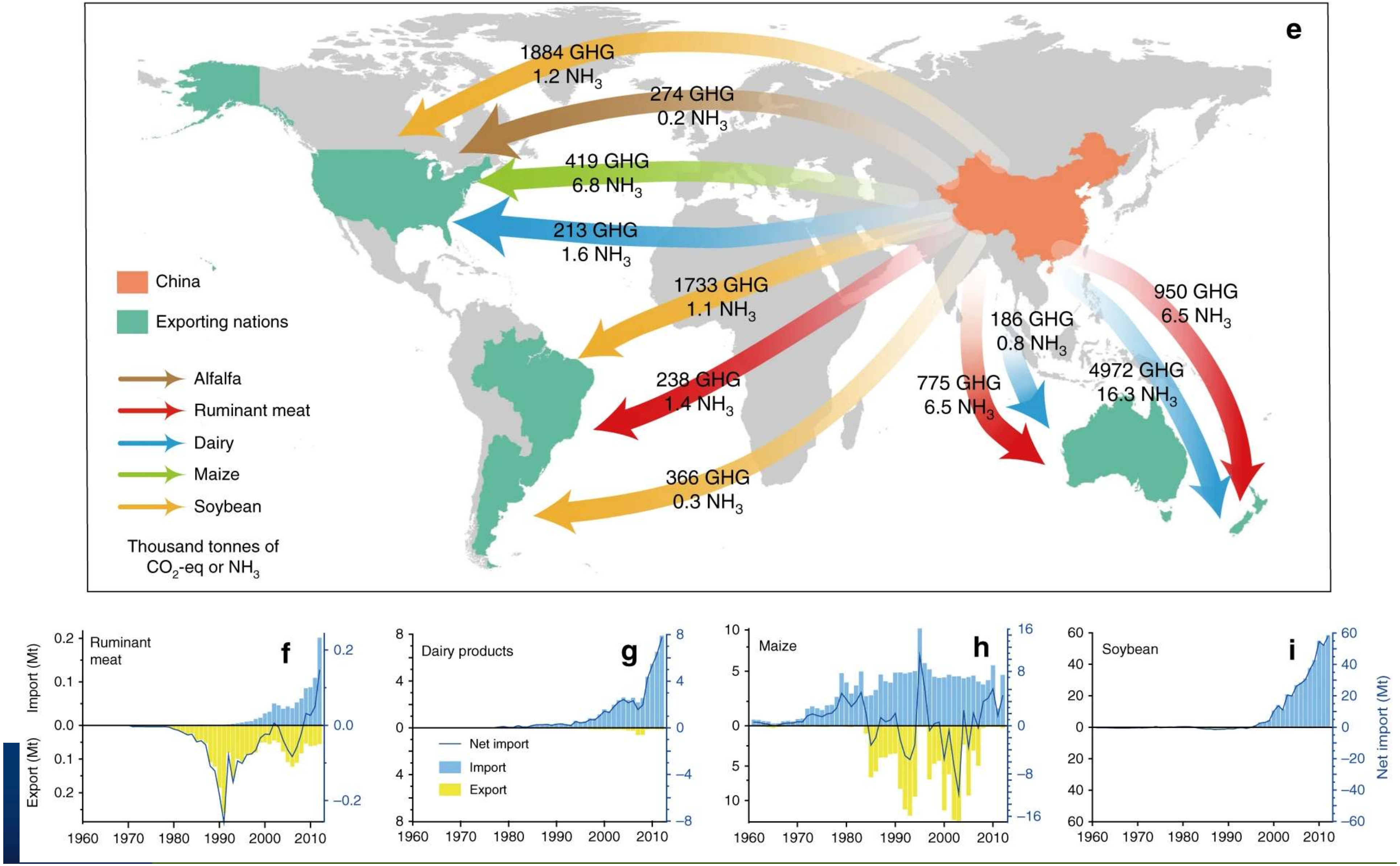
= If we remove ALL livestock farms, we can save 5% of total emission

«Mitigation» means to control the most important sources!



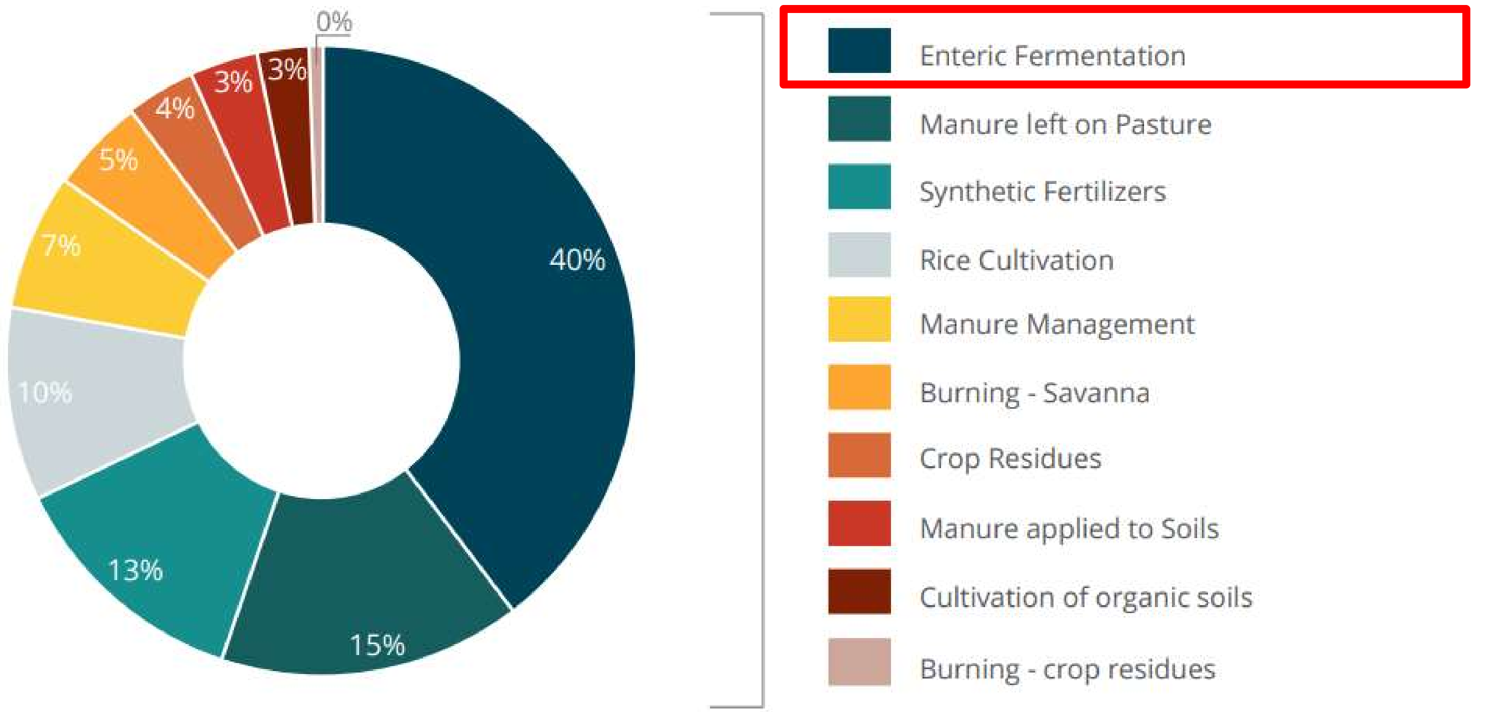
Source: EEA (2015).

Another way to mitigate: Global economy and Climate Change - Chinese example



Agriculture and Climate Change

World total agriculture emission



Agriculture emissions by sub-sector, 2001-2011

GHG emissions from animal farms

	Enteric methane	Manure storage methane	Manure storage nitrous oxide	Total Gigatonnes carbon dioxide equivalents
Beef cattle	91%	3%	6%	1.8 (45%)
Dairy cattle	85%	8%	7%	1 (26%)
Buffaloes	91%	2%	7%	0.5 (12%)
Pigs	11%	69%	20%	0.3 (7%)
Sheep	93%	3%	4%	0.2 (4.5%)
Goats	93%	4%	3%	0.2 (4%)
Chicken	0%	34%	66%	0.1 (1.5%)

FAO. 2017. Global Livestock Environmental Assessment Model (GLEAM)

GHG total emissions from EU farms

J.P. Lesschen et al. / Animal Feed Science and Technology 166–167 (2011) 16–28

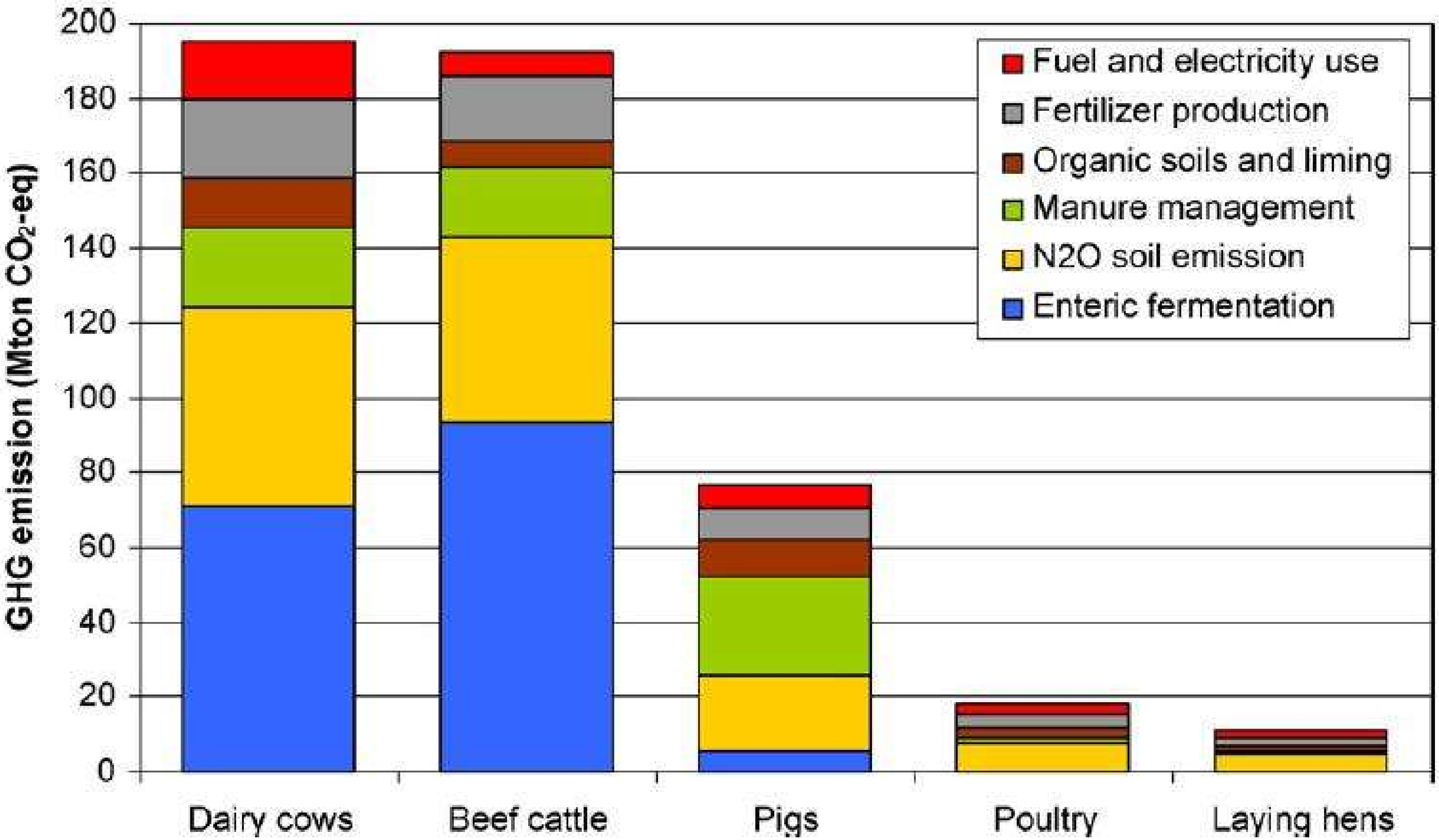
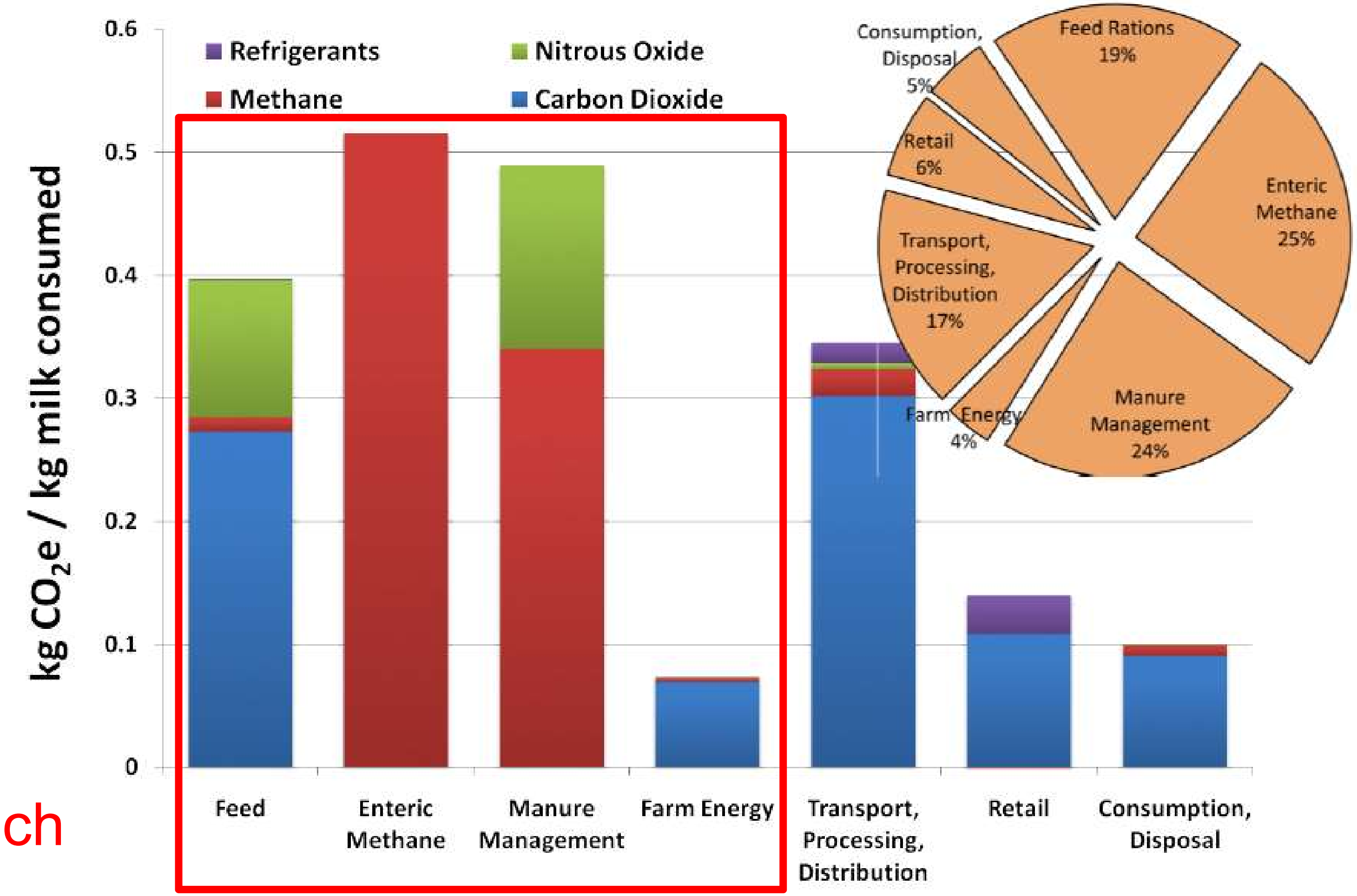


Fig. 7. Total greenhouse gas emissions from the various emission sources associated with livestock production in the EU-27.

GHG for milk production



LCA approach

Figure 1-3. Supply chain contribution to carbon footprint of 'generic' milk. Generic milk refers to regional-production-weighted (raw milk input) and purchase-volume-weighted (milk fat content) average milk consumed in the U.S. during 2007.

