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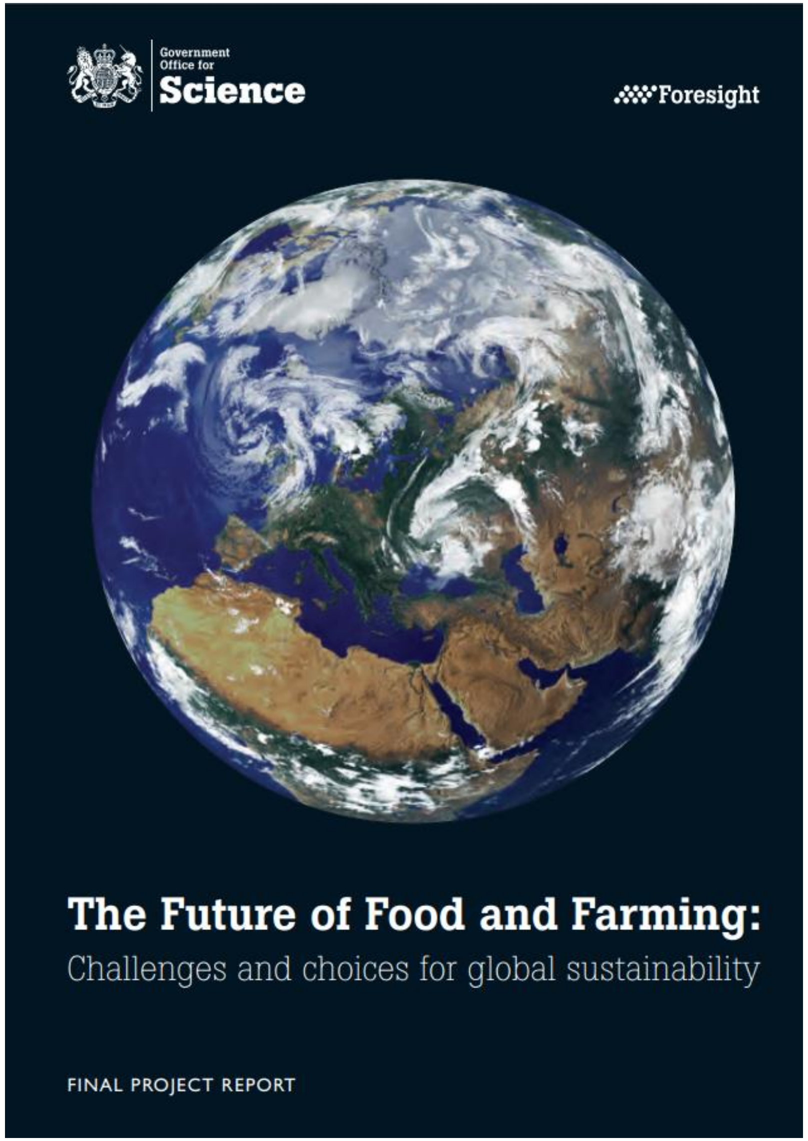
Sustainable intensification of animal production: what does it mean?

Phil Garnsworthy
Professor of Dairy Science
The University of Nottingham, UK

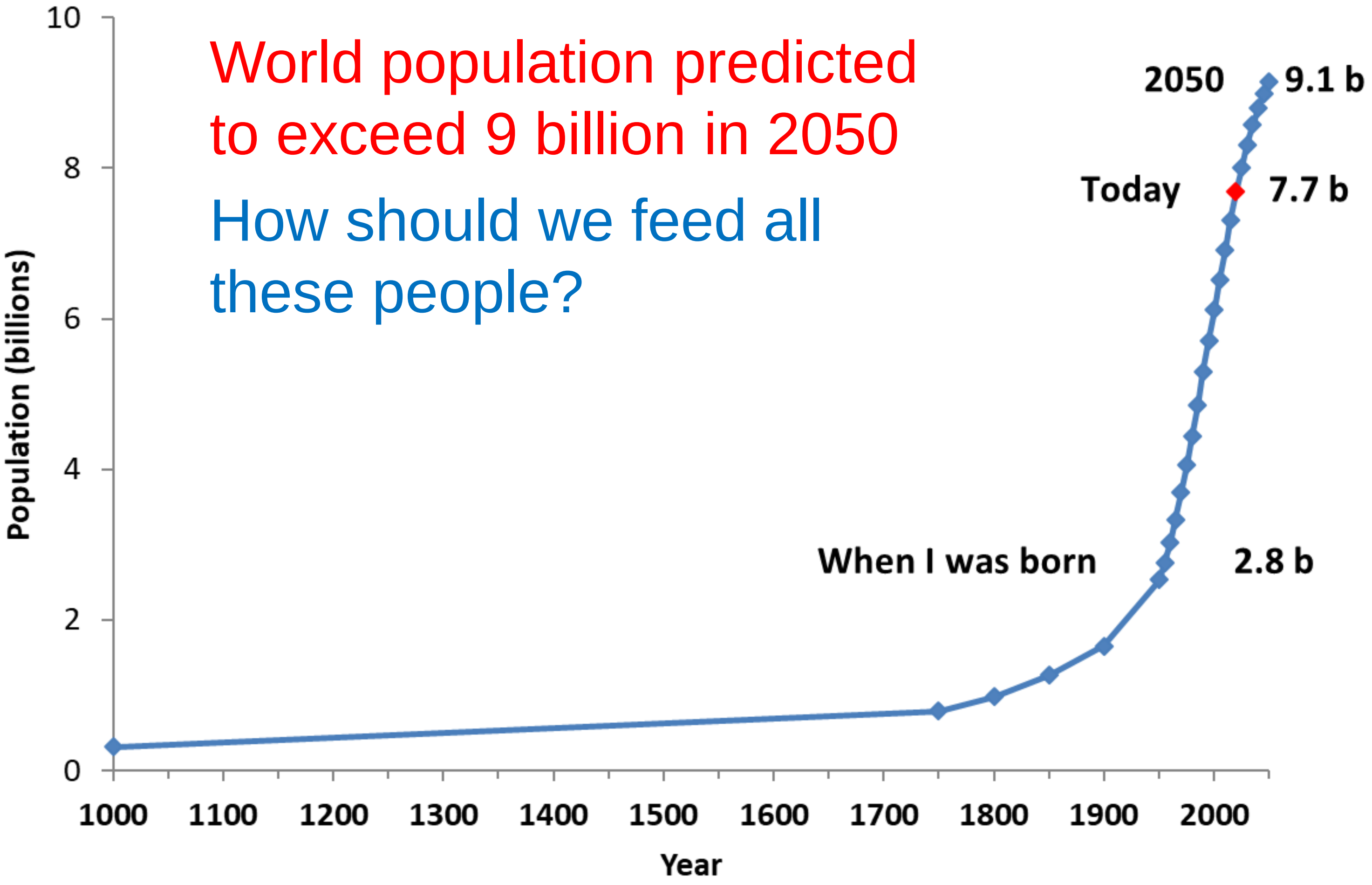
70th Annual Meeting of the
European Federation of Animal Science
Ghent, Belgium, 27 August 2019

Foresight Report 2011 – The Future of Food and Farming



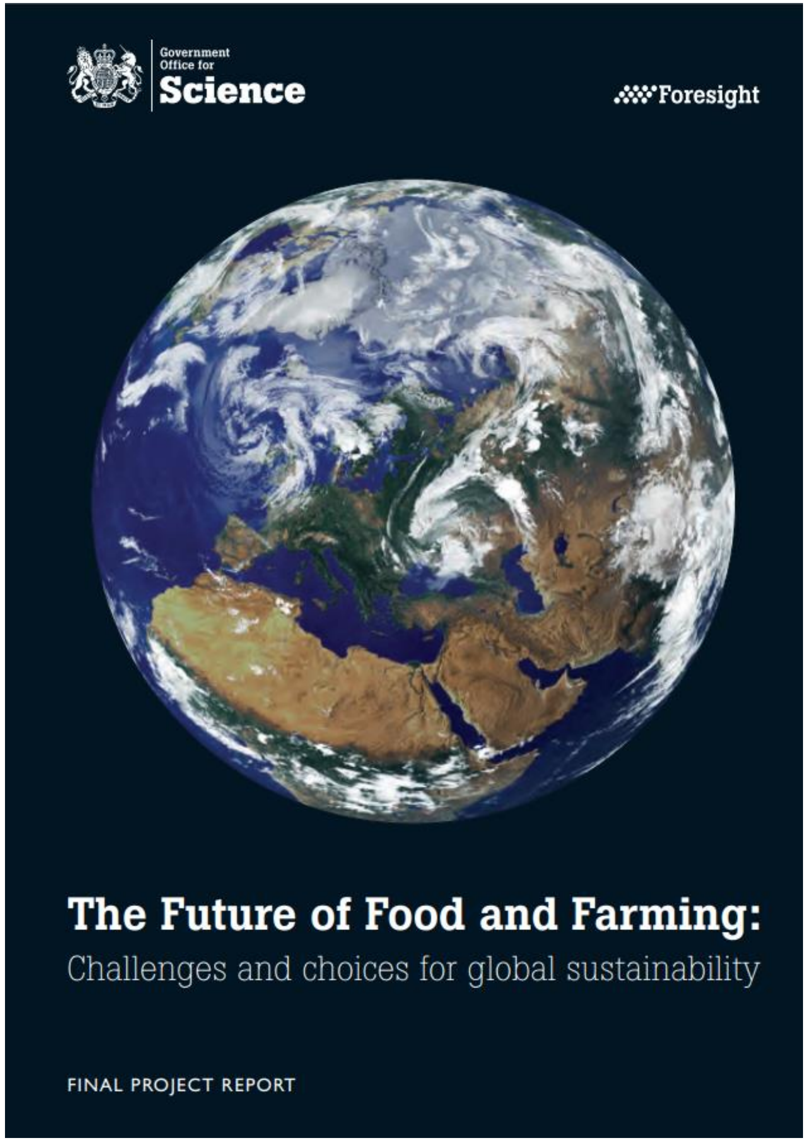
World population predicted to exceed 9 billion in 2050

How should we feed all these people?



Data source: UN-ESA

Foresight Report 2011 – The Future of Food and Farming



The challenges we face

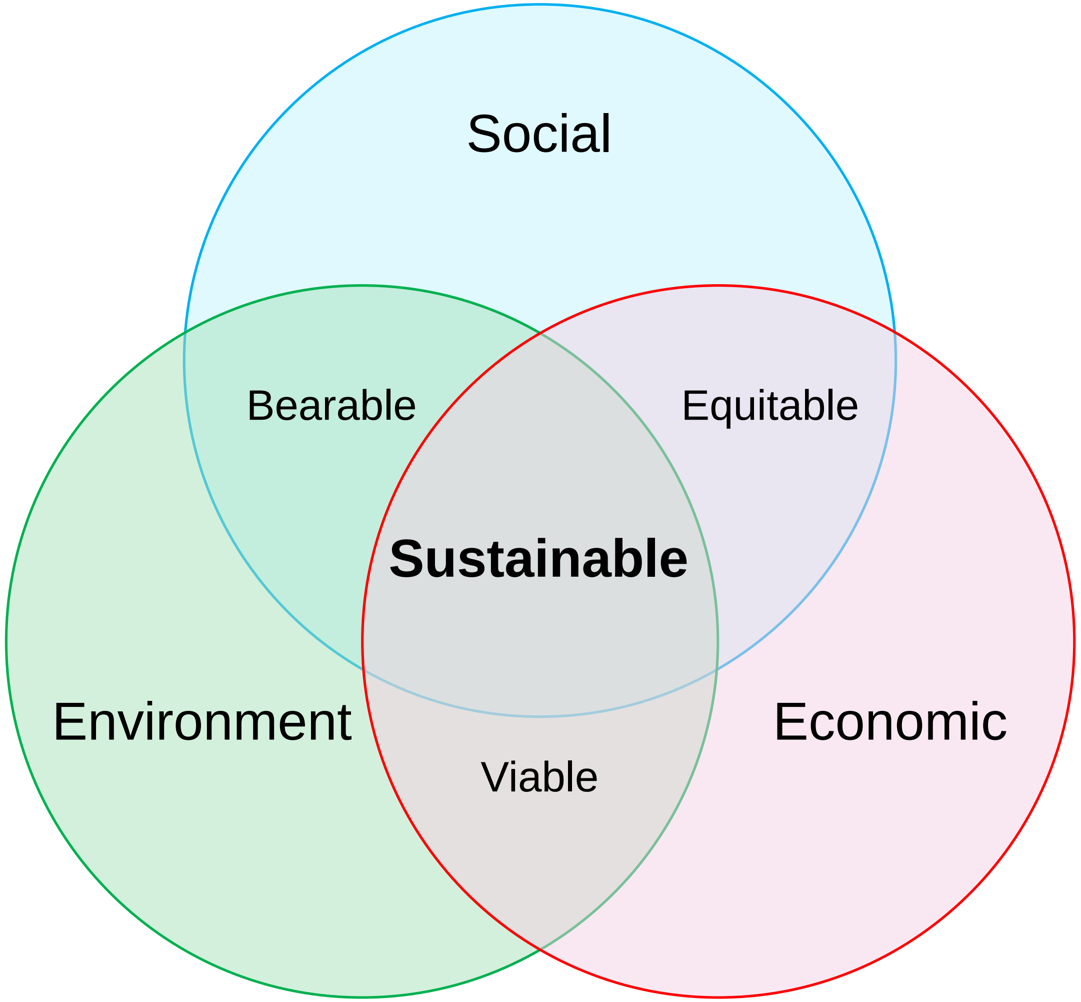
- Balancing future demand and supply sustainably
- Addressing the threat of future volatility in the food system
- Ending hunger
- Meeting the challenges of a low emissions world
- Maintaining biodiversity and ecosystem services while feeding the world

Global food supply will need to increase without the use of substantially more land and with diminishing impact on the environment:

sustainable intensification is a necessity

Sustainable Intensification

Sustainability



Intensification

Increase in productivity per unit of land or other resource

Milk per hectare
Pigs per sow per year
Weight gain per day
Feed conversion efficiency
Sheep per shepherd
Electricity per chicken shed

Intensification does NOT mean only moving from extensive to intensive systems

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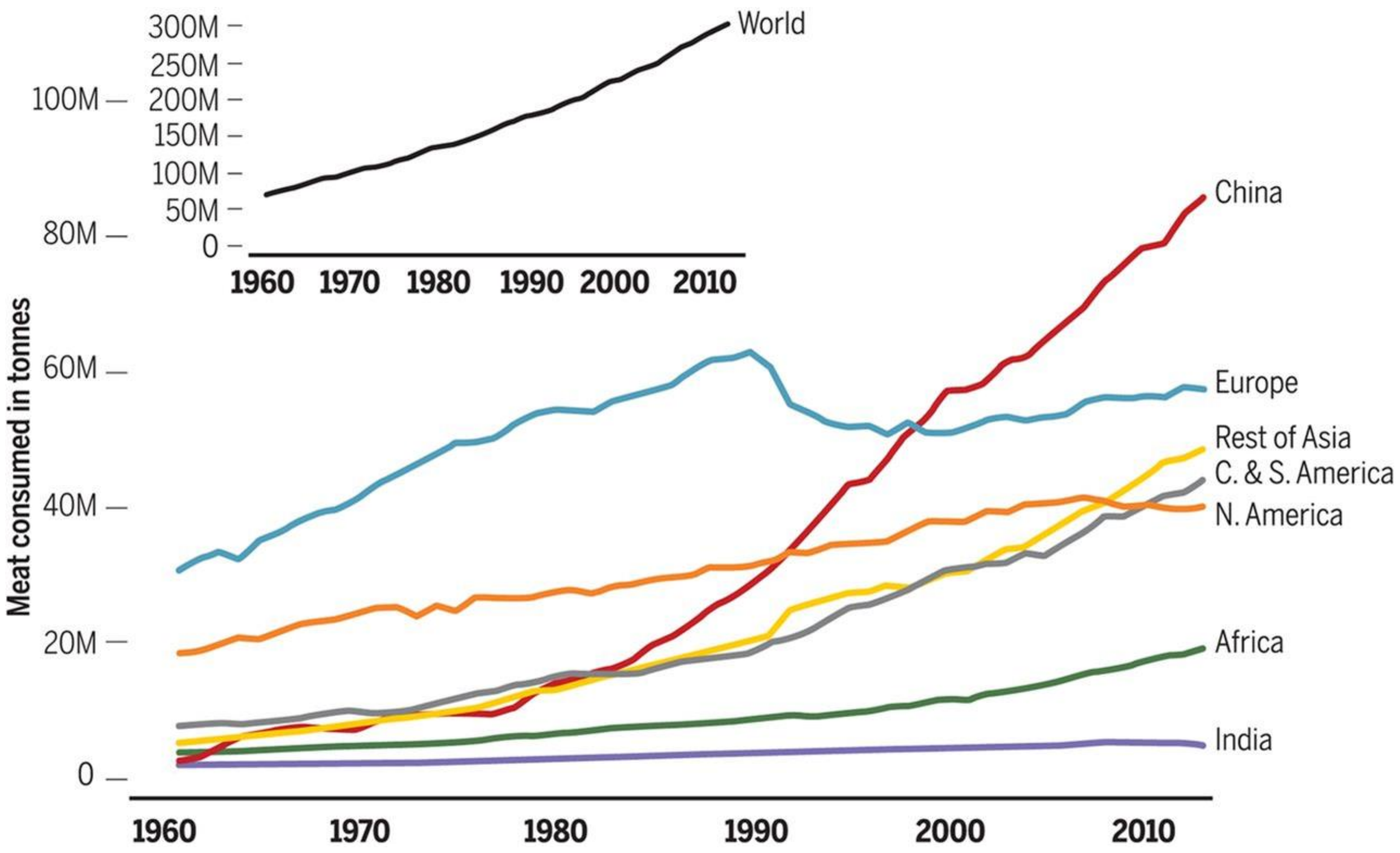
The Big Issues with Livestock