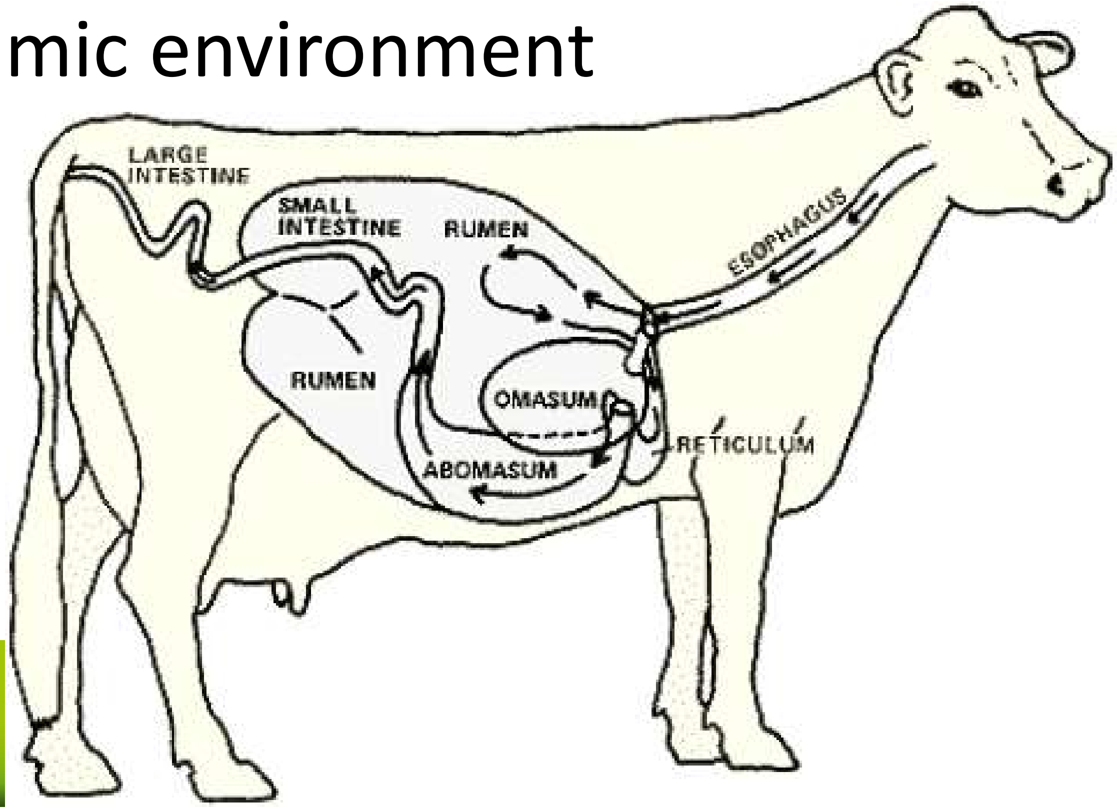
Thoma et al., 2013

Methane
GHG

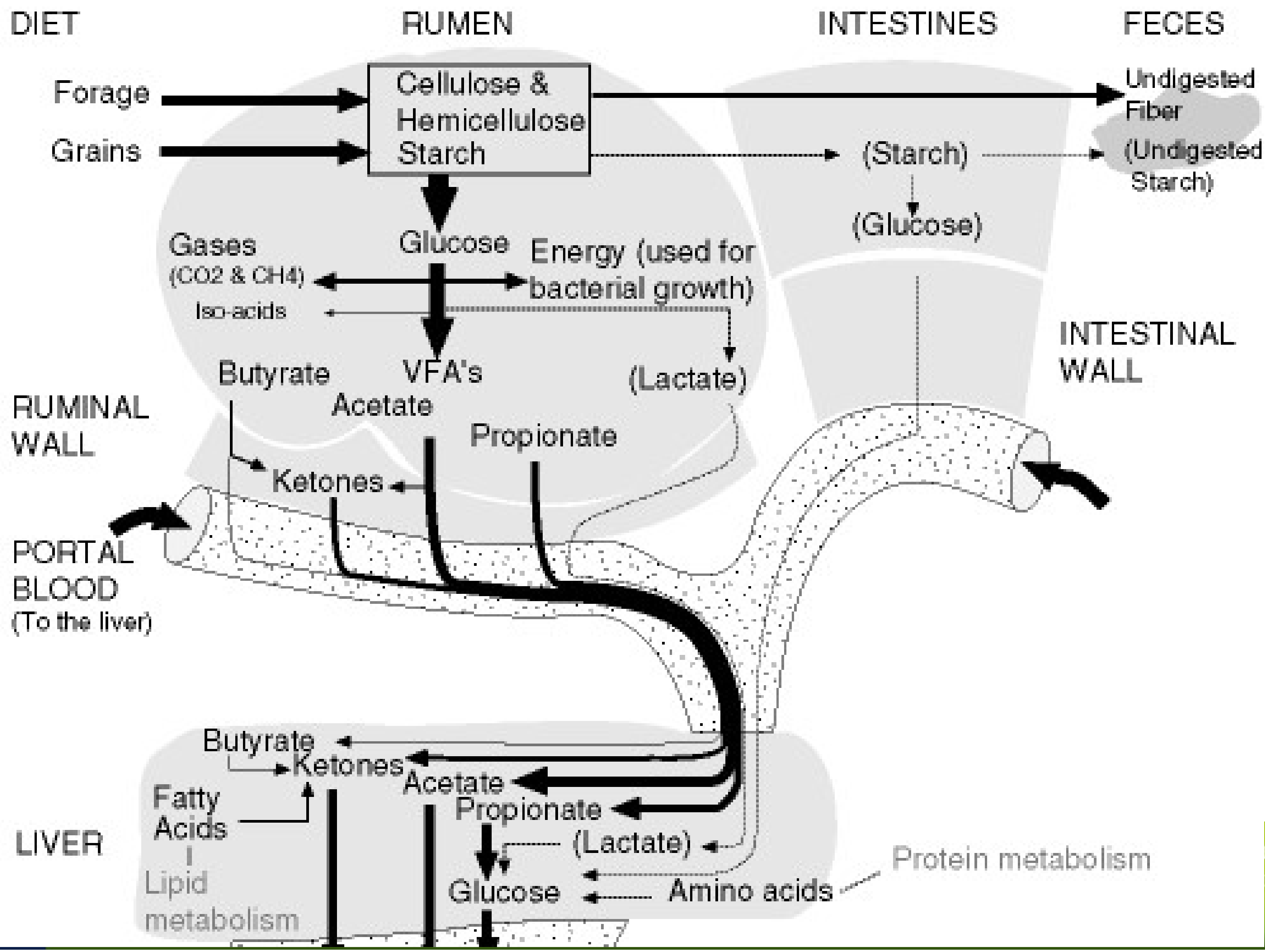
Why methane and ruminants?

Ruminal environment

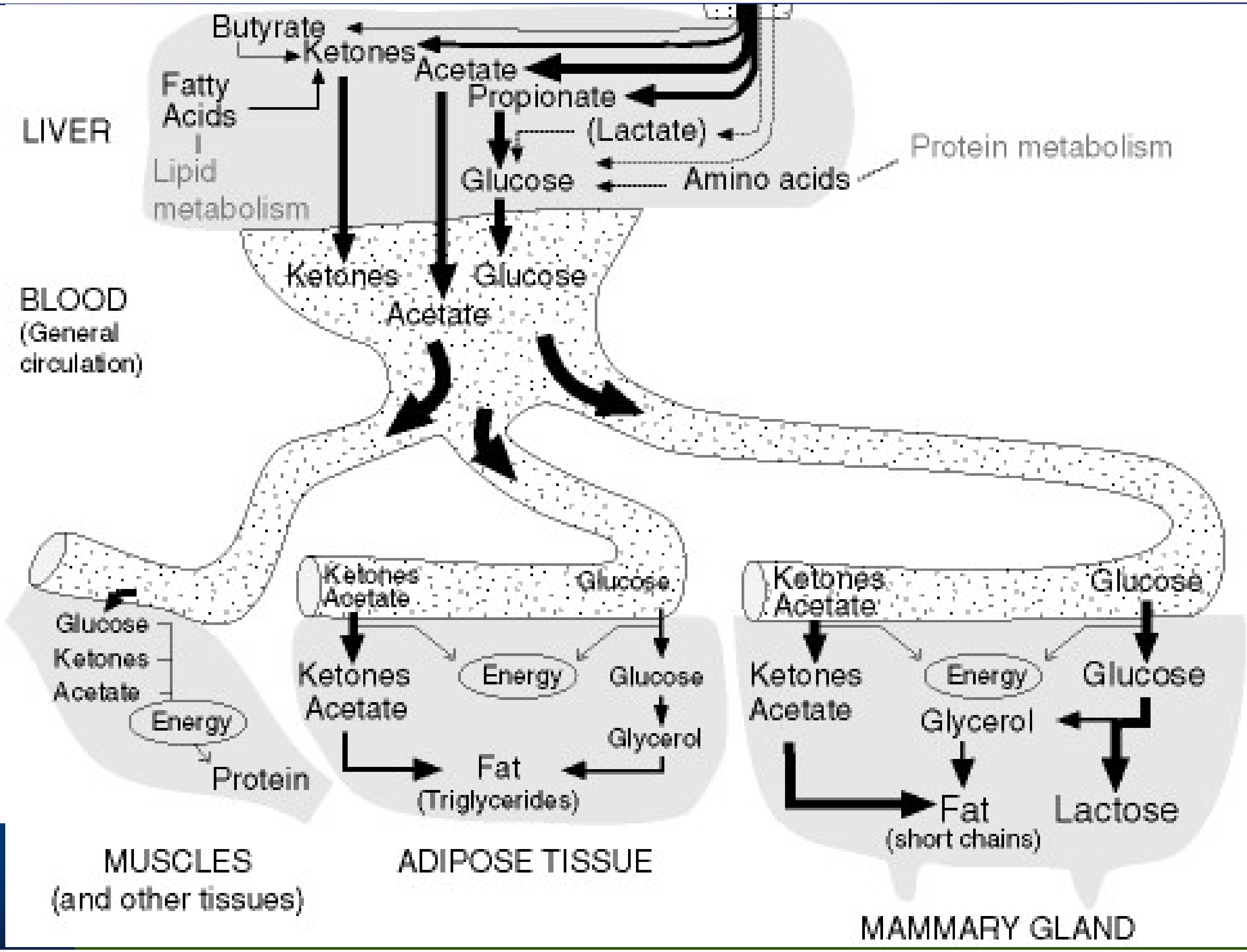
- Feed (for bacterial fermentation)
- Ruminal bacteria ($50*10^9$/mL)
- Complex and dinamic environment



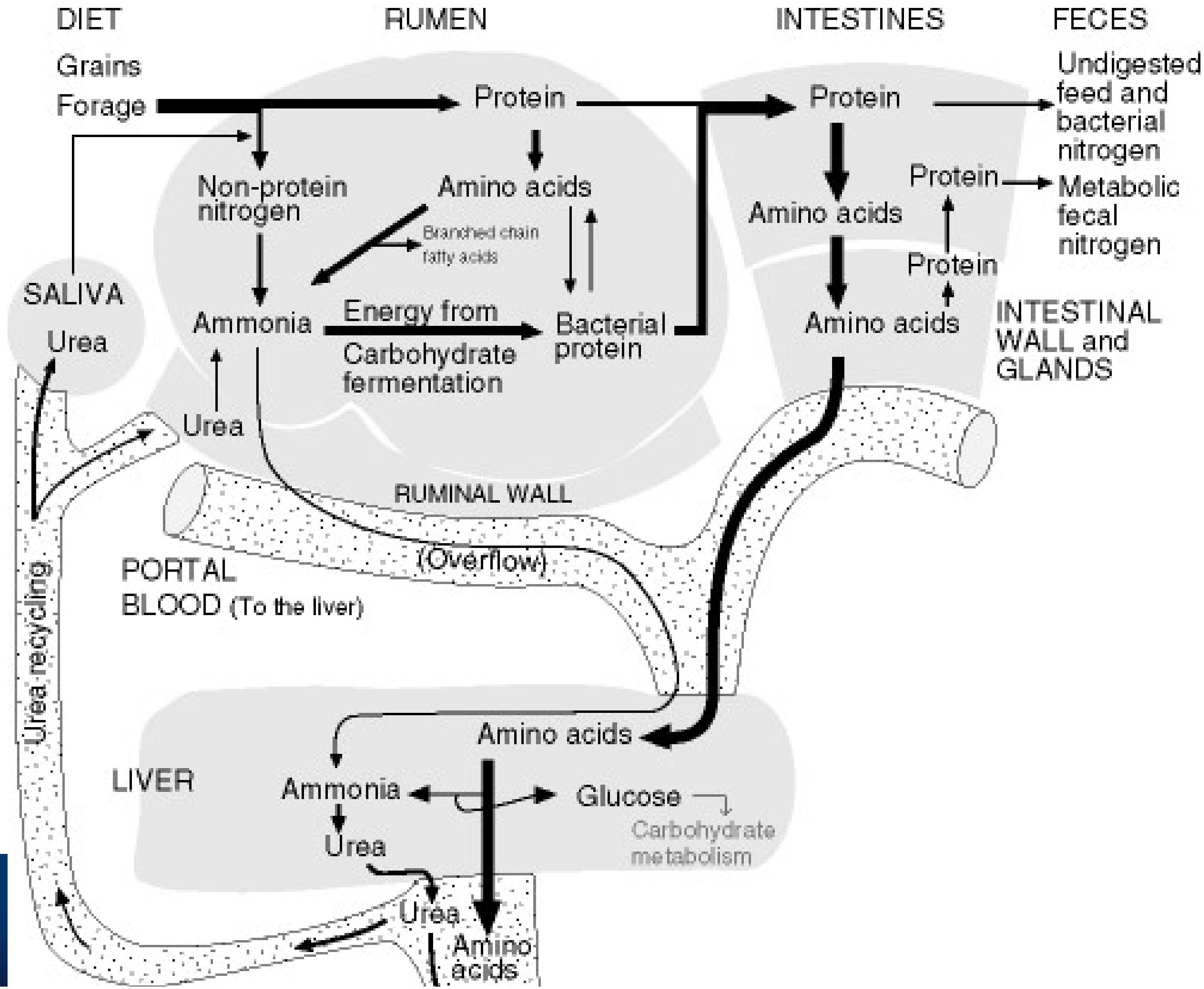
Carbohydrate Metabolism in cow - 1



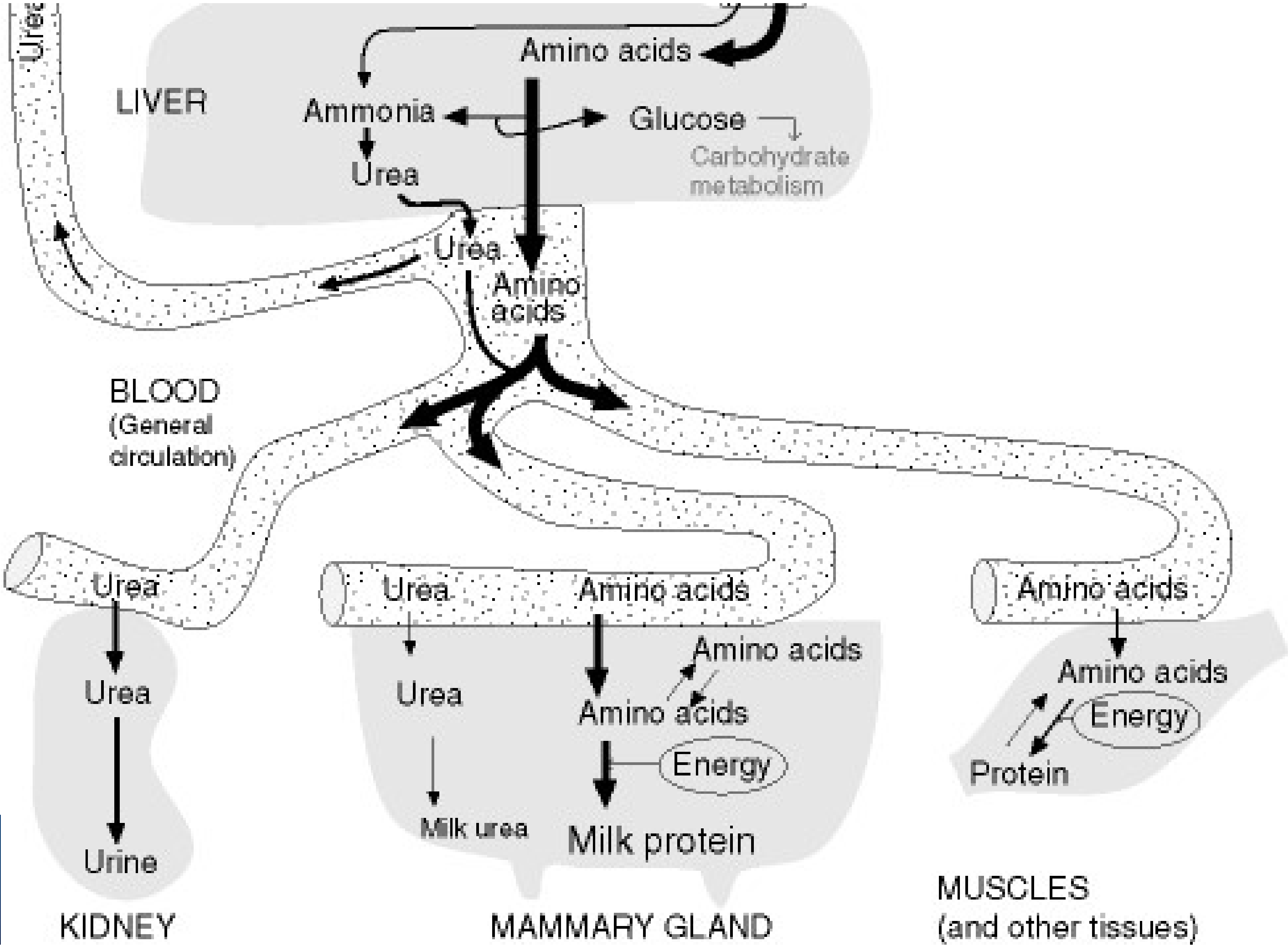
Carbohydrate Metabolism in cow - 2



Protein Metabolism in cow - 1



Protein Metabolism in cow - 2



Stechiometry of ruminal fermentation

Sugars (glucose) utilization

$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2$ — acetate

$3C_6H_{12}O_6 \rightarrow 2CH_3COOH + 4CH_3CH_2COOH + 2CO_2 + 2H_2O$ — propionate

$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH + 2CO_2 + 2H_2$ — butyrate

$5C_6H_{12}O_6 + 6NH_3 \rightarrow 6C_5H_7O_2N + 18H_2O$

Amino acid utilization

$$C_5H_{9.8}O_{2.7}N_{1.5} \rightarrow (1 - Y_{aa}) \cdot \sigma_{ac,aa} CH_3COOH + (1 - Y_{aa}) \cdot \sigma_{pr,aa} CH_3CH_2COOH + Y_{IN,aa} NH_3 + (1 - Y_{aa}) \cdot \sigma_{bu,aa} CH_3CH_2CH_2COOH + (1 - Y_{aa}) \cdot \sigma_{IC,aa} CO_2 + (1 - Y_{aa}) \cdot \sigma_{H_2,aa} H_2 + Y_{aa} C_5H_7O_2N$$

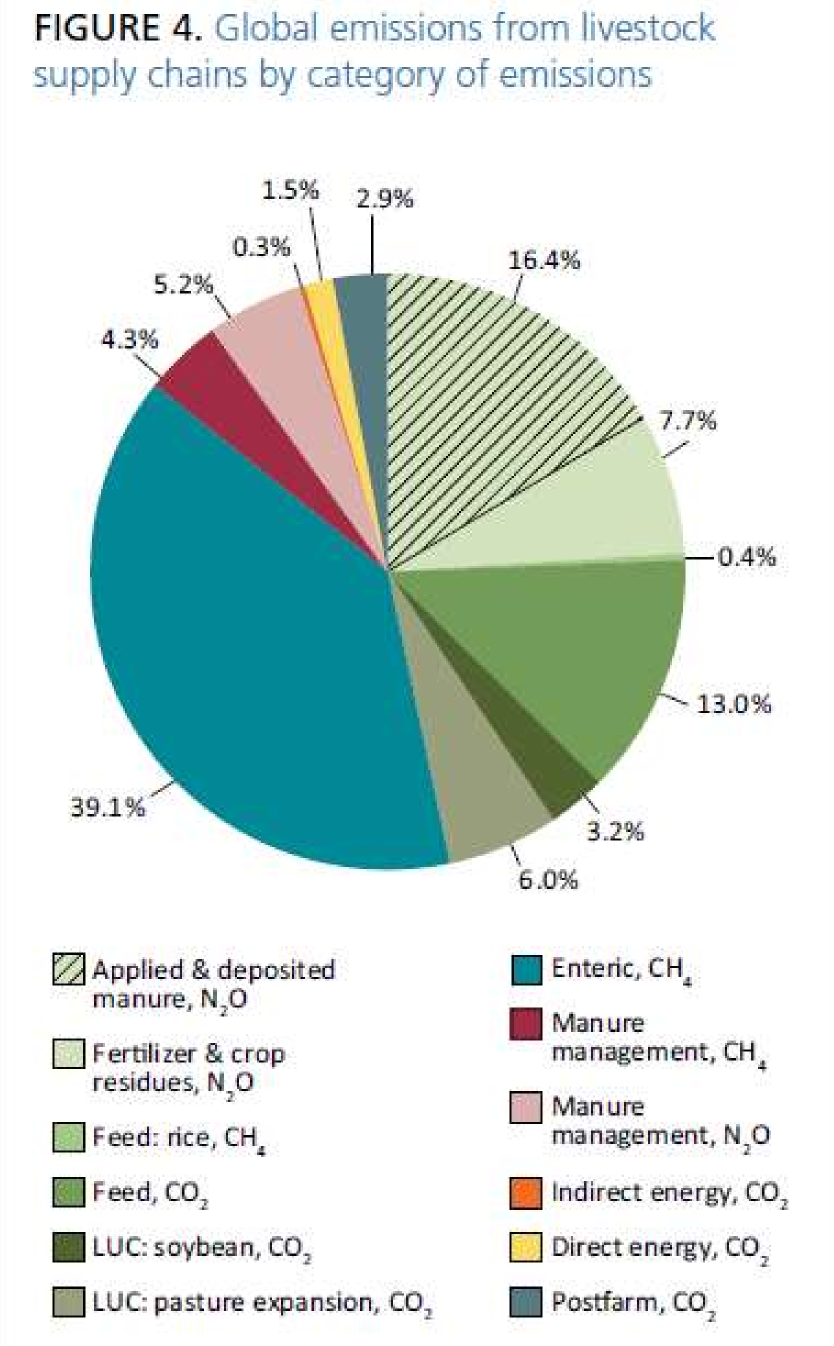
Hydrogen utilization: methanogenesis reaction