- Global demand for animal products is increasing
- Negative publicity about animal production
- Competition for land to grow animal feed versus human food
- Pressure on the environment
- Need more efficient use of resources

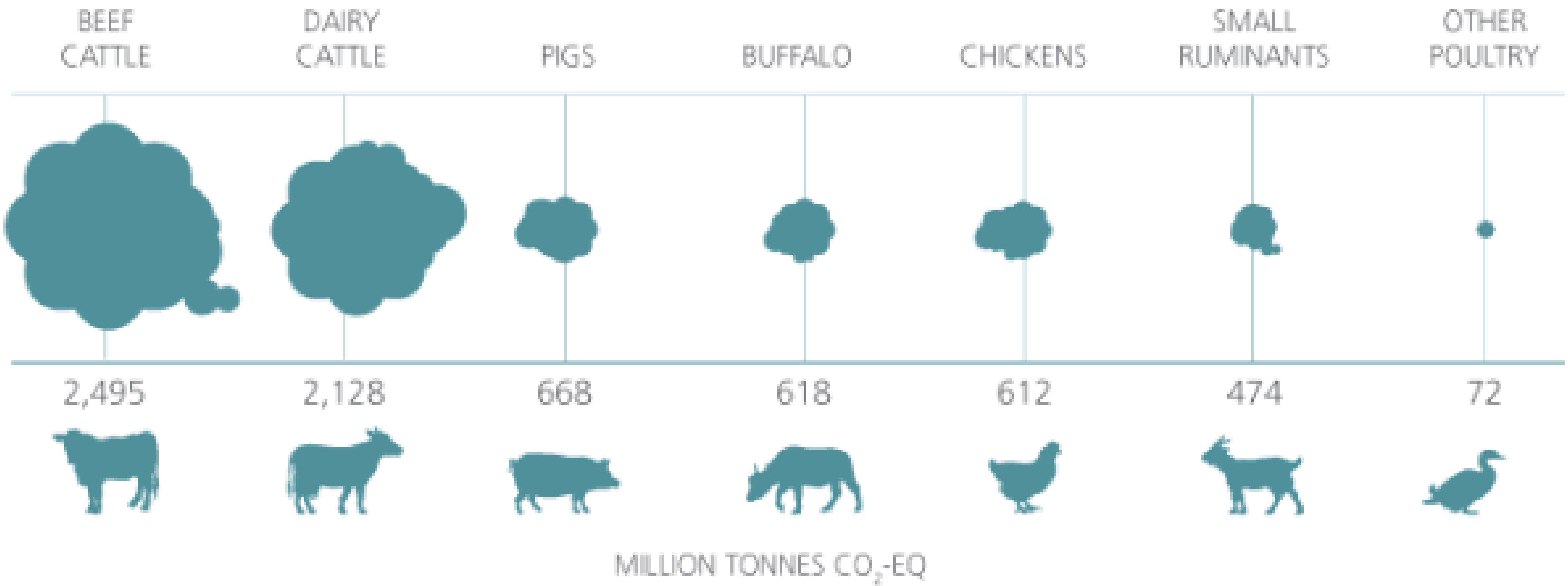
Our Task: To increase production efficiency whilst reducing environmental impact

Global consumption of meat is increasing



H. Charles J. Godfray et al. Science 2018;361:eaam5324

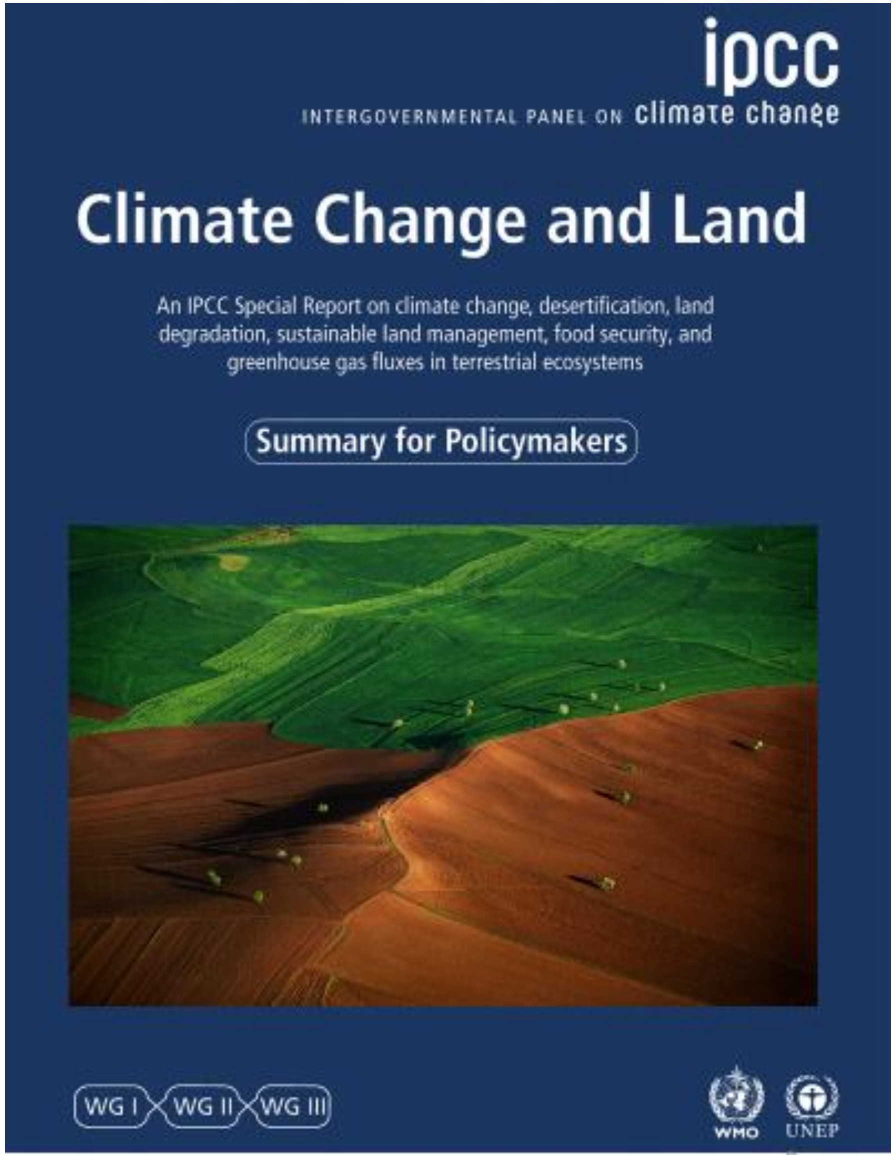
Global livestock GHG emissions



Cattle = 65% of Total livestock GHG

Source: FAO

Negative publicity



"Balanced diets,
featuring plant-based foods, such as those based on coarse grains, legumes, fruits and vegetables, nuts and seeds,
and animal-sourced food produced in resilient, sustainable and low-GHG emission systems,
present major opportunities for adaptation and mitigation while generating significant co-benefits in terms of human health.“