$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$

$10H_2 + 5CO_2 + NH_3 \rightarrow C_5H_7O_2N + 8H_2O$

Acetic and butyric fermentation can produce H_2 and CH_4

→ **MOST IMPORTANT MITIGATION STRATEGIES**



Global emissions from Livestock farming in the world

- 45% from feed cultivation
- 39% enteric production of methane (ruminants!)
- 3,2% from soybean production and 6 % pasture expansion (LUC)
- 2,9 % post-farm effect

FAO, 2013 Tackling climate change through livestock

Global emissions from Livestock farming in EU-27

J.P. Lesschen et al. / Animal Feed Science and Technology 166–167 (2011) 16–28

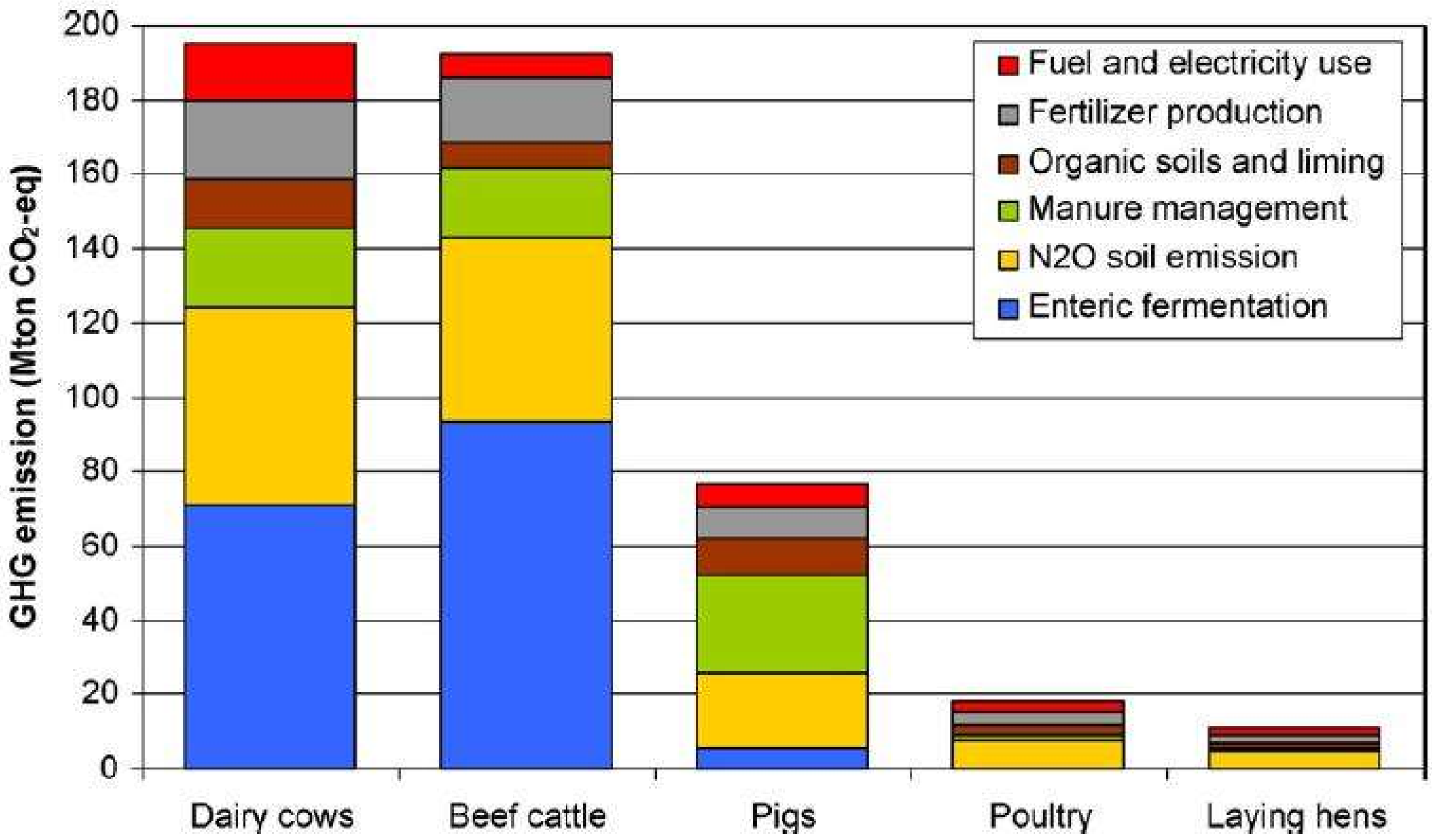
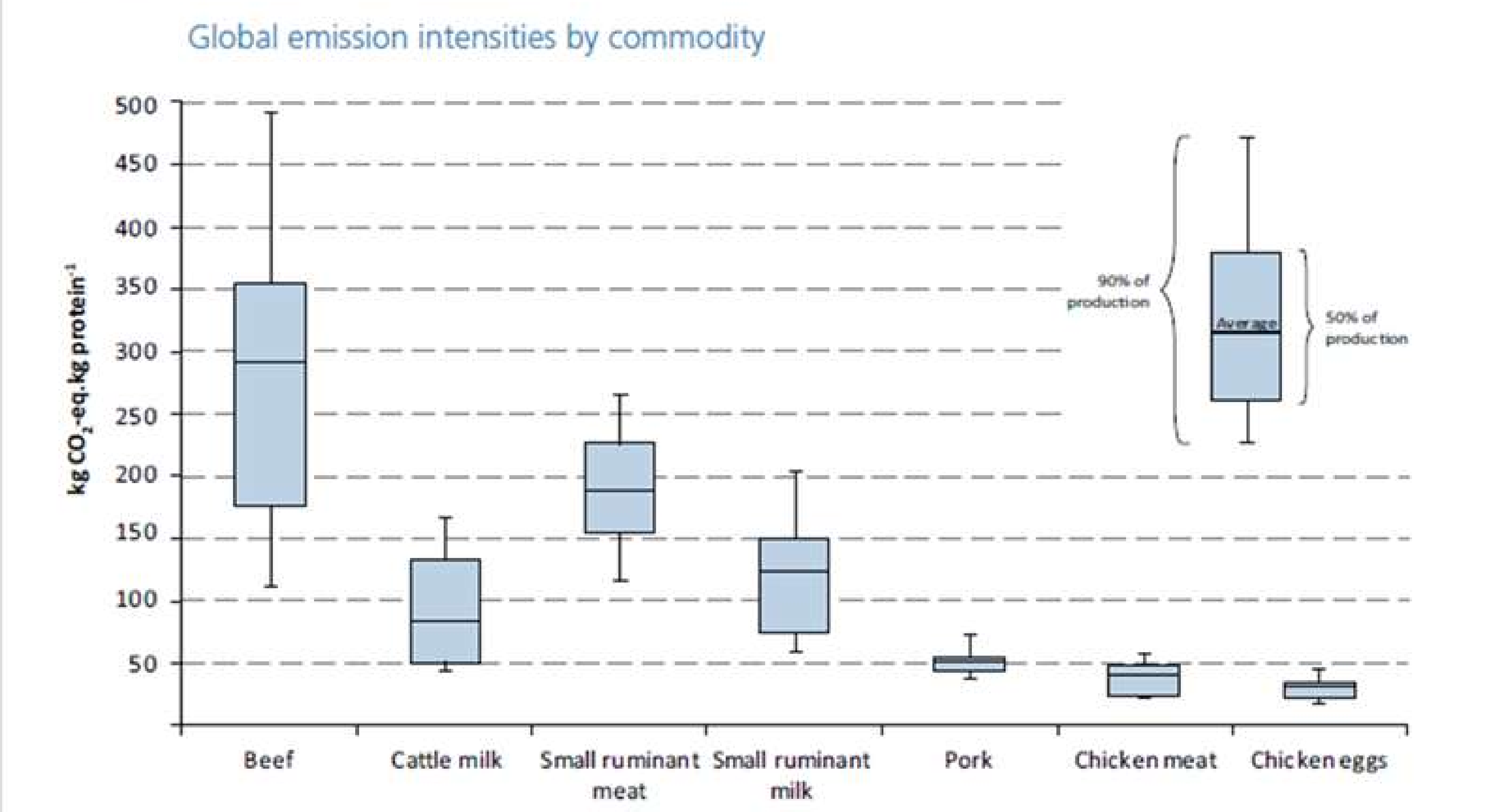


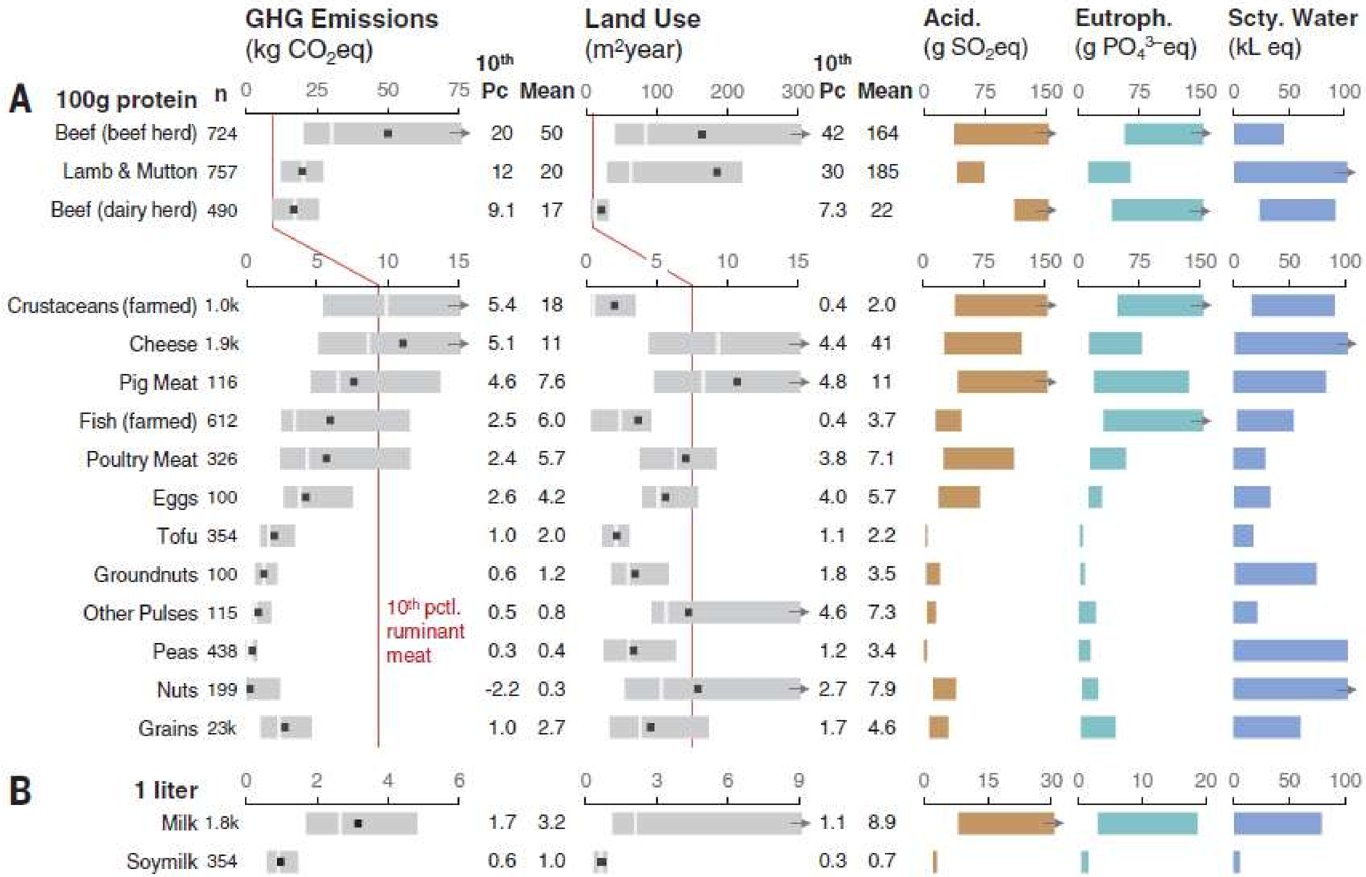
Fig. 7. Total greenhouse gas emissions from the various emission sources associated with livestock production in the EU-27.

Variability in CO_2 eq. emission
Due to many factors = Mitigation strategies



Source: GLEAM.

Variability in environmental impact
Due to many factors



Reducing food's environmental impacts through producers and consumers
Poore and Nemecek, Science 360, 987–992 (2018)

Variability in environmental impact
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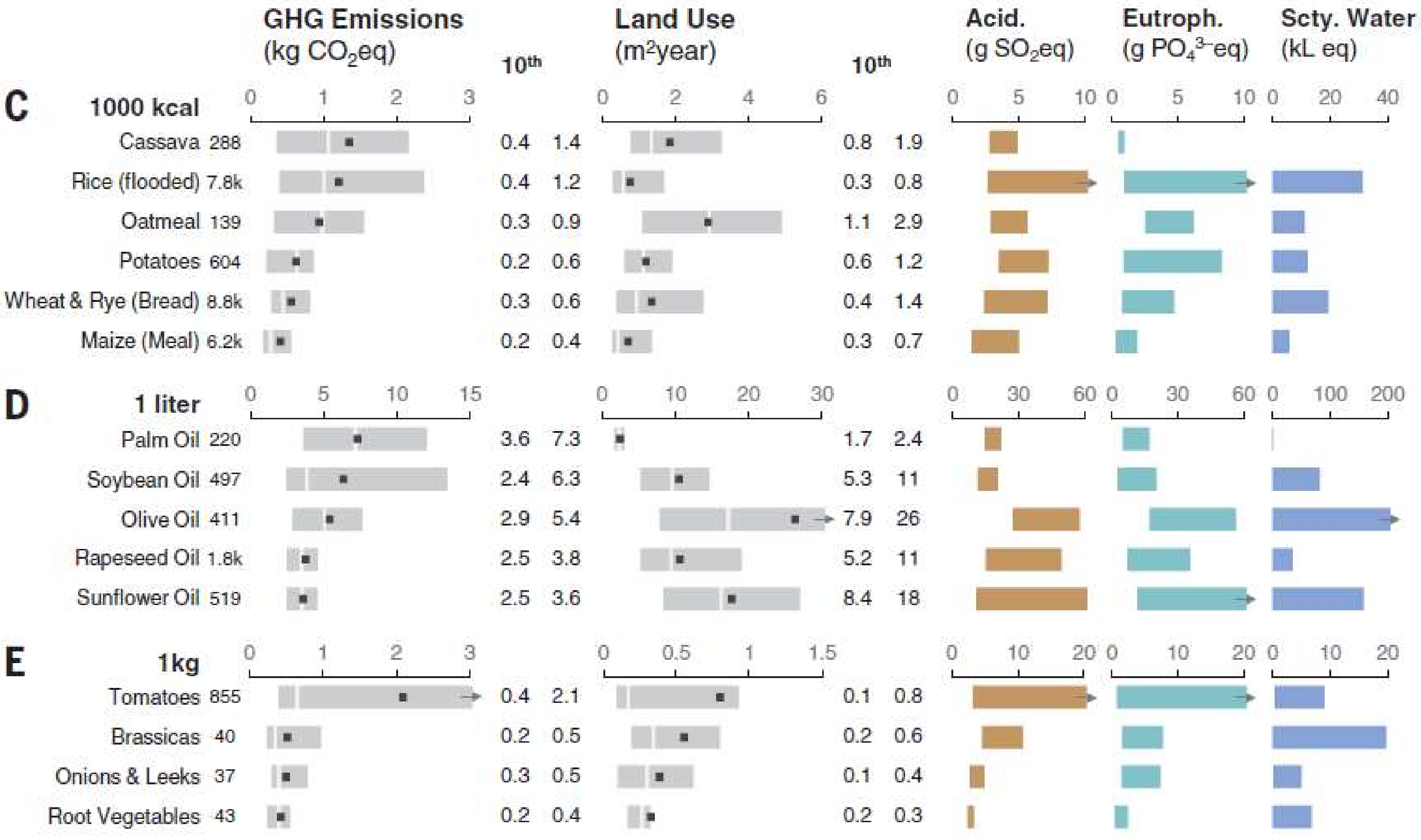