IPCC (2019) Section B6.2

Negative publicity – eat less beef

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NEWS

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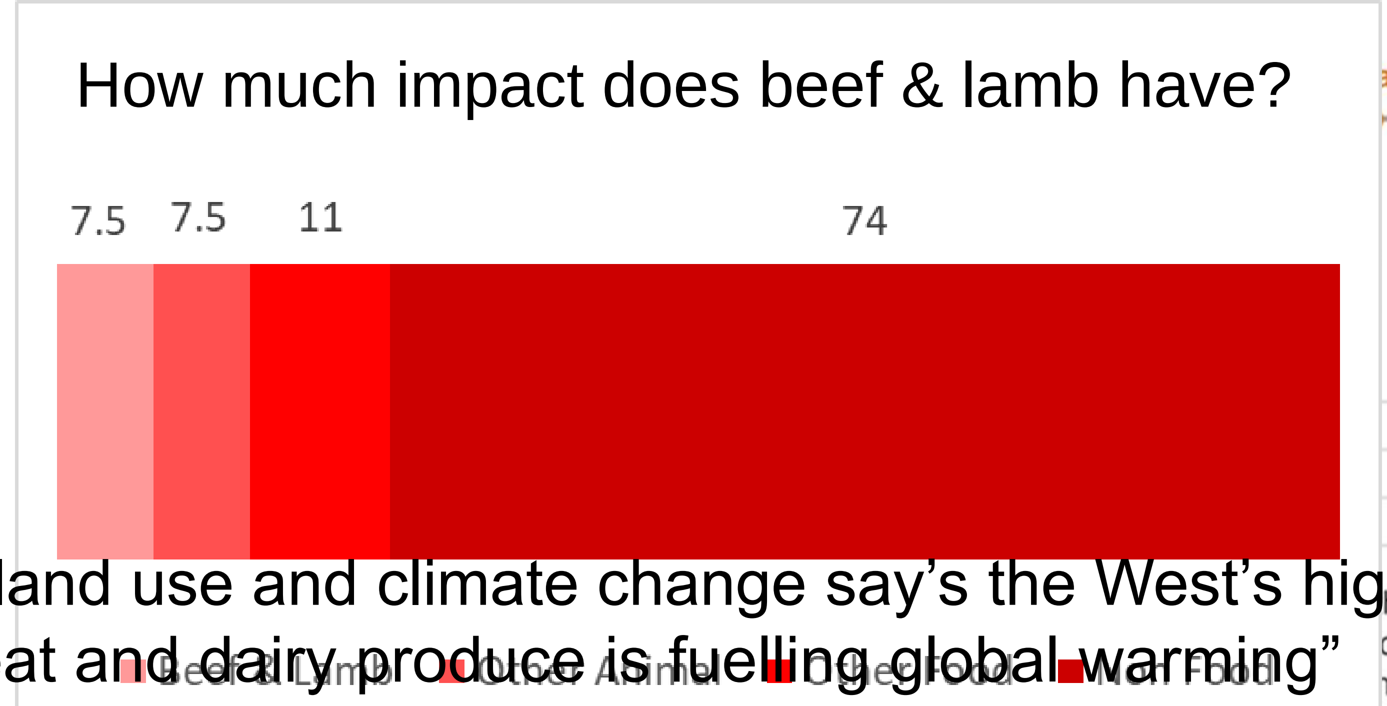
Science & Environment

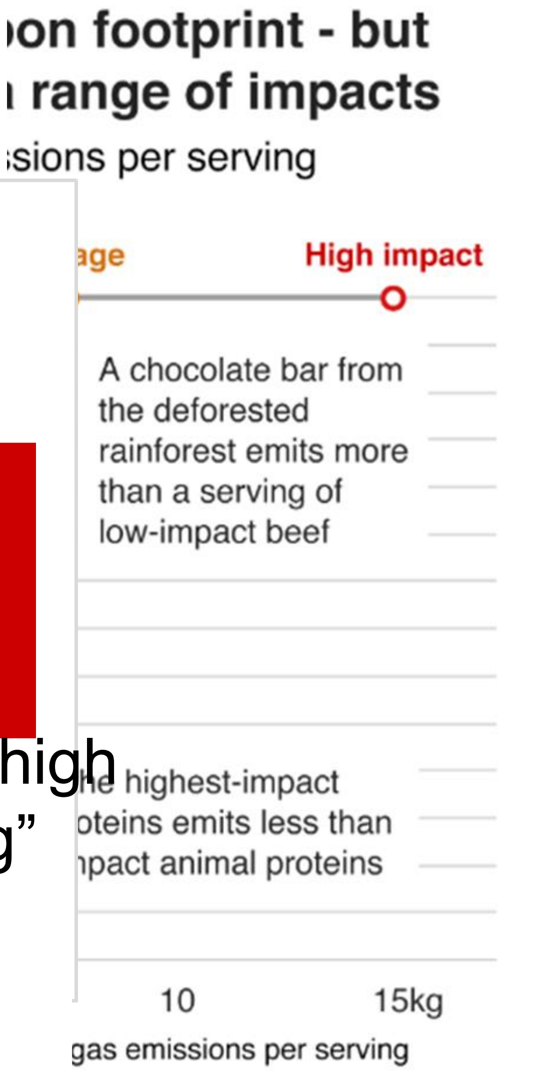
Plant-based diet (- UN

By Roger Harrabin
BBC environment analyst, Geneva

How much impact does food have?

Proportion of total greenhouse gas emissions from food





"A major report on land use and climate change say's the West's high consumption of meat and dairy produce is fuelling global warming"

Over 90% of human impact comes from activities other than eating beef

Source: Poore & Nemecek (2018), Science

BBC

Protein quality

Digestible amino acids supply

	Protein %	Digestibility %	Amino acid score	PDCAAS	DAA supply
Egg	12.5	98	121	118	14.8
Milk	3.3	95	127	121	4.0
Beef	31	98	94	92	28.5
Soya	13	95	96	91	11.8
Wheat	12.6	91	47	42	5.3

PDCAAS = Protein Digestibility–Corrected Amino Acid Score

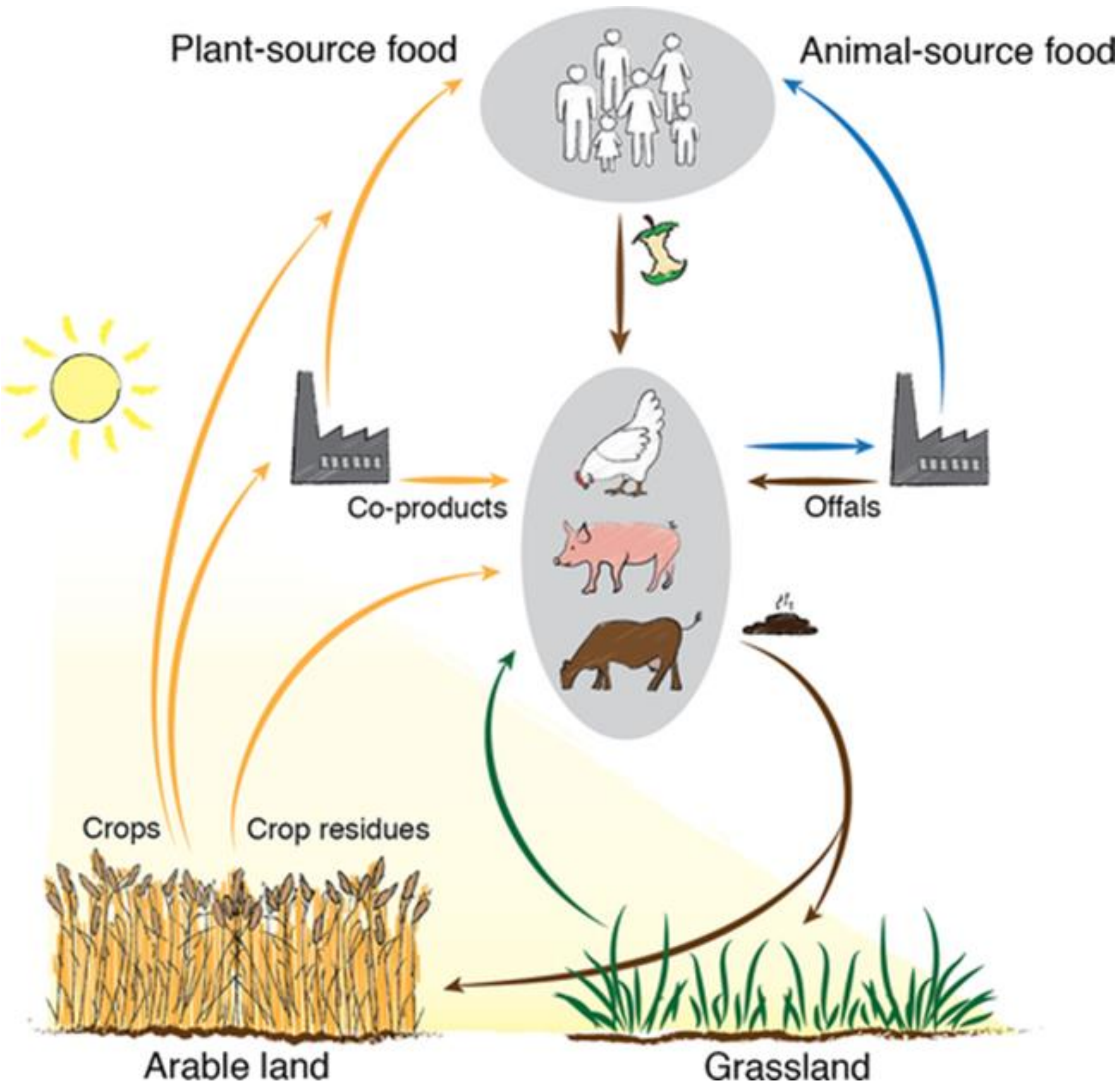
Beef supplies 2.5 times more digestible amino acids than soya and 5.3 times more than wheat