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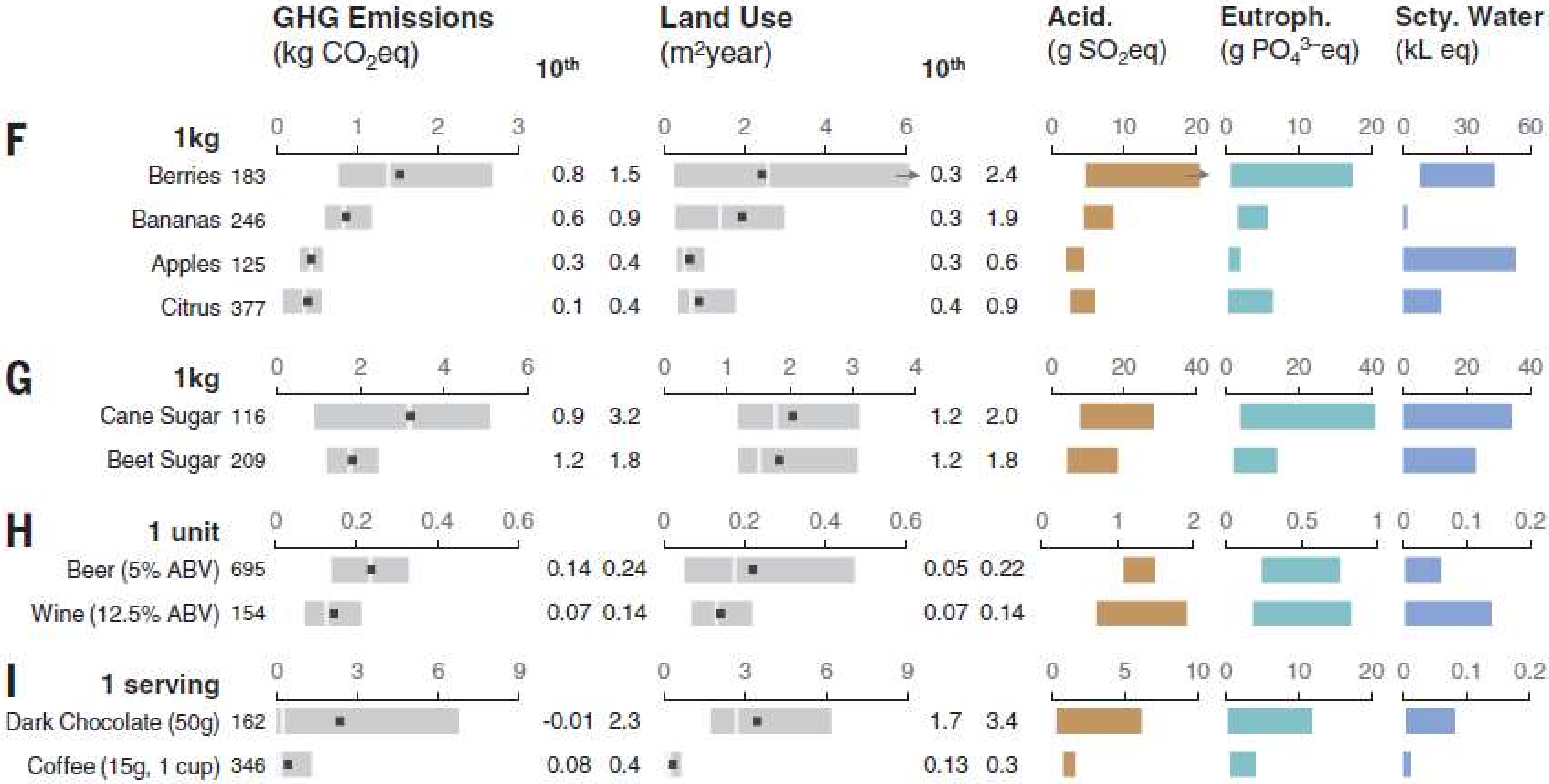
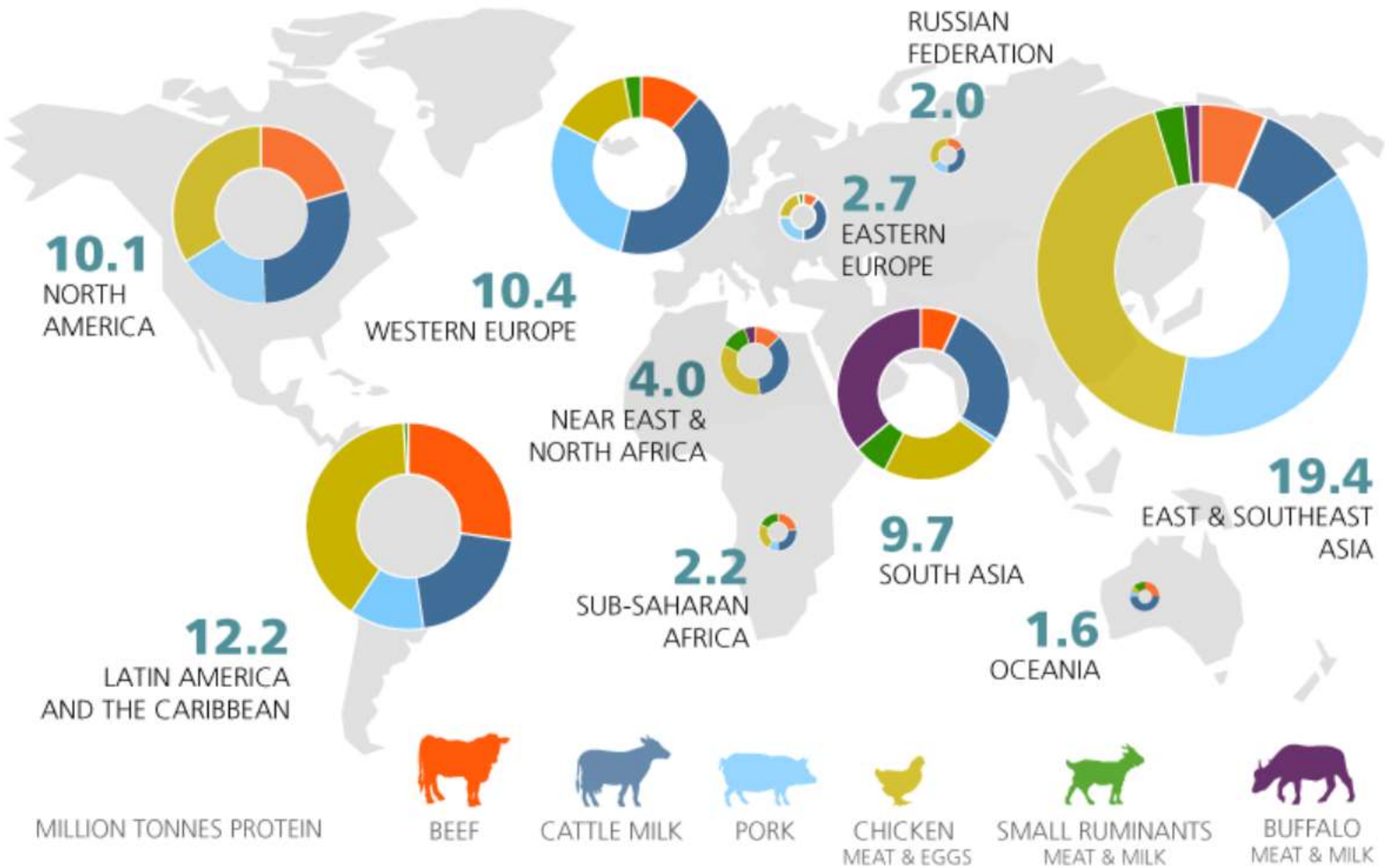


Reducing food's environmental impacts through producers and consumers
Poore and Nemecek, Science 360, 987–992 (2018)

Source of animal protein for food



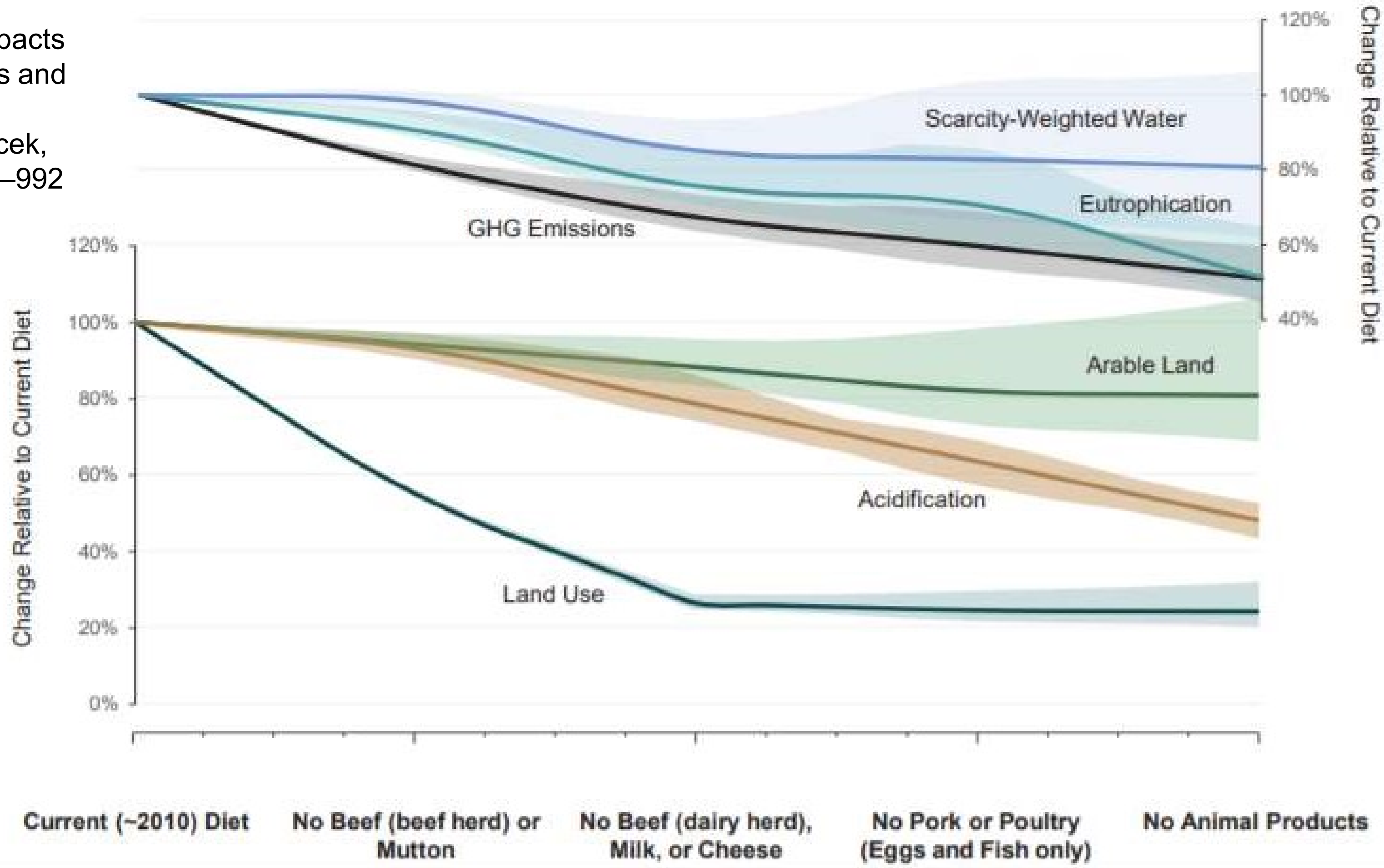
Mitigation potential

(with all Best Practices, at same level of production)

Mitigation potential of the global livestock sector. *The mitigation potential estimate excludes changes between farming systems and assumes the overall output remains constant.*

Food diet changes drive to mitigation

Reducing food's environmental impacts through producers and consumers.
Poore and Nemecek, Science 360, 987–992 (2018)



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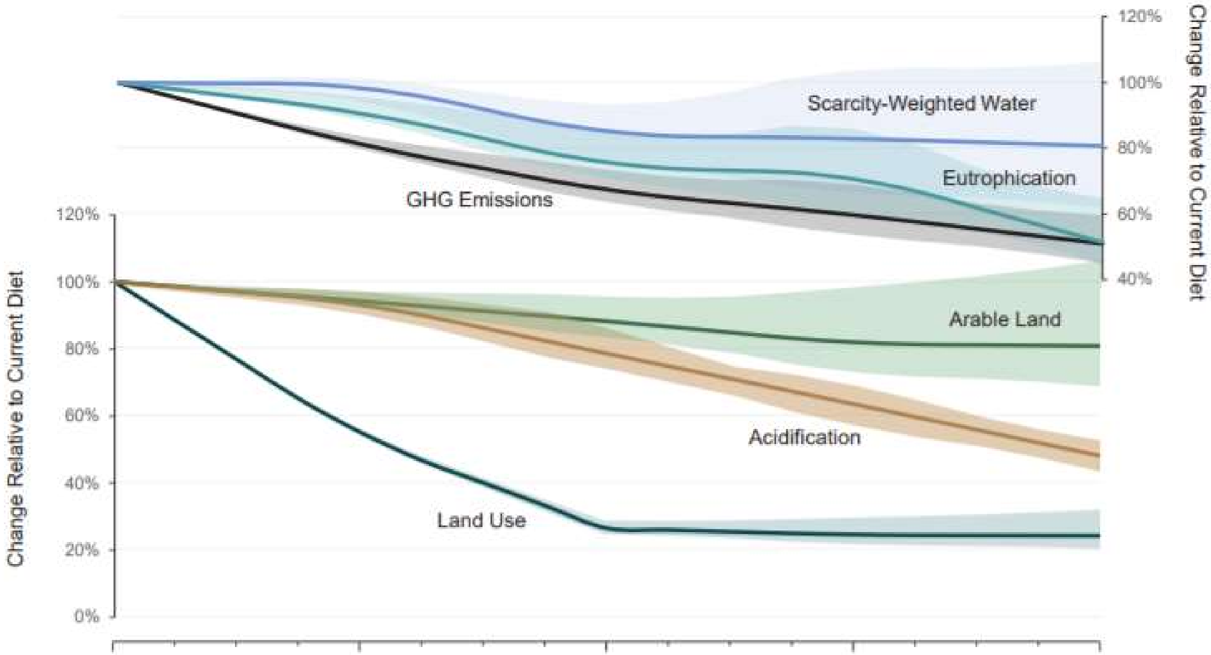

	Current (~2010) Diet	No Beef (beef herd) or Mutton	No Beef (dairy herd), Milk, or Cheese	No Pork or Poultry (Eggs and Fish only)	No Animal Products
Land Use (million ha)	**4,130**	**2,210**	**1,100**	**1,010**	**1,000**
Arable Land	1,240	1,170	1,100	1,010	1,000
Permanent Pasture	2,890	1,040	0	0	0
GHG Emiss. (Gt CO_2eq)	**13.65**	**10.98**	**9.08**	**8.13**	**7.04**
Land Use Change	2.67	1.84	1.54	1.05	1.02
Feed Production	1.10	1.09	0.98	0.52	0.00
Food Production	7.46	5.69	4.21	4.41	3.70
Processing	0.60	0.55	0.52	0.44	0.54
Packaging	0.80	0.79	0.80	0.74	0.78
Transport	0.63	0.63	0.63	0.61	0.62
Retail	0.39	0.39	0.40	0.36	0.38

Stimulants 17%
Sugar Cane 17%
Palm 7%
Cereals 12%
Cassava 10%
Soy 33%

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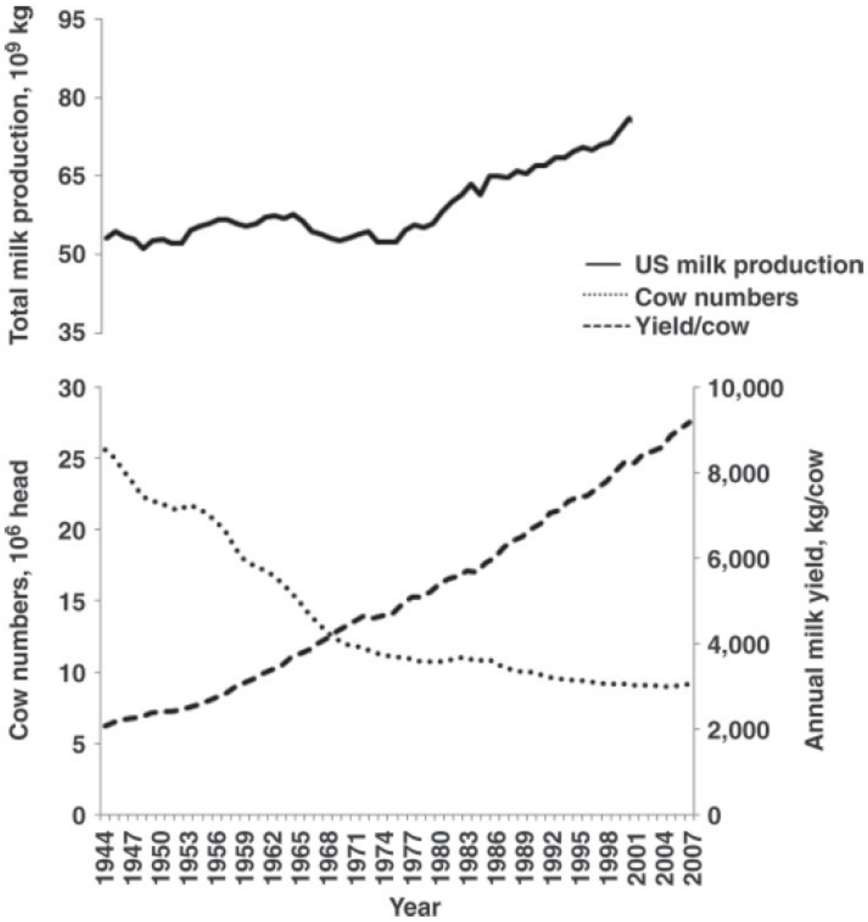
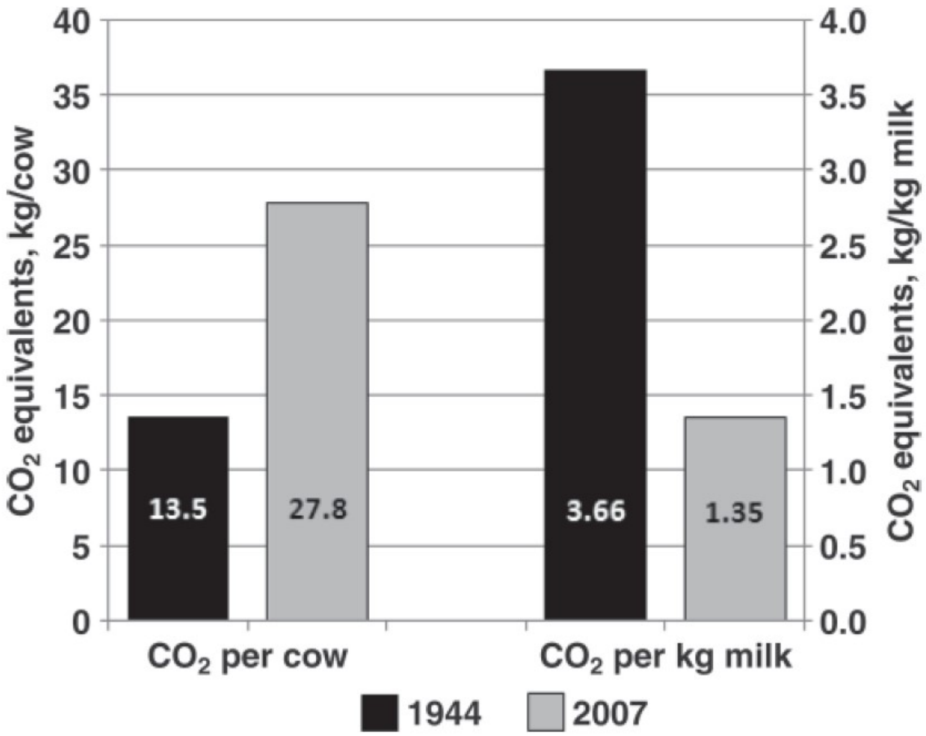
Transport	0.63	0.63	0.63	0.61	0.62
Retail	0.39	0.39	0.40	0.36	0.38
Acidification (Mt SO_2eq)	**89.0**	**83.4**	**69.4**	**55.8**	**44.1**
Farm	72.3	66.8	52.3	41.7	29.4
Post-Farm	16.7	16.6	17.1	14.1	14.7
Eutr. (Mt PO_4^{3-}eq)	**64.7**	**58.8**	**48.3**	**46.6**	**32.7**
Farm	61.6	55.8	45.4	43.9	29.7
Post-Farm	3.1	3.0	2.9	2.7	3.0
Freshwater Withdr. (km^3)	**2,200**	**2,200**	**1,900**	**1,900**	**1,700**
Scarce-Wtd. Wtr. (km^3eq)	**74,300**	**73,800**	**62,300**	**61,600**	**59,900**
Food Losses (%)	**26.7%**	**26.6%**	**26.6%**	**26.4%**	**26.8%**
Farm to Distribution	4.9%	4.9%	4.8%	4.6%	4.8%
Distribution to Retail	13.8%	13.8%	14.2%	14.2%	14.4%
Consumer (not incl.)	10.5%	10.5%	10.2%	10.0%	10.2%
Food Miles (million tkm, farm to consumer)	**9,395**	**9,395**	**9,385**	**9,385**	**9,375**
Road	2,910	2,900	2,890	2,880	2,870
Rail	930	930	930	930	930
Water	5,540	5,550	5,550	5,560	5,560
Air	15	15	15	15	15