Resource Use

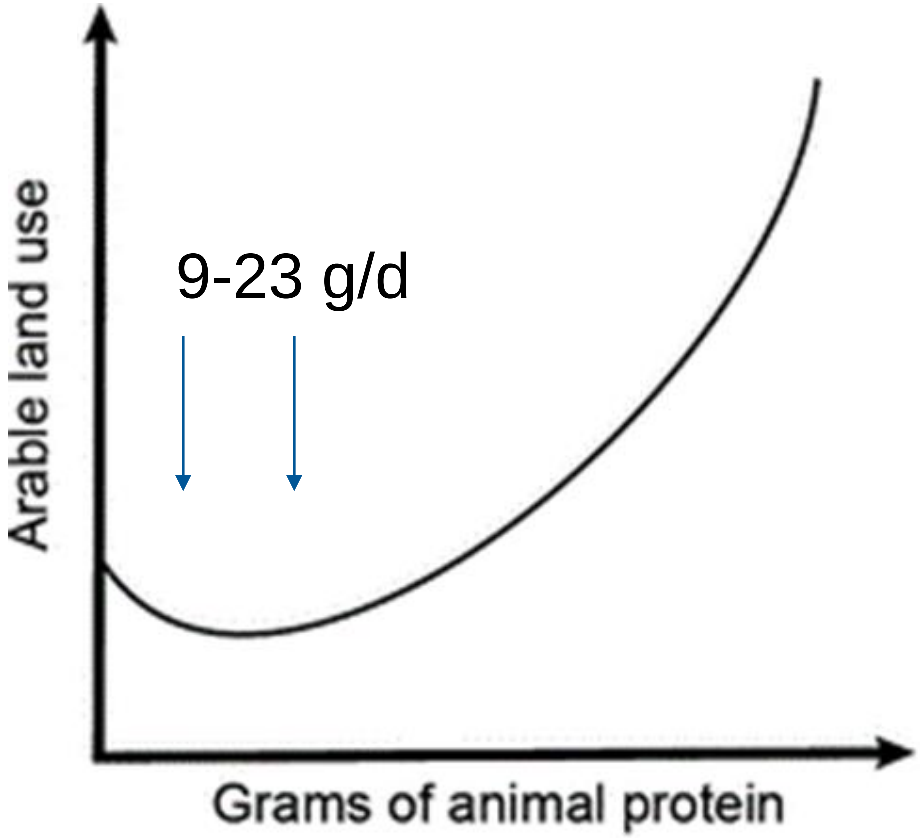
- World Land Utilisation
    22% crops, 39% grass, 39% marginal

Milk

Feeding animals on grass and leftovers



Imke de Boer, EAAP Leroy 2018



Van Zanten et al. (2018) Global Change Biology 24:4185–4194.

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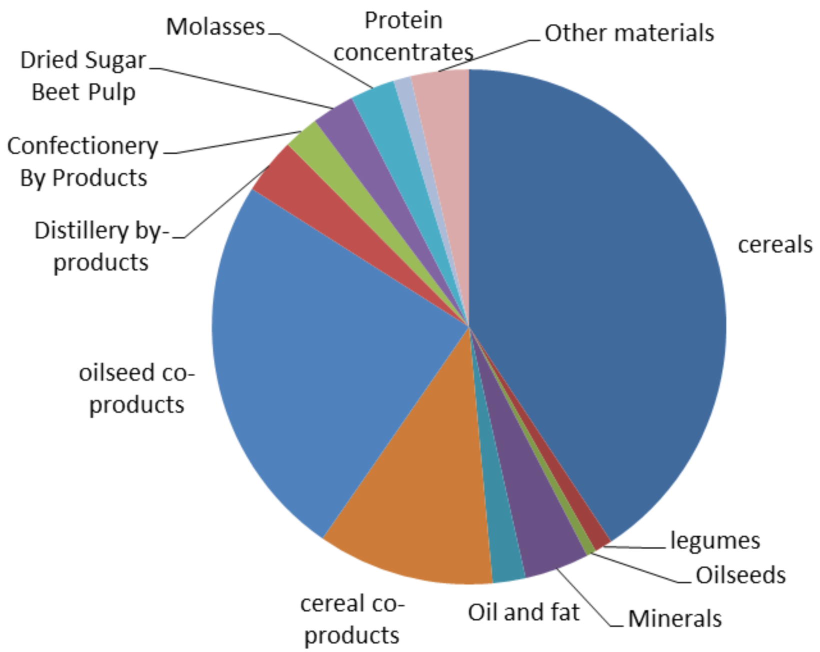
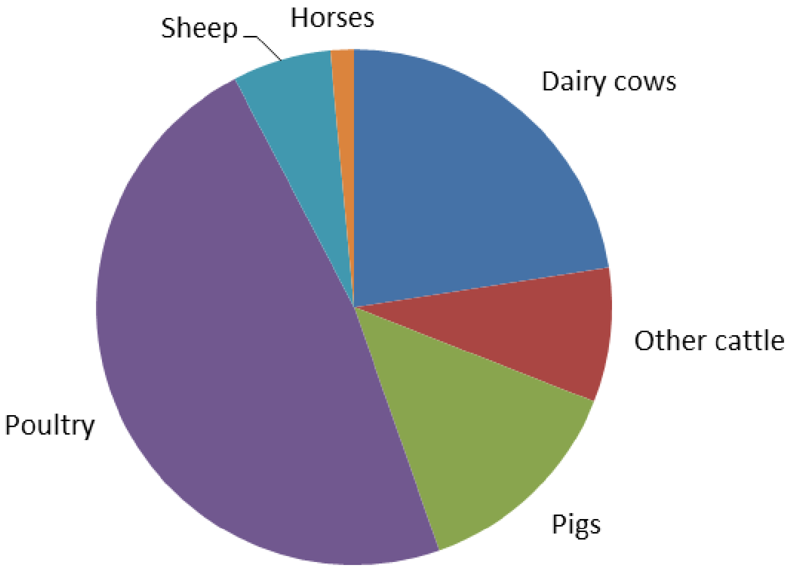
Raw materials in manufactured feeds (UK)