Stimulants 17%
Sugar Cane 17%
Palm 7%
Cereals 12%
Cassava 10%
Soy 33%

Reduction in food waste and food miles associated with changing from animal to vegetable proteins is offset by higher consumption of fresh fruit and vegetables

Milk productivity is a driver

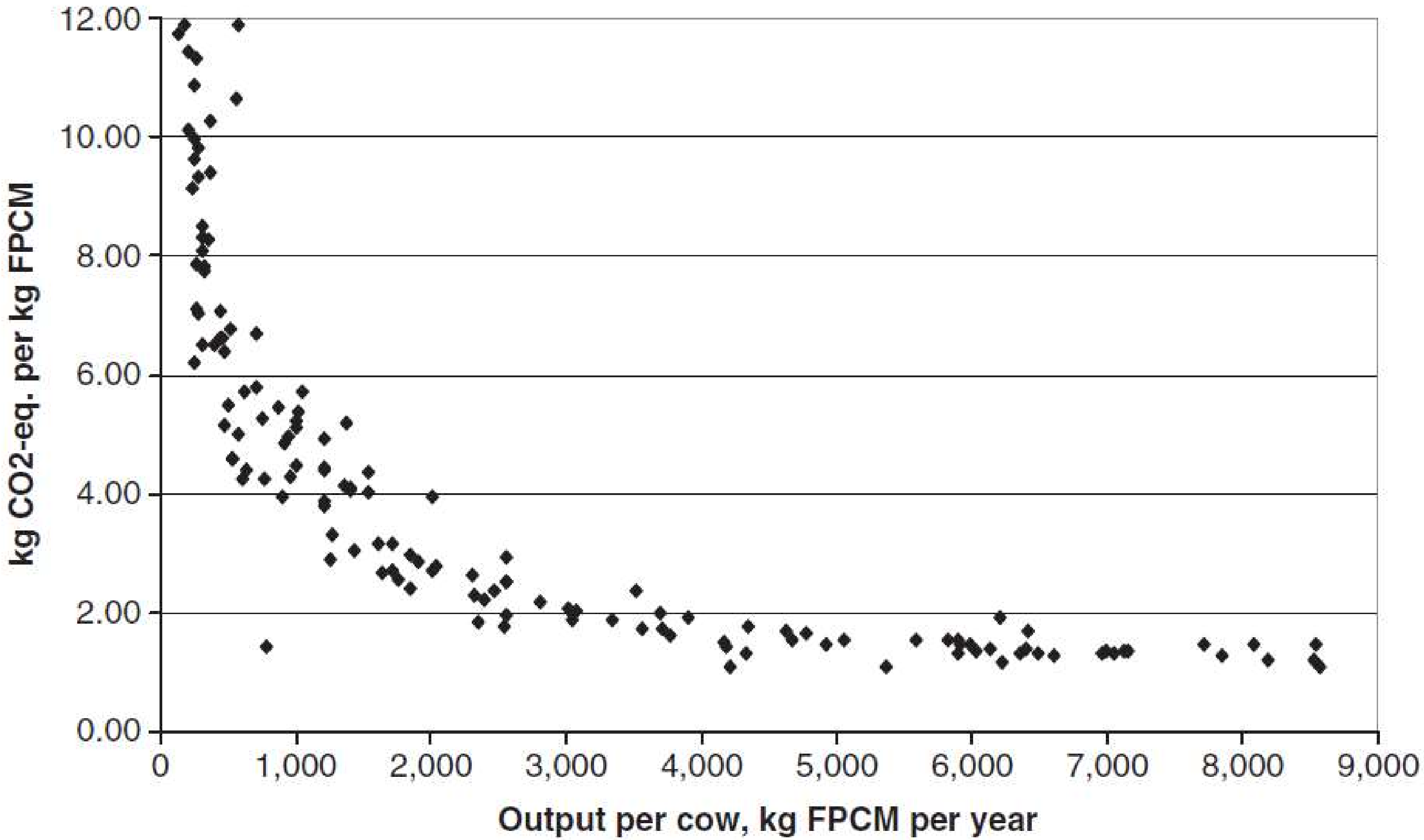




The environmental impact of dairy production: 1944 compared with 2007
Capper et al., *J ANIM SCI* 2009, 87:2160-2167

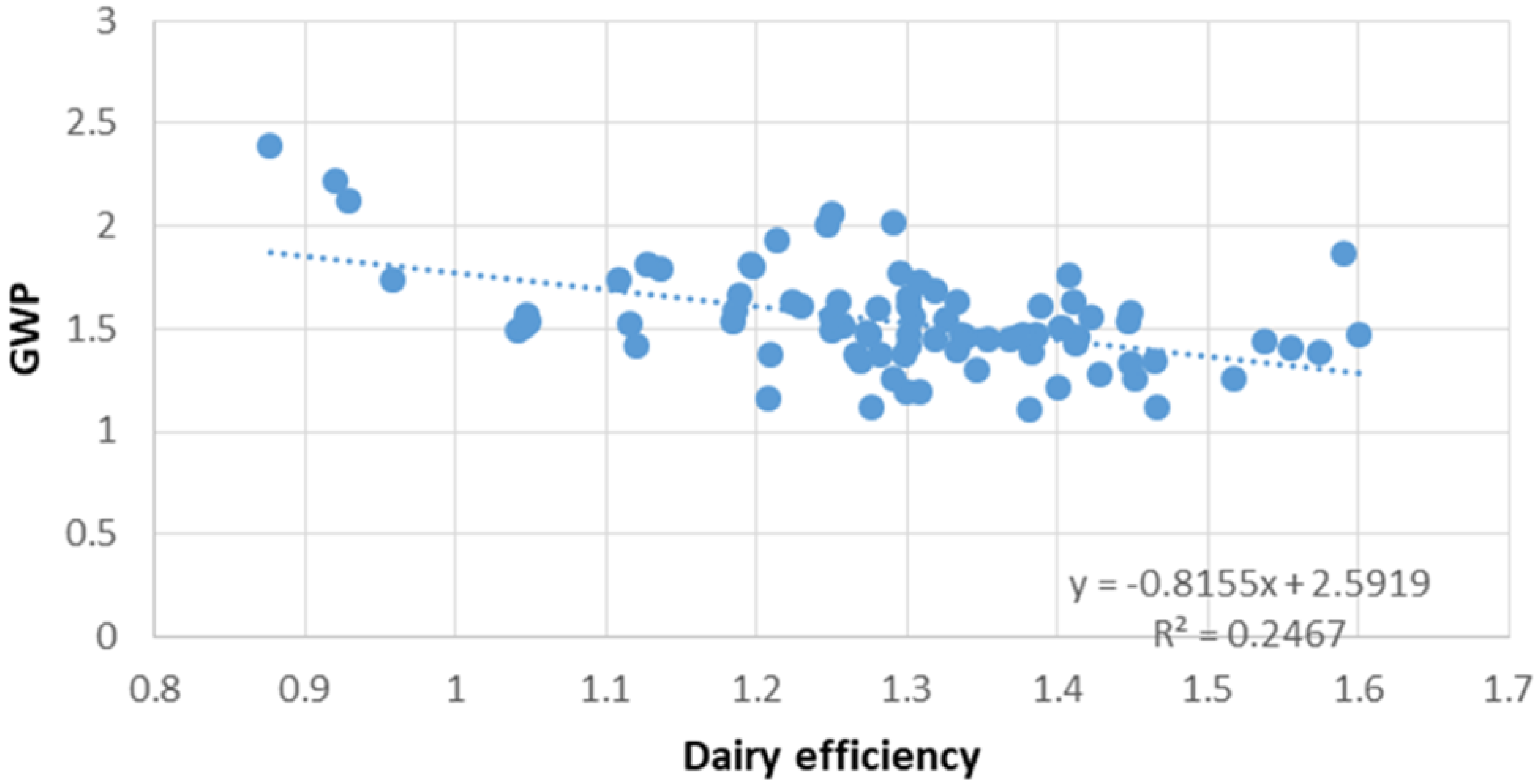
Total milk production per cow is a way

Milk production and improvement depend on: genetic performance, feeding enhancement, reproduction factors, animal health, animal welfare……



Dairy Efficiency (kg FPCM/kg DMI)

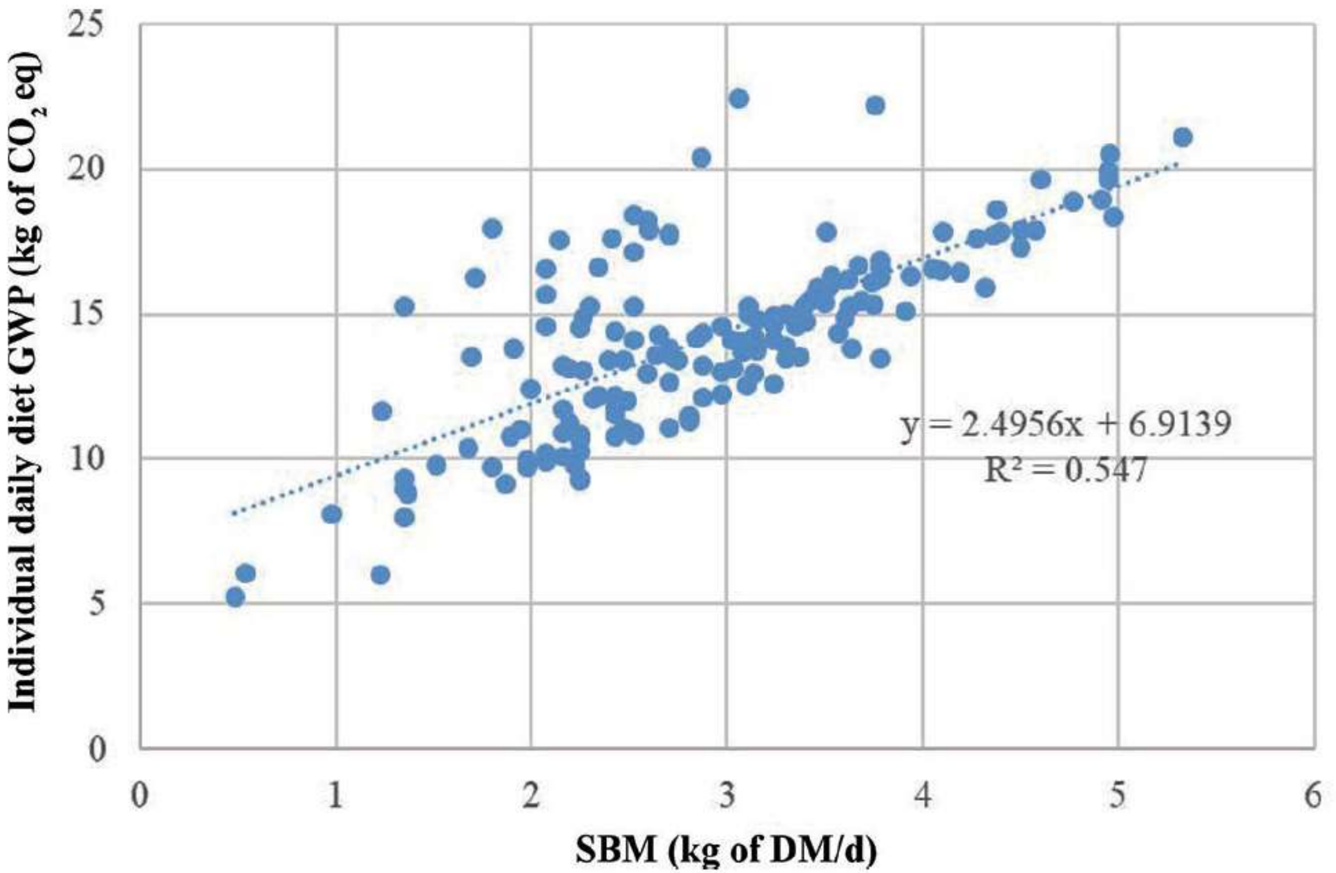
White (2016): decrease of 10% of *Dairy Efficiency* can cause increase of 6-8 % in CO_2 eq. kg/kg FPCM



Feed rations for dairy cows

Most of responsibility is on SoyBean Meal production

Gislon et al., 2020 - J. Dairy Sci. 103:4863–4873



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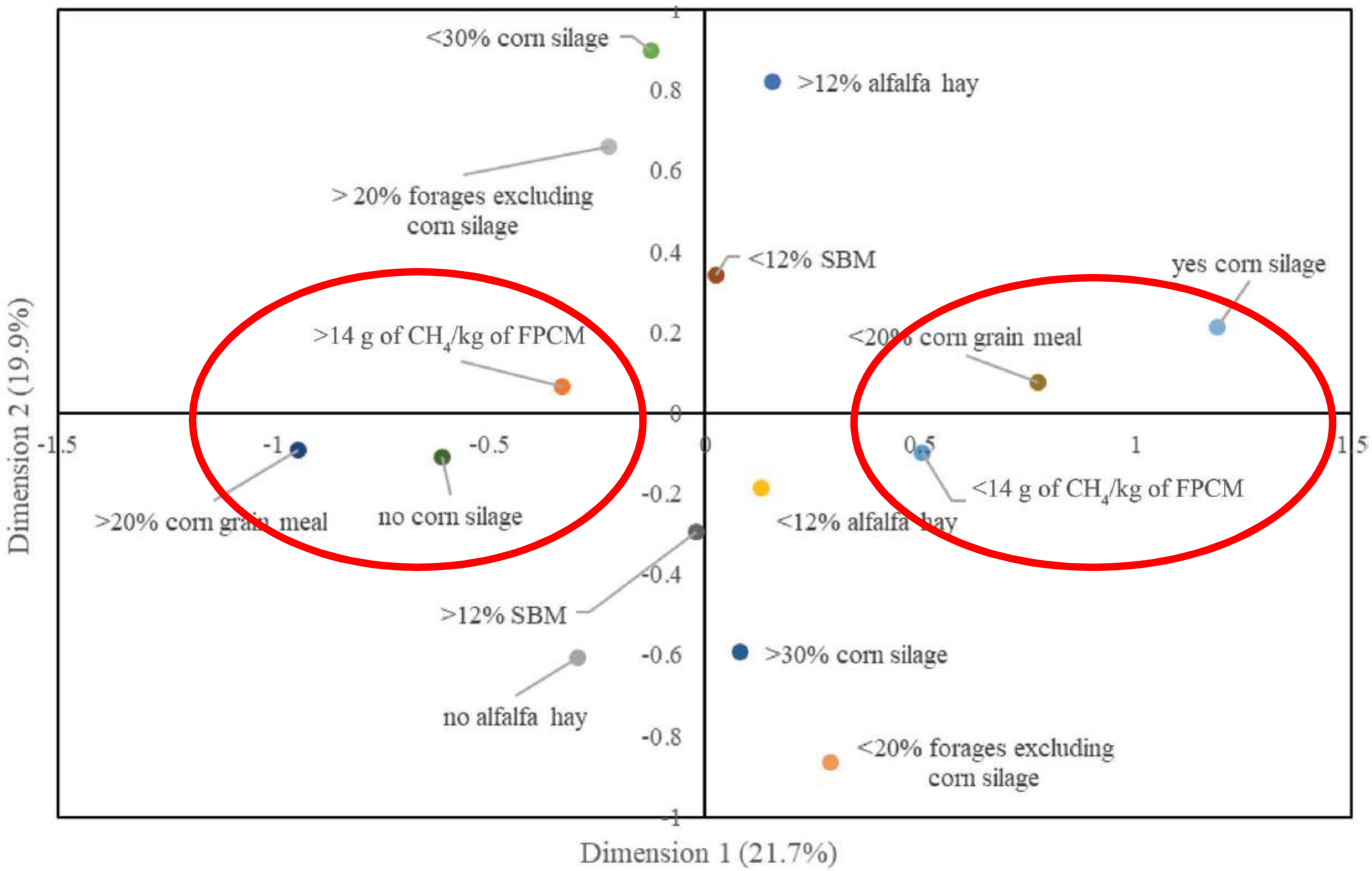


Methane mitigation on Enteric emission

Integrated approaches at long term: ruminal microbiota, diets, animals, manure management…..

Knowledge and economic premium: farmers' education, incentive, NO taxes (i.e. Carbon Tax)

- Methane mitigation is driven by decreasing of **Production of H_2 ,** without any effects on digestibility/degradability of feeds (but negative effects on milk production)
- Inibition of methanogenes (*Archaea*)

Martin et al., Animal (2010), 4:3, 351–365

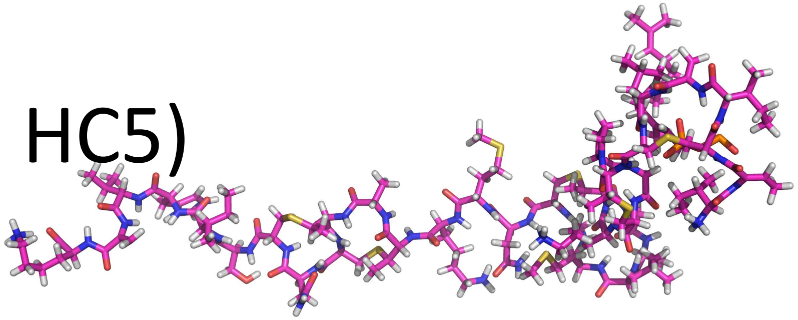
Methane mitigation by biotechnology

- Vaccination against methanogenes

  low effect (8-10%), no replicable, no in the long term

  (probably due to other methanogenes species)

- Antibodies
  - No in the long term
- Bacteriocins (nisin, bovicin HC5)
  - Just *in vitro*

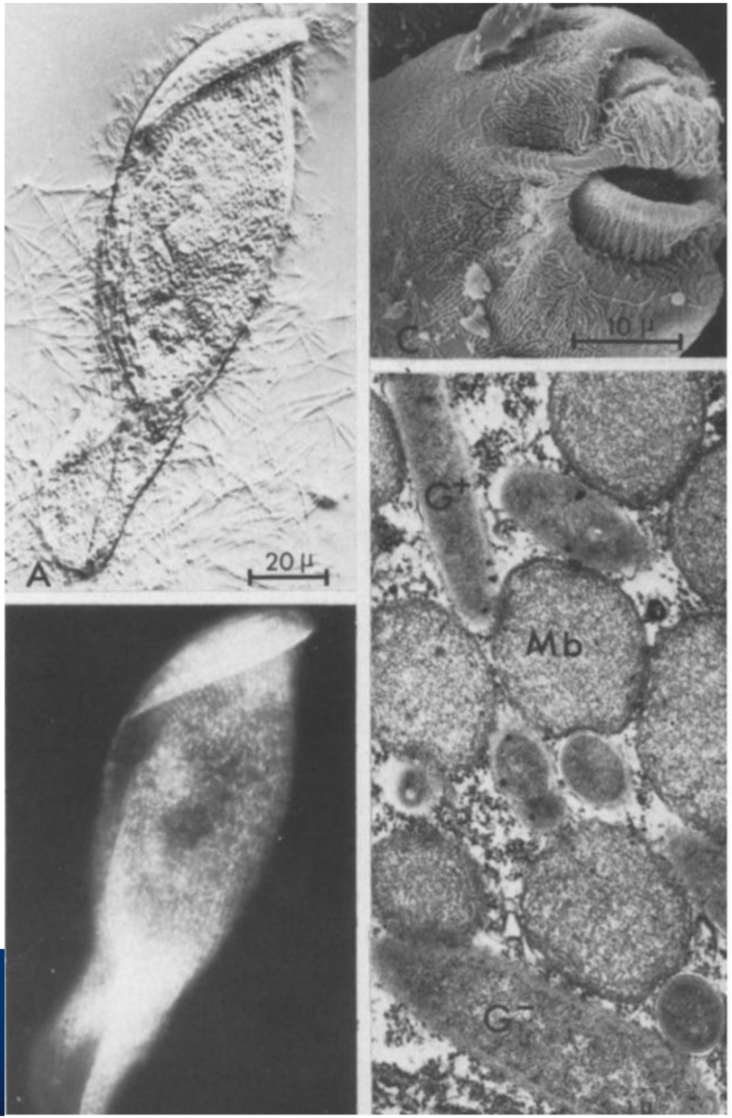


- Virus bacteriophages: active on methanogenes?

Methane mitigation by probiotics

- Probiotics to stimolate **acetogenesis bacteria** (capture of CO_2 e H^+ to produce acetic acid) as in small intestine with pH>7. In rumen they are less efficient than methanogens, because of high concentration of CO_2 , and the reaction is thermodynamically unfavorable
- Use of **yeast** as *Saccaromyces* (positive effect as a probiotic, but low effect on methanogenes)

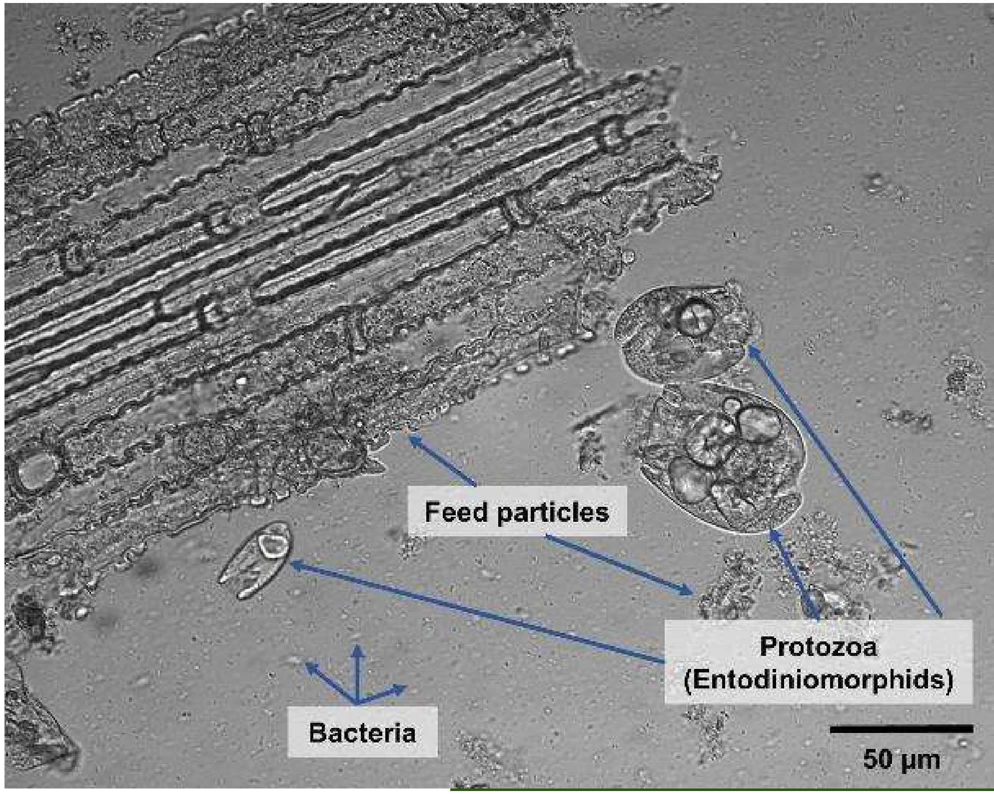
Methane mitigation by elimination of protozoa



Fig

Capt

Fig. 3. Symbiosis of methanogens with ciliates. A. Metopus laminarius from freshwater sapropel. The cell is surrounded by extruded trichocysts; differential interference contrast. B. Same cell; methanogens revealed by epifluorescence microscopy as intracellular rods. C. Eudiplodinium maggii from a cellulose-fed culture; the celt is covered with… Read more



Methane mitigation by elimination of protozoa

- **Protozoa** are also producers of H_2, and host *archaea* on the surface. These *Archaea* are responsible of 10-35% of total CH_4
- Lipids, saponins, tannins and ionophores are toxic for protozoa ➡ MITIGATION ACTIONS
- BUT, the capacity to adaptation on new conditions in rumen, it is due to protozoa capacity to adaptation
  ➡ short term effect
- AND protozoa represent 40-50% of protein in intestine

Methane mitigation

additive use in the diet

Use of forages

Legume for decreasing CH_4

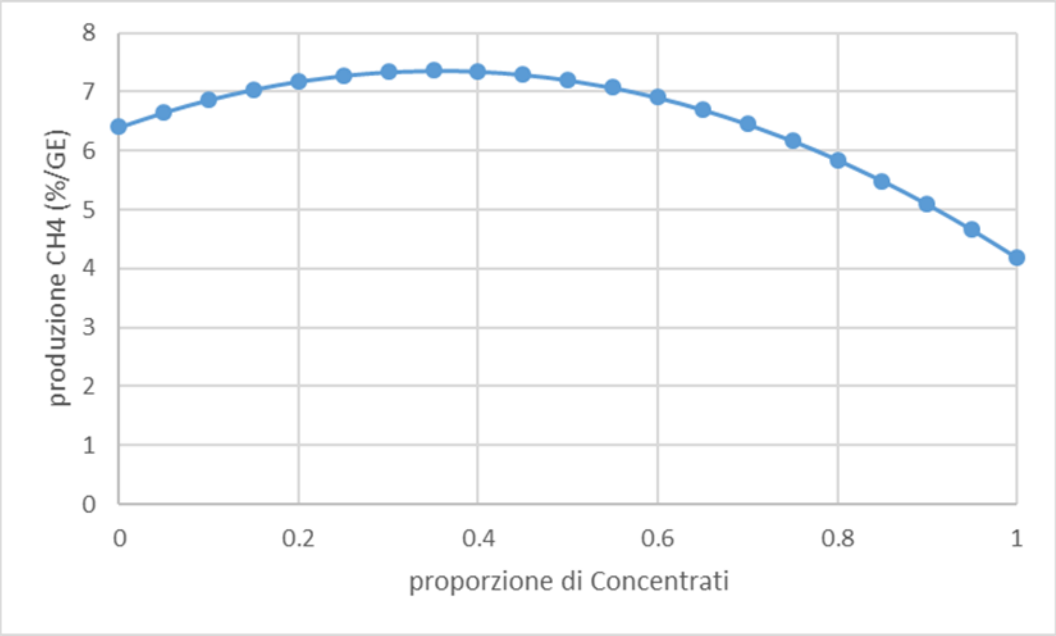
- Because of digestibility/degradability and intake increase
- Presence of tannins (sulla, lupinella, ginestrino….no trifogli)
- Young forages decrease CH_4, high sugars
- Silages decrease CH_4
- Pelleted forage decrease CH_4

Methane mitigation

additive use in the diet

Use of concentrate

<u>decreasing</u> CH_4 maximum level of 7,6% GE for 35% concentrate



Methane mitigation

additive use in the diet

Use of concentrate

- *Because of cellulose and hemicellulose produce acetate, while starch and sugars produce propionate*
- *And decrease pH that decrease protozoa,*
- An example: in Buffalo no effects (*Fibrobacter succinogenes* don't produce H_2)

Methane mitigation

additive use in the diet

Use of lipids

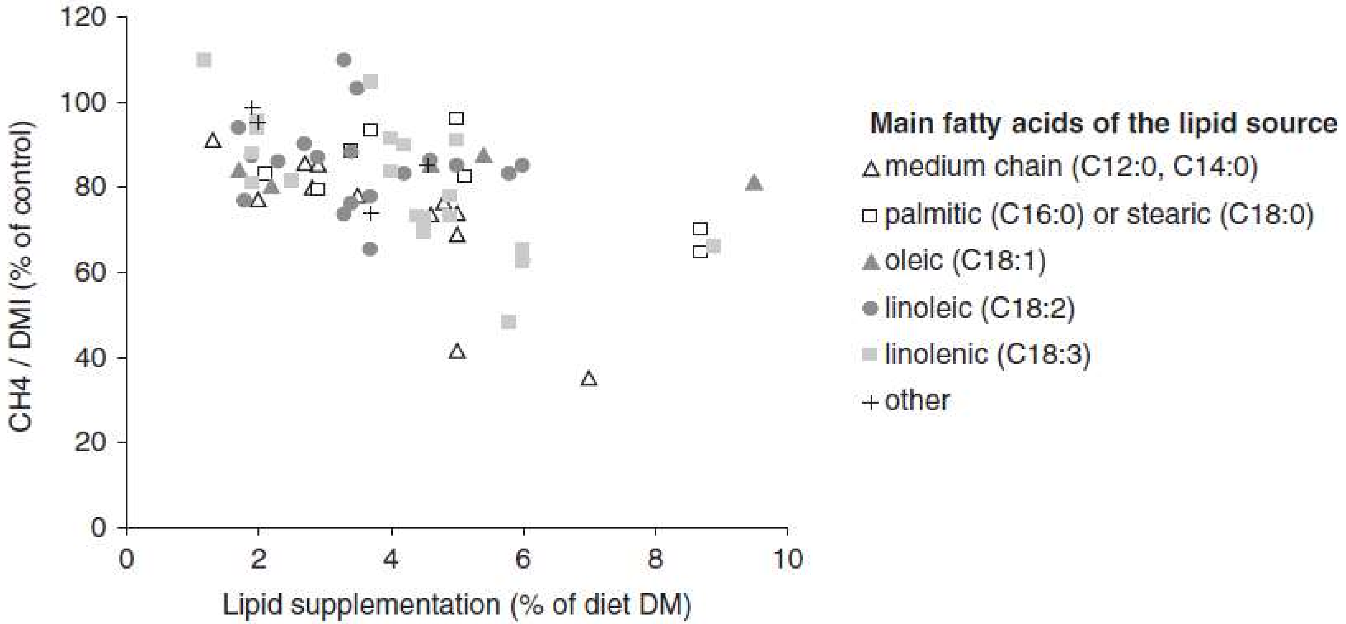
- Lipids decrease CH_4 2,2% for each % of added lipids
  (Giger-Reverdin et al., 2003; Eugene et al., 2008)
- Lipids decrease CH_4 5,6% for each % of added lipids, on sheep and goats (Beauchamin et al., 2008)
- Short term effect – adapation of bacteria

Methane mitigation

additive use in the diet

Use of lipids

- Review Martin et al. (2010) decrease 3,8% for each % of added lipids, but dependent on FA origin (*medium chain*)



Mitigation effects on farm level

Effect of mitigation options on direct and indirect emissions on grass/fertiliser-N farm.

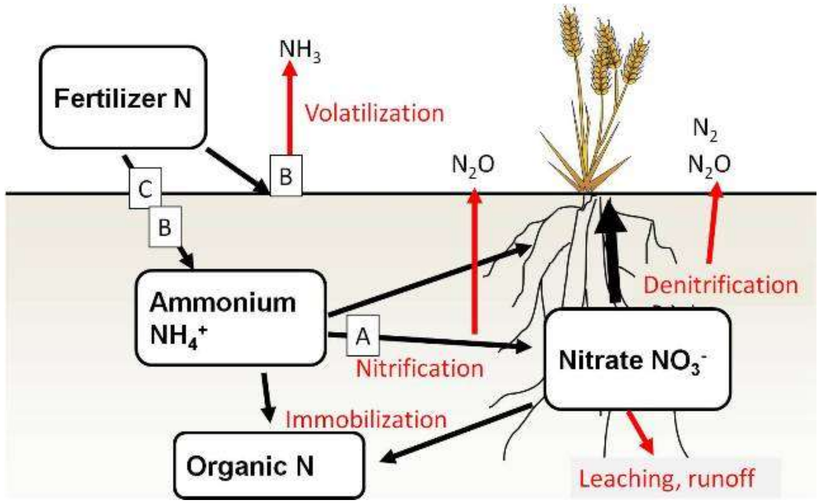
	Present	Less mineral fertiliser	Less grazing	More milk per cow	No grassland renovation
Methane	7623		+289	−281	
Nitrous oxide (direct)	3220	−151	−273	−73	−10
Nitrous oxide (indirect)	1381	−34	−29	−88	+24
Carbon dioxide (direct)	263		+55	+10	−10
Carbon dioxide (indirect)	3582	−82	−5	−11	−4
Carbon sequestration	−6468				−843
Total (kg CO_2 ha^{-1})	9597	−267	+37	−443	−843
Total (kg CO_2 kg $FPCM^{-1}$)*	0.70	−0.02	0.00	−0.03	−0.06
Ammonia volatilisation (kg N ha^{-1})	57	−0.6	+3.4	−1.1	0
Nitrate leaching (kg N ha^{-1})	20	−1.5	−1.8	−2.1	0

A farm level approach to define successful mitigation strategies for GHG emissions from ruminant livestock systems. Schils et al., Nutrient Cycling in Agroecosystems 71: 163–175, 2005.

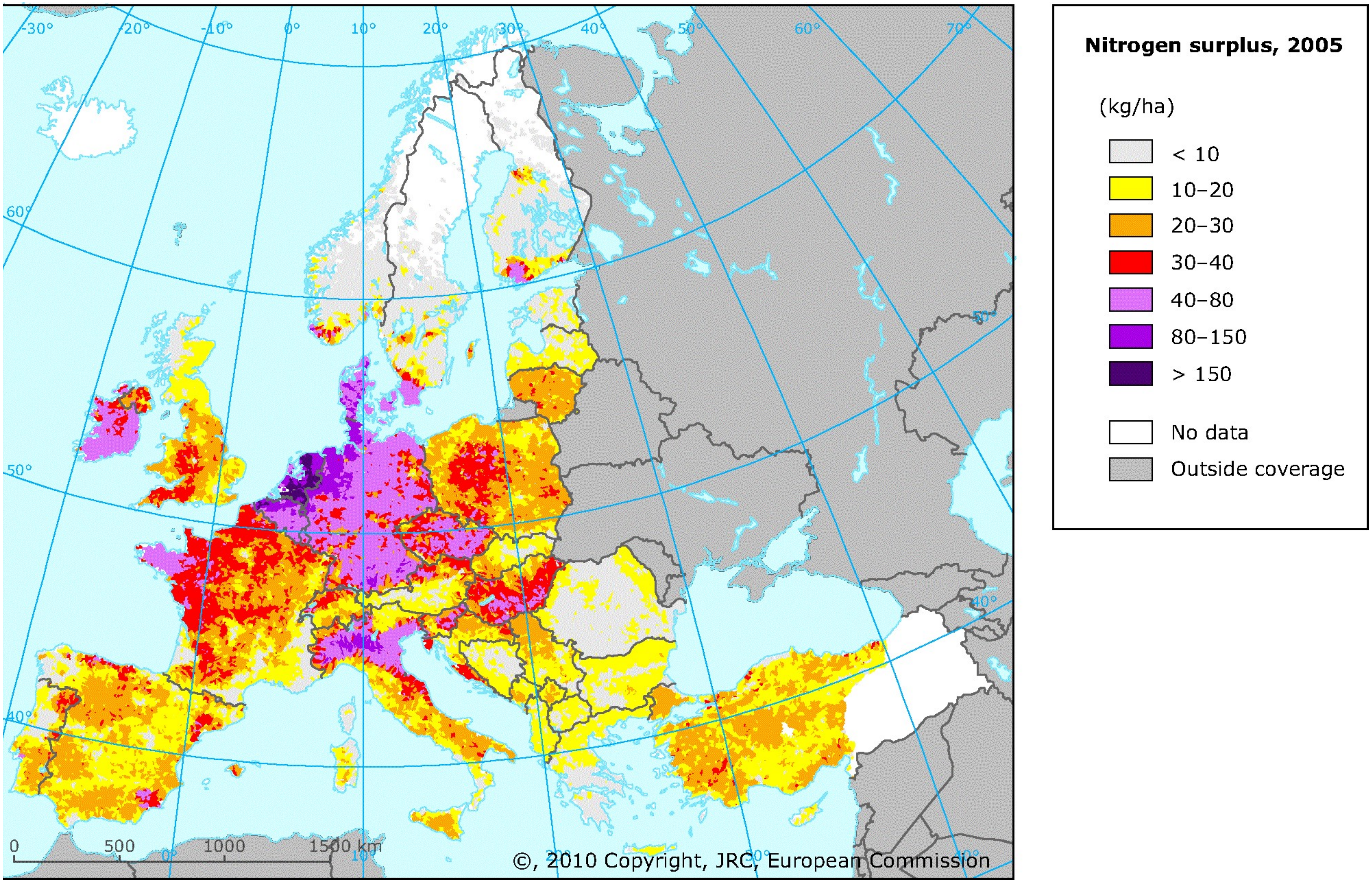
Eutrophication

Eutrophication of the waters

- Caused by nitrogen and phosphorus released on agricultural soils in the form of mineral fertilizers and animal wastes in excess compared to the utilization ability by the plants, or to the immobilization capability of the soil
- Nutrients accumulate in the soil and tend to transfer to surface waters (runoff; N and P) and groundwater (leaching; N)