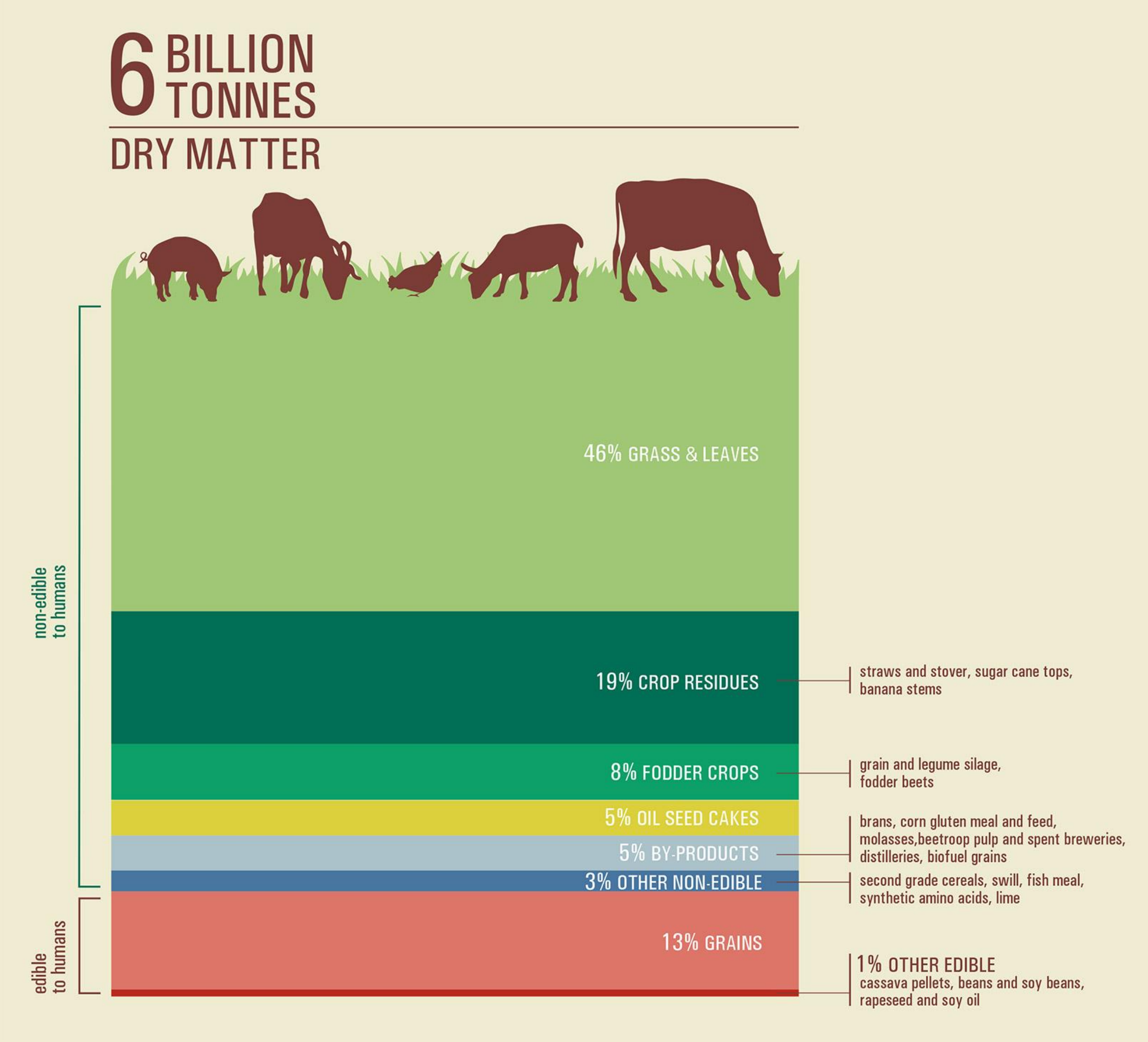




Defra stats 2010-2017

- 50% products, 50% co-products
- Cereals and soya meal main ingredients
- Poultry, pigs, dairy cows main species

Global consumption of feed by livestock



86% of the global livestock feed intake is not edible for humans

1 kg of meat requires 2.8 kg of human-edible feed for ruminants and 3.2 for monogastrics

Livestock consume one third of global cereal production and uses about 40% of global arable land

Livestock use 2 billion ha of grasslands, of which about 700 million could be used as cropland

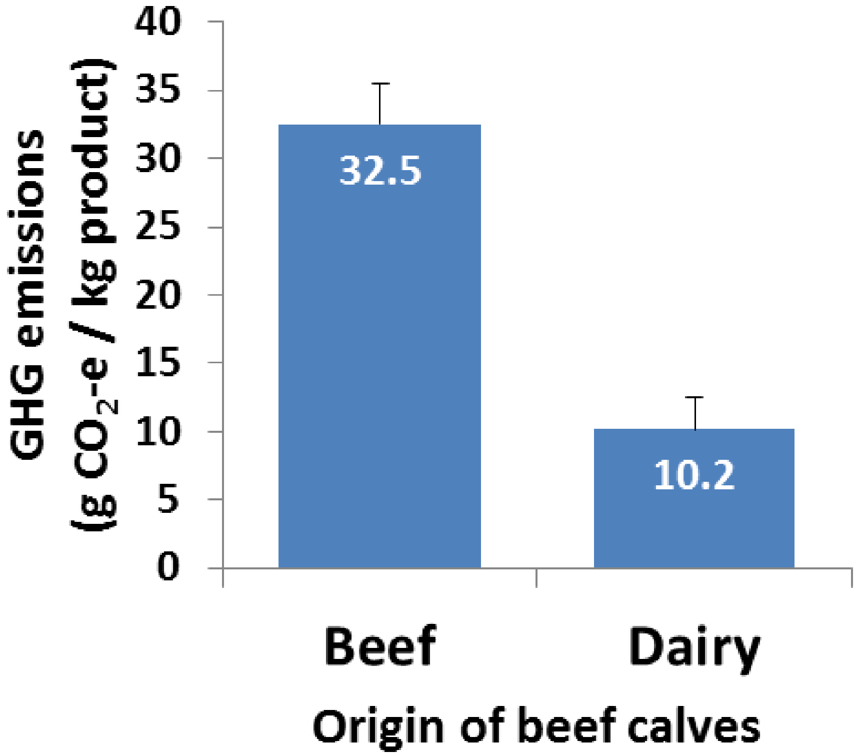
Modest improvements in feed conversion ratios can prevent further expansion of arable land dedicated to feed production.

FAO: Mottet et al. 2017. Global Food Security 14, 1-8

Beef production – calf origin

- Environmental impact depends on origin of calves for fattening

- Beef Suckler Herd
  - impact of breeding animals is allocated to beef
- Dairy Herd
  - impact of breeding animals is allocated to milk

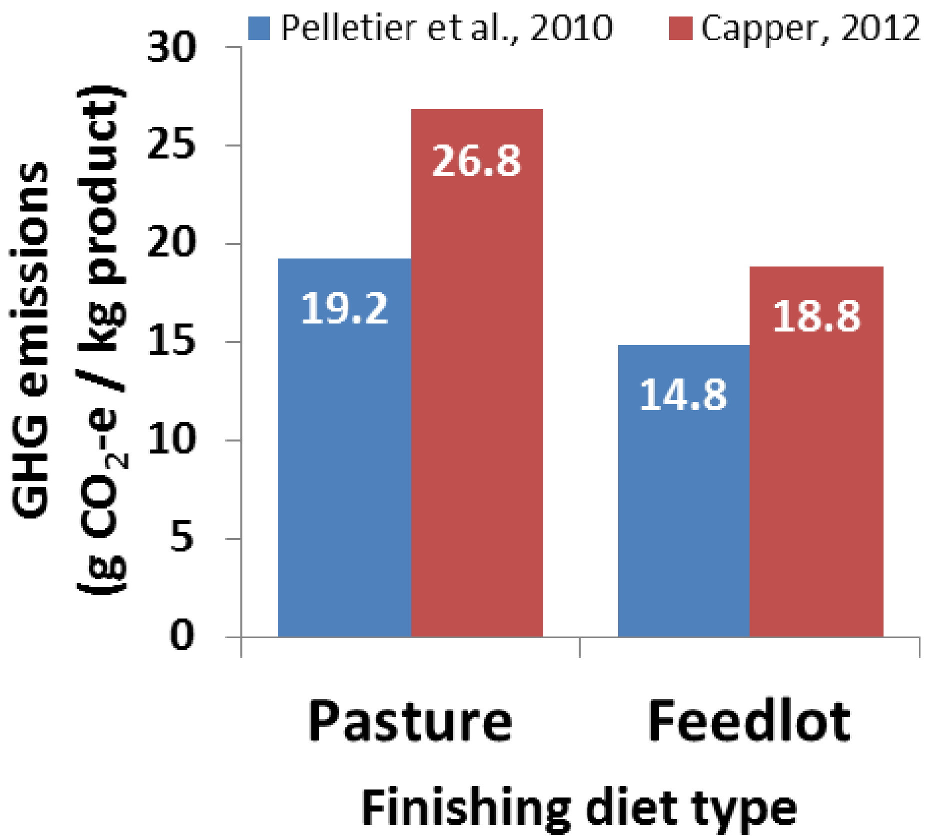


Source: Opio et al., 2013

Beef production – diet type

- Environmental impact depends on diet

- Pasture/roughage
  - More enteric methane
- Feedlot/concentrates
  - Lower enteric methane
  - More N_2O from fertilizer
  - Faster growth rates