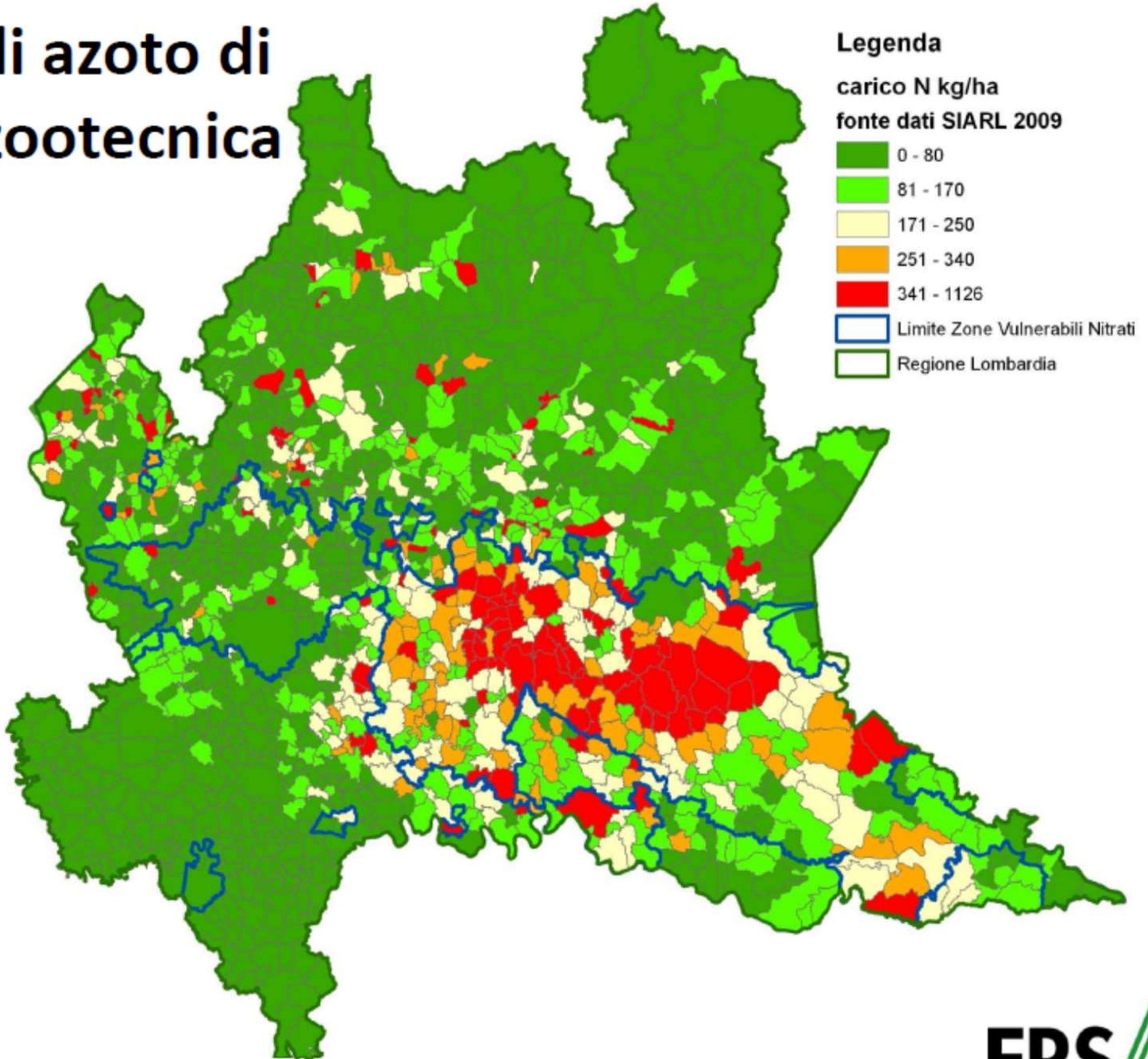


N balance per ha (EU)

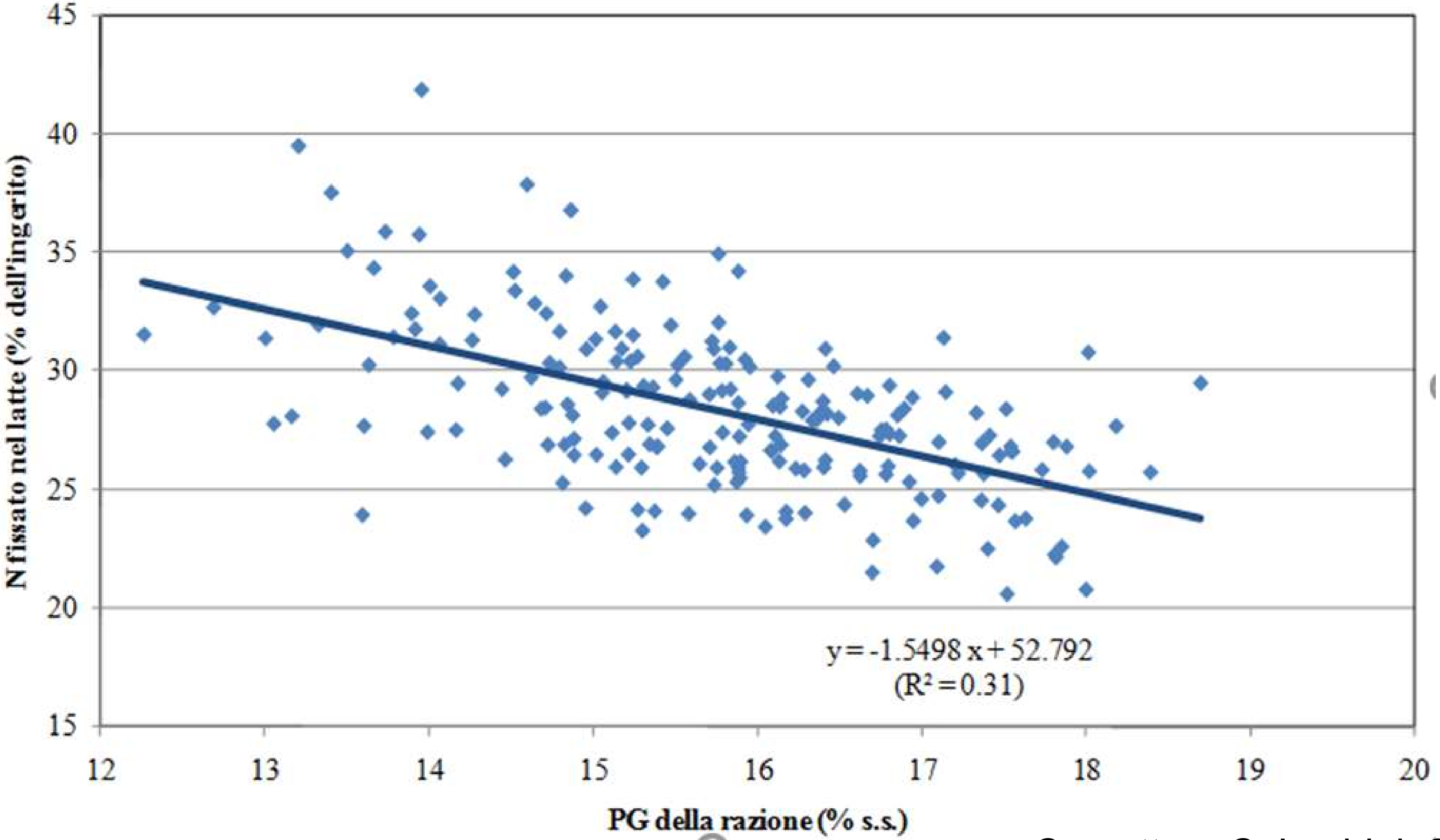


Carichi di azoto di origine zootecnica

DIRETTIVA NITRATI

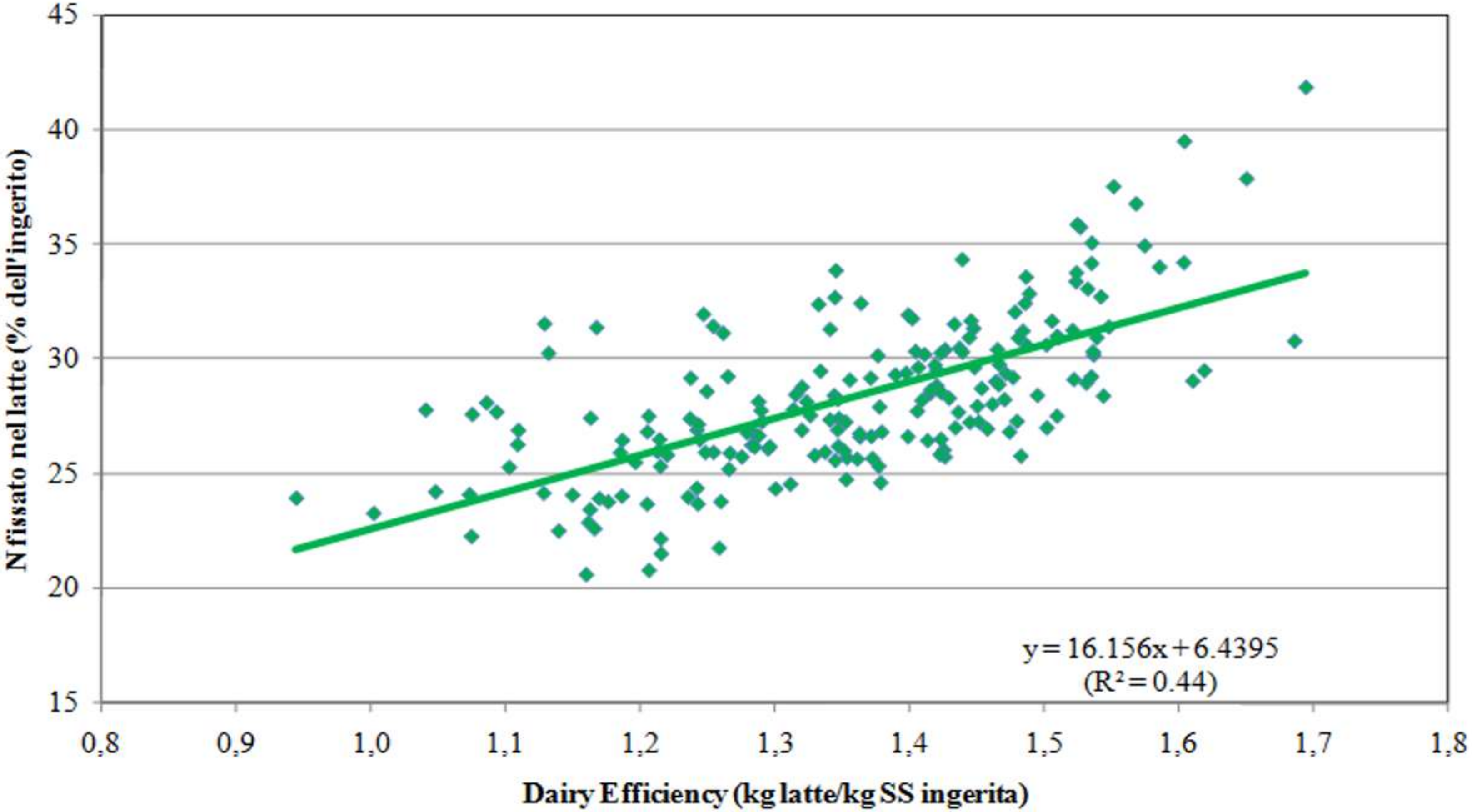


N efficiency in dairy cows



Crovetto e Colombini, 2010

N efficiency and Dairy Efficiency



Crovetto e Colombini, 2010

Equations for N uptake

- N uptake (g/d) = 2,82 x Milk (kg/d) + 346 (Nennich et al., 2005)
- N uptake (g/d) = DMIntake (kg/d) × diet CP (g/g DM) × 84,1 + BW (kg) × 0,196 (Nennich et al., 2005)

- **N fecal, depends of apparent digestibility of N**
- N urinary (g/d) = 2,76 x diet CP – 233 (Nousiainen et al., 2004)
- N urinary (g/d) = 2,64 x diet CP + 1,66 x Milk – 262 (Nousiainen et al., 2004)

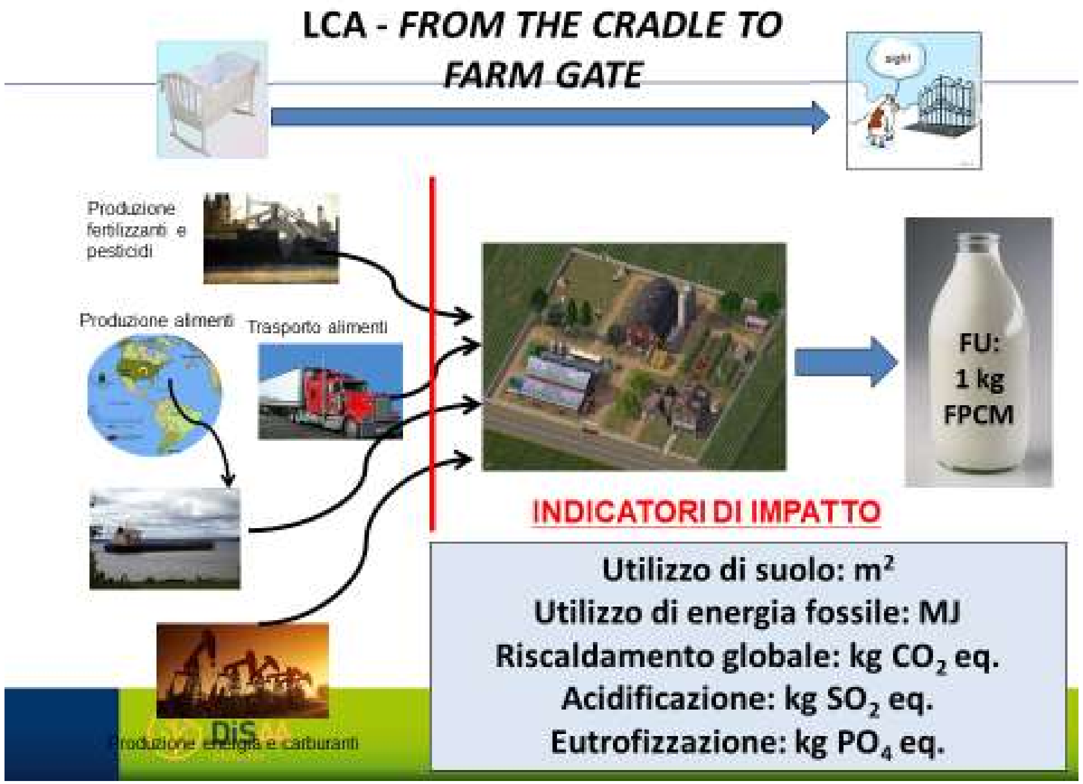
Equation verification

(Rapetti et al., 2018)

	Pirondini et al., 2015[3]	CNCP S vs 6.5[4]	Nennich et al., 2005[5]	Nennich et al., 2005[6]
Peso vivo (kg)	626	626		626
Ingestione di sostanza secca (kg/d)	22,8	22,8		22,7
Proteina grezza della dieta (%)	14,7	14,7		14,7
Latte prodotto (kg/d)	27,0	27,0	27,0	
Proteina grezza del latte (%)	3,77	3,77		
MUN[1] (mg/dL)	10,1	**8,9**		
Bilancio dell'azoto				
N ingerito (g/d)	533	**533**		
N fecale (g/d)	207	**210**		
N urinario (g/d)	168	**163**		
N deiezioni (g/d)	375	**373**	**422**	**402**
N latte (g/d) 30 %	160	160		
N ritenuto (g/d)	-2	0		
Volatilizzazione[2] dell'N (%)	28	28	28	28
N al campo (g/d)	270	**269**	**304**	**290**

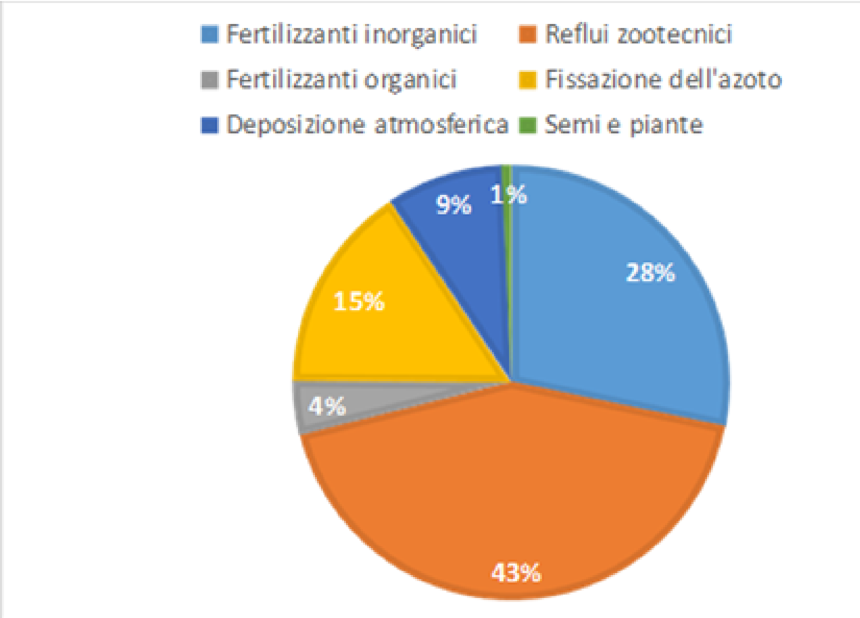
Easy use of N farm balance (kg/ha)

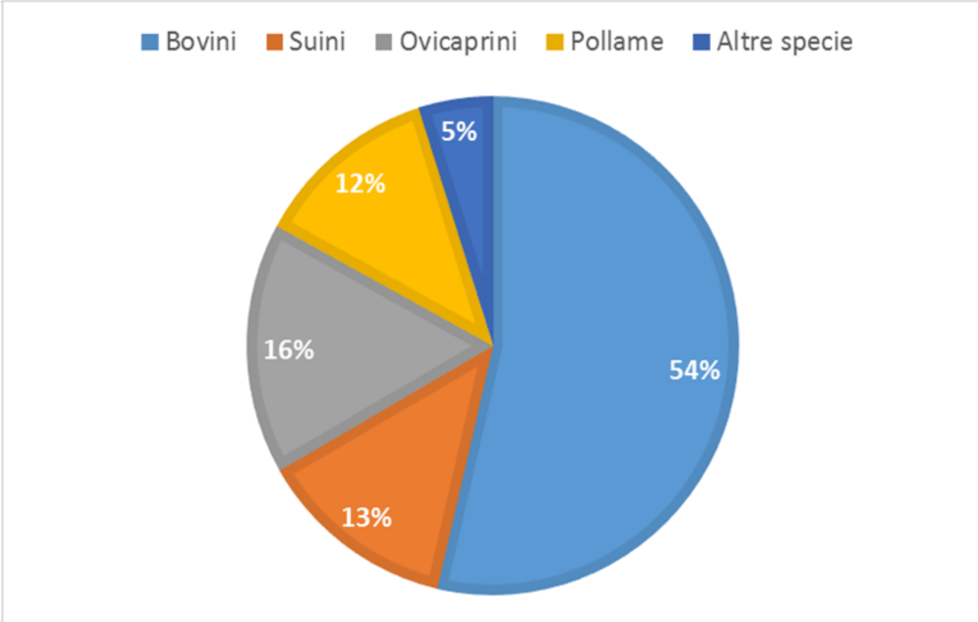
Balance (kg N/ha) = (Output N – Input N)/ha



Contributionof N sources on soils

Italy 2014





Eurostat, 2017
Gross Nutrient Balance

Acidification

Acidification (g SO_2)

Soil and water problems

- SO_x (mainly sulfur oxide) not from agriculture
- SO_2 sulfur dioxide (not from agriculture)
- NO_x = NO monoxide and NO_2 dioxide from NH3

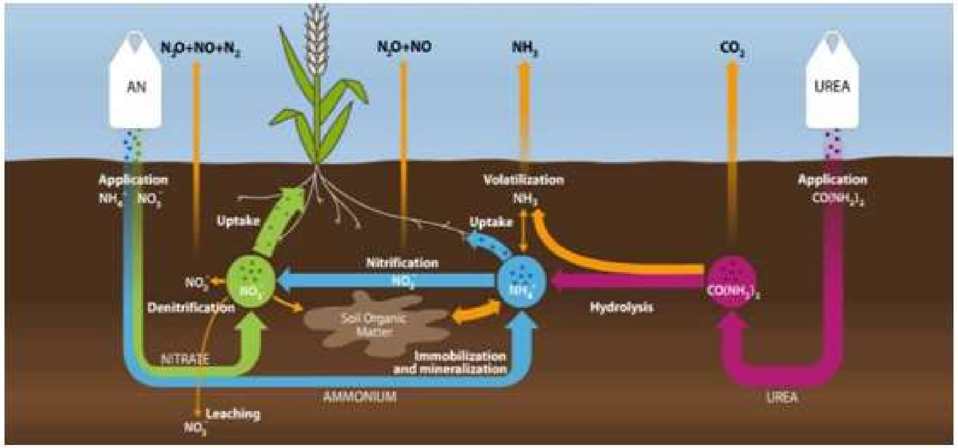
From these molecules, sulfuric and nitric acid are generated in the atmosphere, which precipitate by gravity or by rain (pH modification in soil and water)

Ammonia Emissions

Acid rain (**acidification**)
Particulate (PM 2,5)

More than 90% of ammonia come from agriculture:

- Manure and slurry (urease)
- N fertilizers



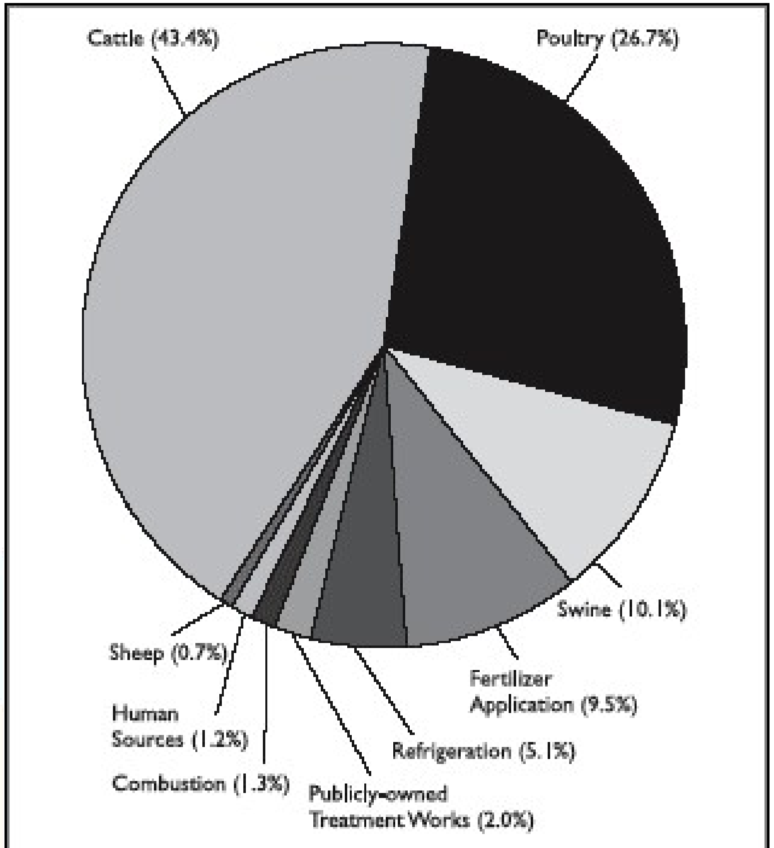
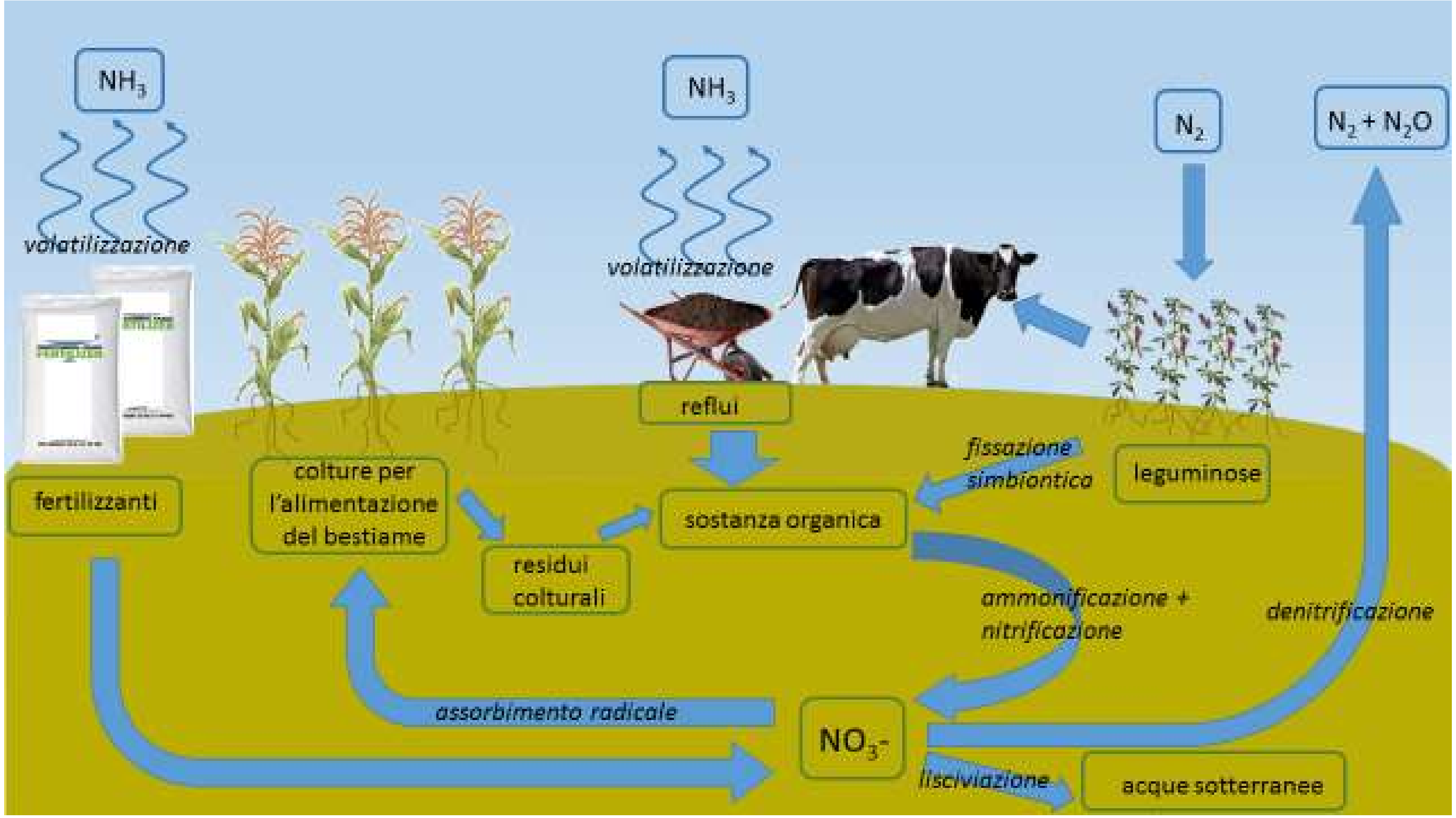
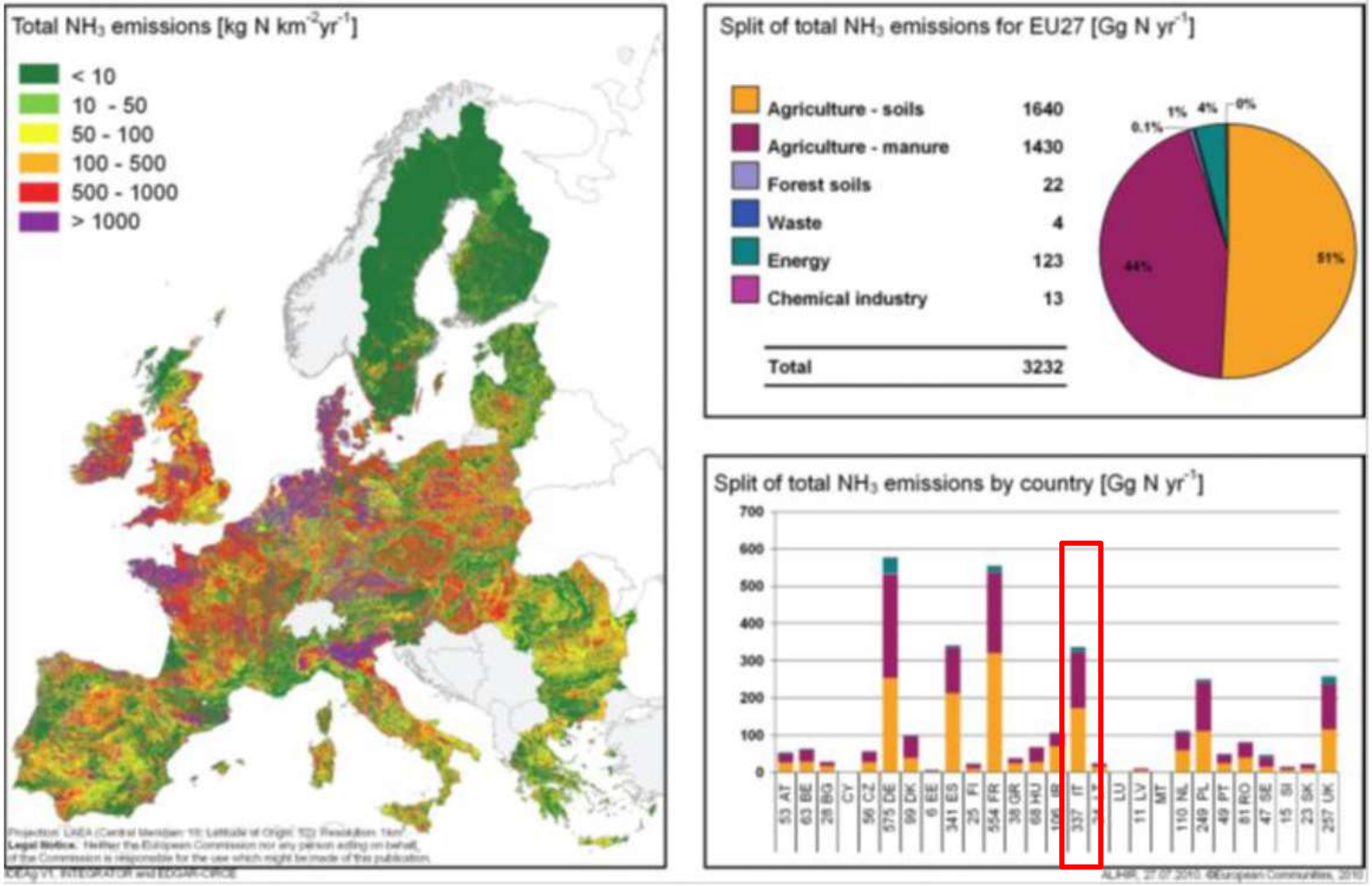


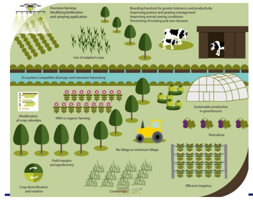
Figure 2. Estimates of ammonia emissions from man-made sources in the U.S. in 1994 (Battye et al., 1994).

N and NH_3


NH3
volatilizzazione
fertilizzanti
colture per
l'alimentazione
del bestiame
residui
colturali
NH3
volatilizzazione
reflui
sostanza organica
N2
N2 + N2O
fissazione
simbiontica
leguminose
ammonificazione +
nitrificazione
denitrificazione
assorbimento radicale
NO3-
lisciviazione
acque sotterranee

Ammonia Emissions in UE



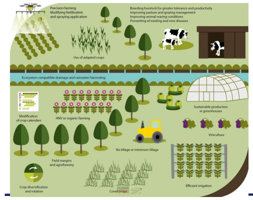


Mitigation and agriculture

Global mitigation potential at 2030

5,5-6 Gt CO_2 eq/year (on total of 50-55 Gt)

90% in the maintainance and increase of organic **Carbon sink** in the fields and in the plants



Mitigation and agriculture

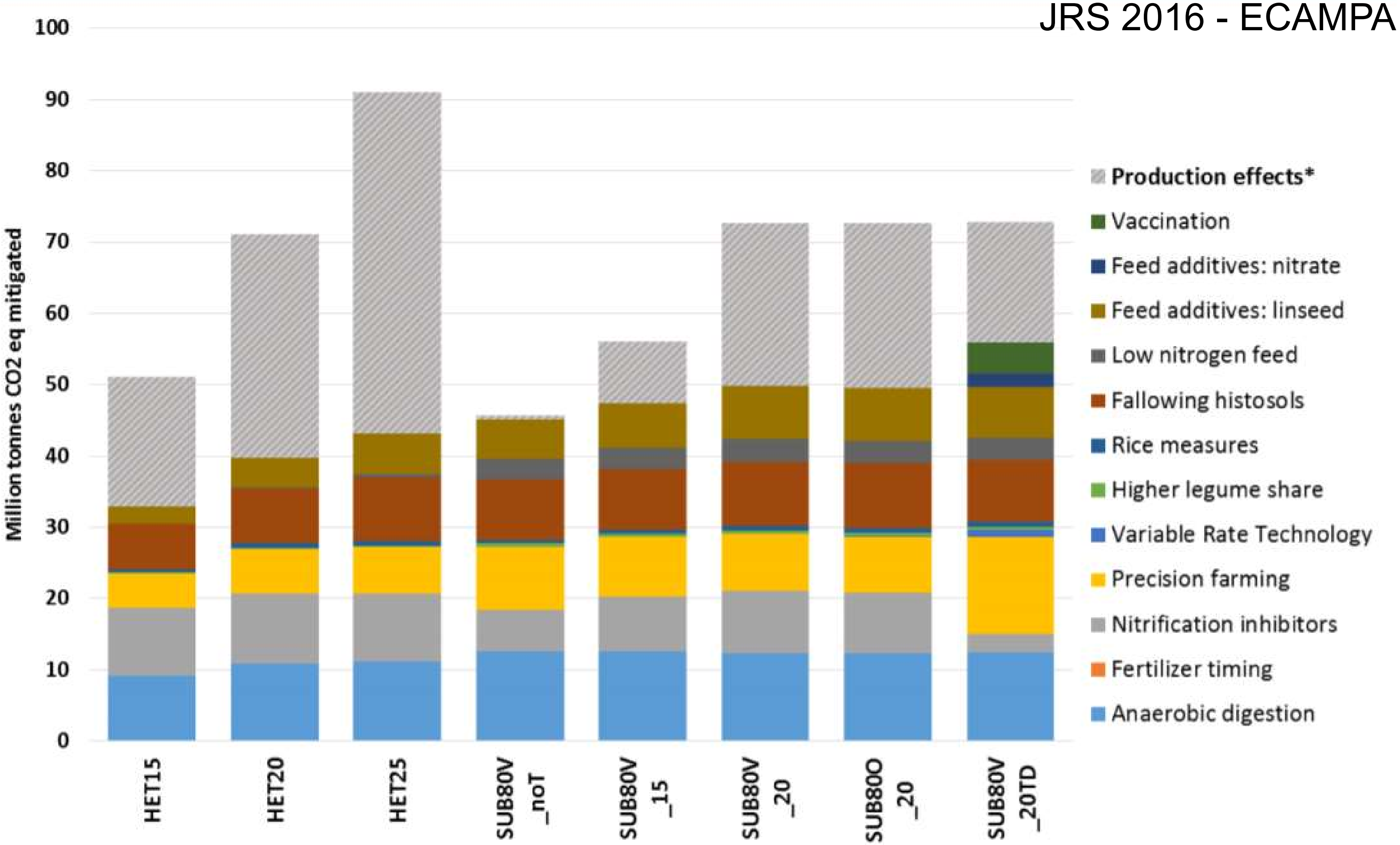
Organic Carbon sink:

- Restoration of cultivated soils (increasing C sink)
- improvements in management and **tillage** practices on cultivated land (manure management)
- **Minimum tillage or no tillage**
- management of **crop residues** and water resources
- the **restoration of degraded land** (afforestation and reforestation, erosion control and organic manure)
- Improvements of **pasture management**

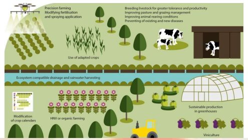
Mitigation and agriculture

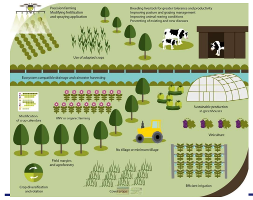
Figure B: Contribution of each technology to total mitigation, EU-28 (2030)

JRS 2016 - ECAMPA 2 Report



Mitigation and agriculture…and diet





Mitigation and agriculture

Carbon Tax ?

EFFECTS OF A USD 20 TAX PER TONNE OF CARBON DIOXIDE EQUIVALENT ON SELECTED AGRICULTURAL PRICES FOR SELECTED COUNTRIES (PERCENT INCREASE)

Country	Wheat	Rice	Beef	Sheep meat	Chicken
Australia	3.0	3.4	11.0	13.4	0.2
Brazil	2.2	2.5	16.5	16.7	0.2
China	2.6	4.0	12.5	5.9	0.6
Ethiopia	1.2	7.1	71.5	25.2	2.8
European Union	2.4	13.1	8.2	10.1	0.2
India	3.6	3.5	54.4	22.4	0.5
Indonesia	2.4	5.6	22.6	22.3	2.9
New Zealand	2.4	-	8.9	8.1	0.2
United States of America	2.4	5.6	6.0	-	0.2

SOURCE: Blandford, D. and Hassapoyannes, K. 2018. The role of agriculture in global GHG mitigation. OECD Food, Agriculture and Fisheries Papers No. 110. OECD Publishing.

The change need us….

A more sustainable food approach reduces at all levels (production, distribution and retail, waste!) the impact on natural systems, biodiversity and balanced diets, **for everybody**