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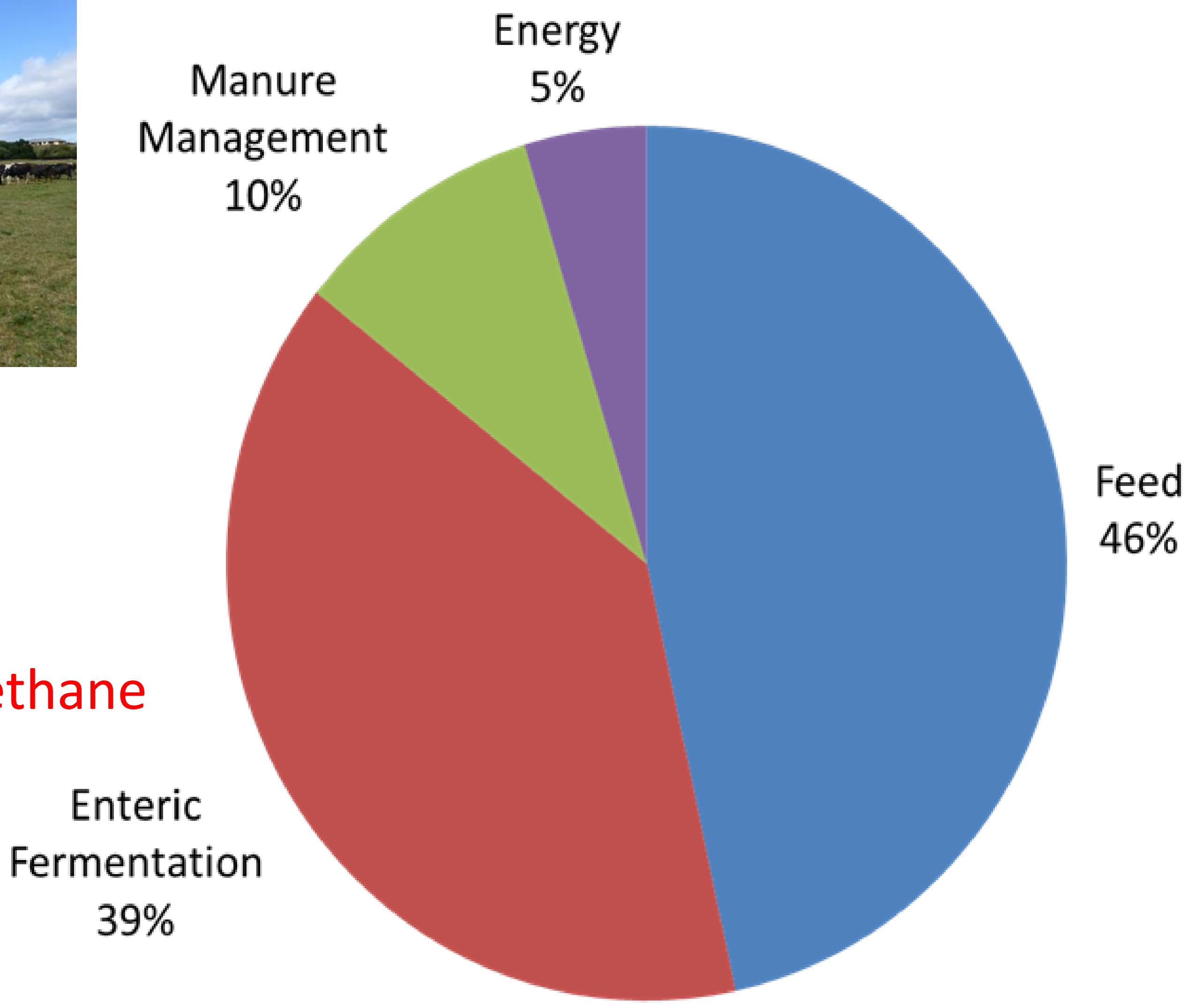
Dairy GHG emissions



Feed Carbon Footprint

Rumen Methane

Feed Carbon Footprint

Feed CFP (g CO_2e/kg DM) of ingredients

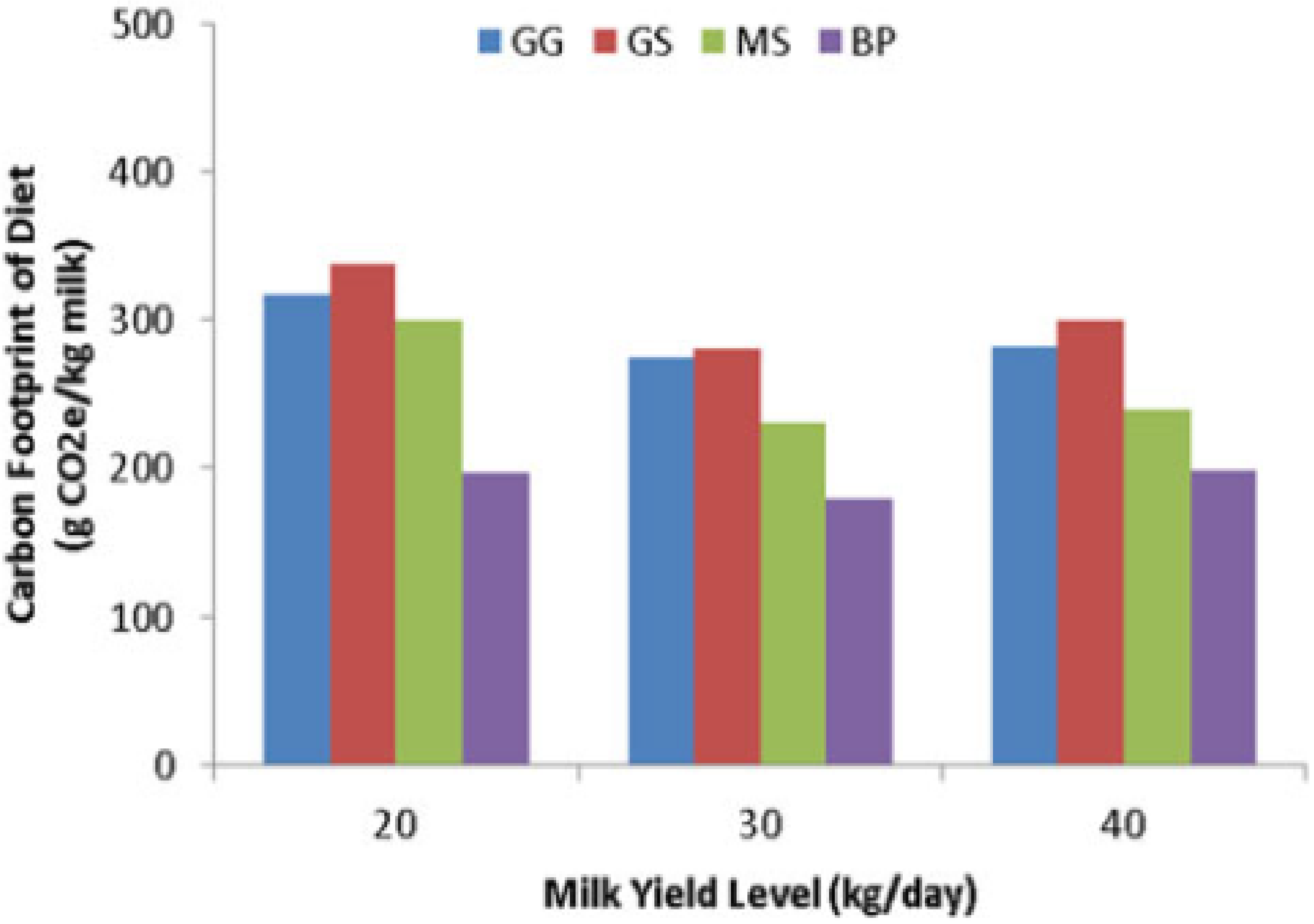
	CFP	LUC	Total
Grazing	329	69	398
Grass silage	304	78	382
Maize silage	163	90	252
Wheat	424	165	589
Sugar beet pulp	322	0	322
Soya bean meal	633	437	1070
Rapeseed meal	534	166	700

FeedPrint Database:
Vellinga et al. 2012
Wageningen UR

Wilkinson & Garnsworthy (2017) J Agric Sci 155, 334-347

Feed CFP of least-cost diets

Diets based on
Grazed Grass
Grass silage
Maize silage
By-products

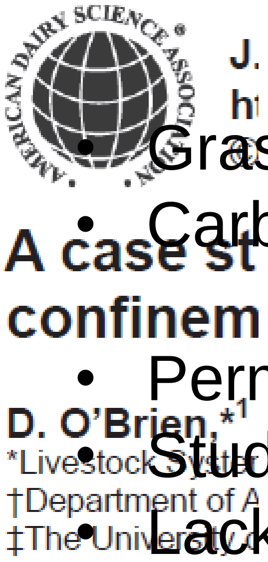


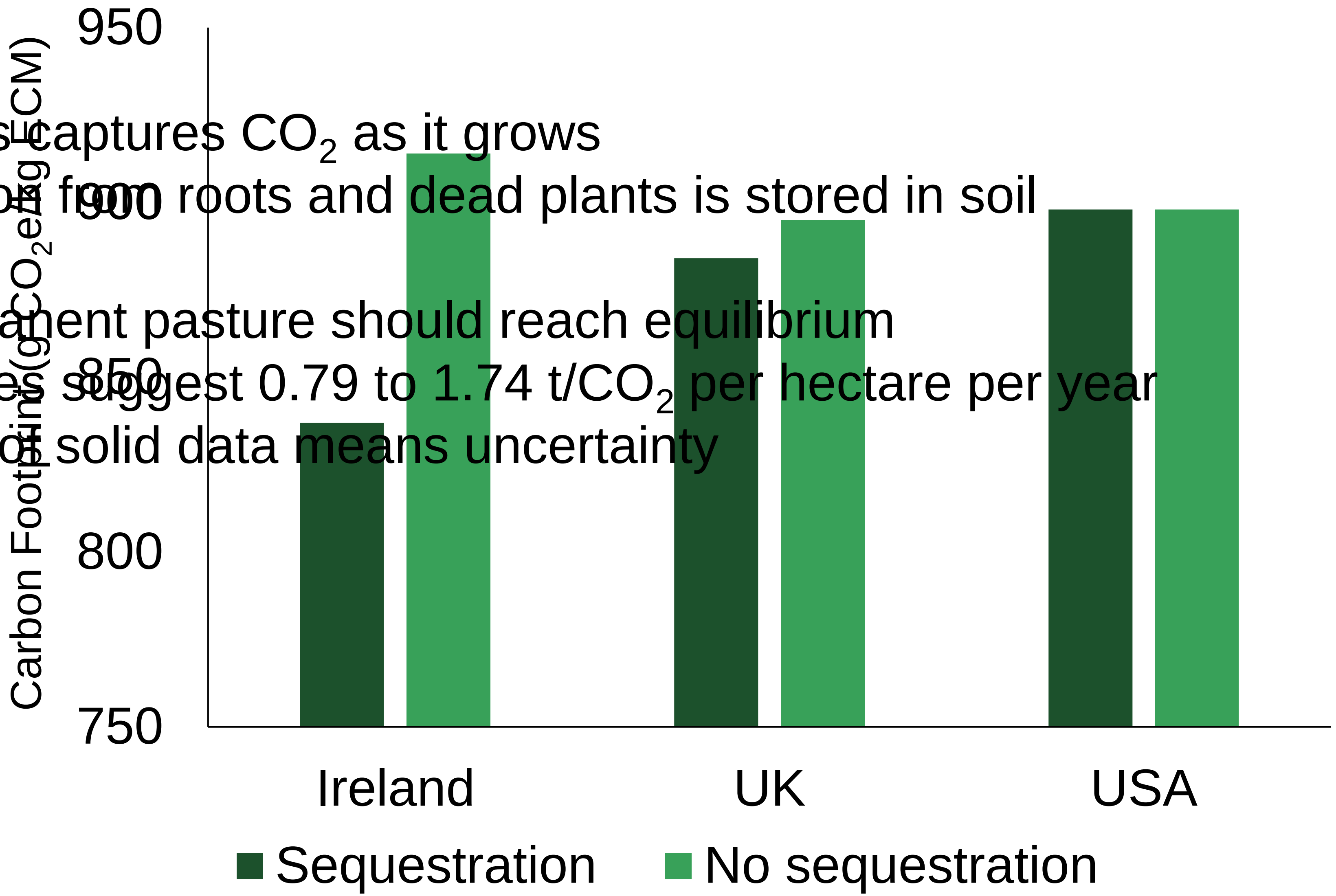
Wilkinson & Garnsworthy (2017) J Agric Sci 155, 334-347

Carbon sequestration

- Grass captures CO_2 as it grows
- Carbon from roots and dead plants is stored in soil

- Permanent pasture should reach equilibrium
- Studies suggest 0.79 to 1.74 t/CO_2 per hectare per year
- Lack of solid data means uncertainty





Carbon

ork, Ireland

Origin of Methane

Archaea

Grass (cellulose) — Rumen microbes → Pyruvate → H_2 → Methane; Pyruvate → Acetate

Cereals (starch) — Rumen microbes → Pyruvate → Propionate

CO_2 → Methane

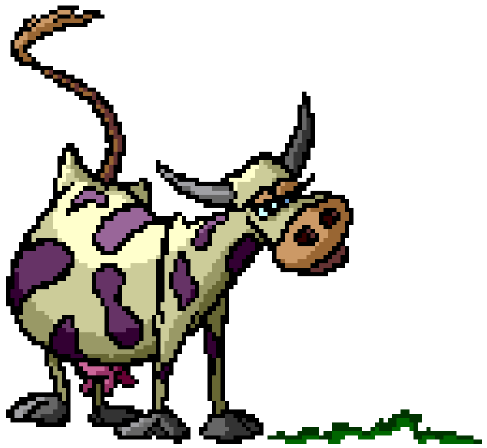
Methane is an essential pathway for metabolic H_2 removal

Without methanogenesis:

- microbial fermentation is compromised
- cellulolysis activity is decreased
- digestive efficiency is compromised
- animals eat less feed
- performance is lower

Methane is influenced by diet

- Dry matter intake +
- Forage to concentrate ratio +
- Forage digestibility −
- Dietary fat content −
- Unsaturated fatty acids −
- Dietary starch content −

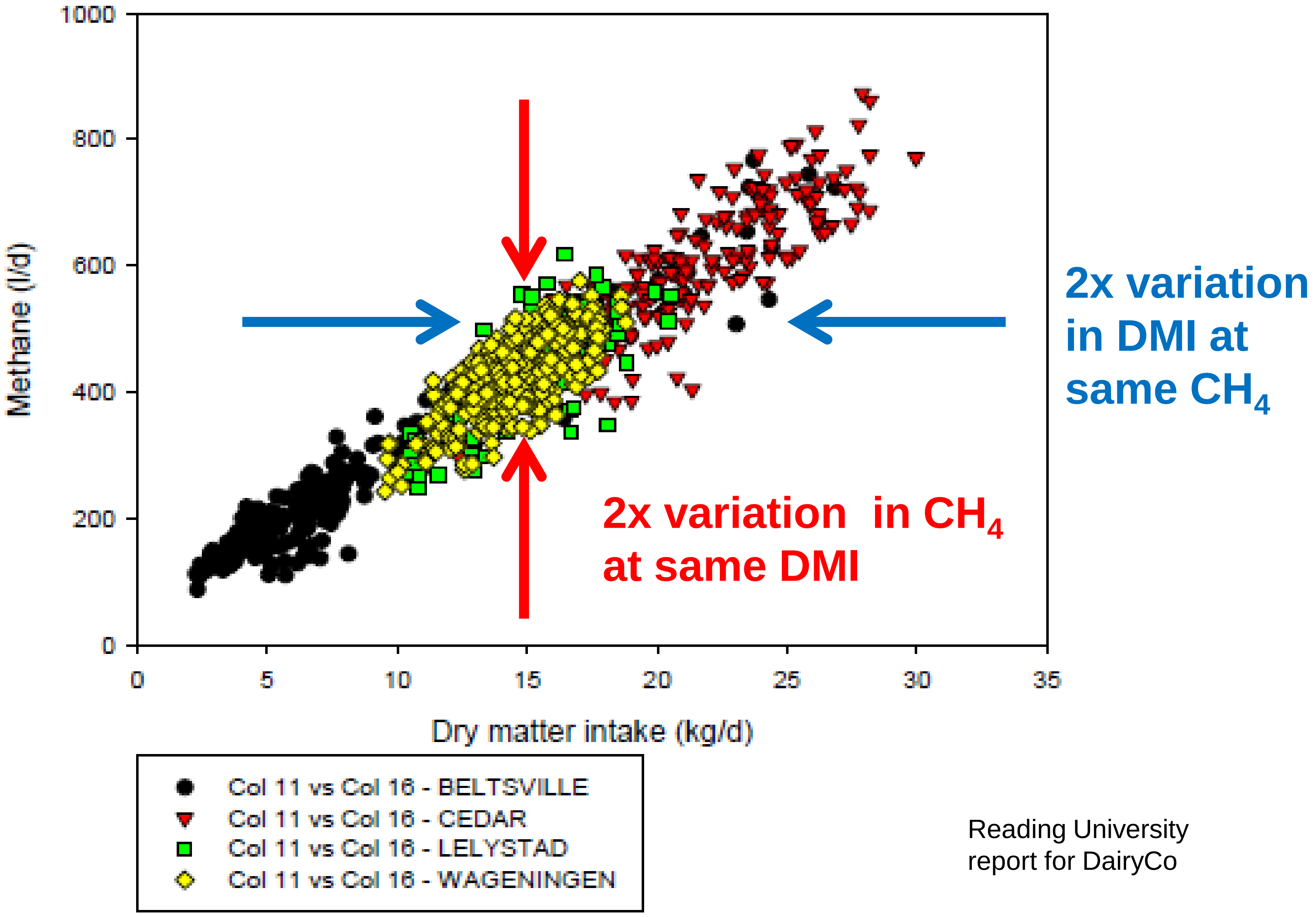


- Methane inhibitors −
  - Monensin (banned in EU)
  - Saponins (short lived)
  - Condensed tannins (reduce NDF digestibility)
  - Essential oils (slower starch and protein degradation)
  - 3-NOP (3-nitrooxypropanol, targets methyl-coenzyme M reductase (MCR))

Methane variation between animals

Dry matter intake affects methane

But large variation between animals

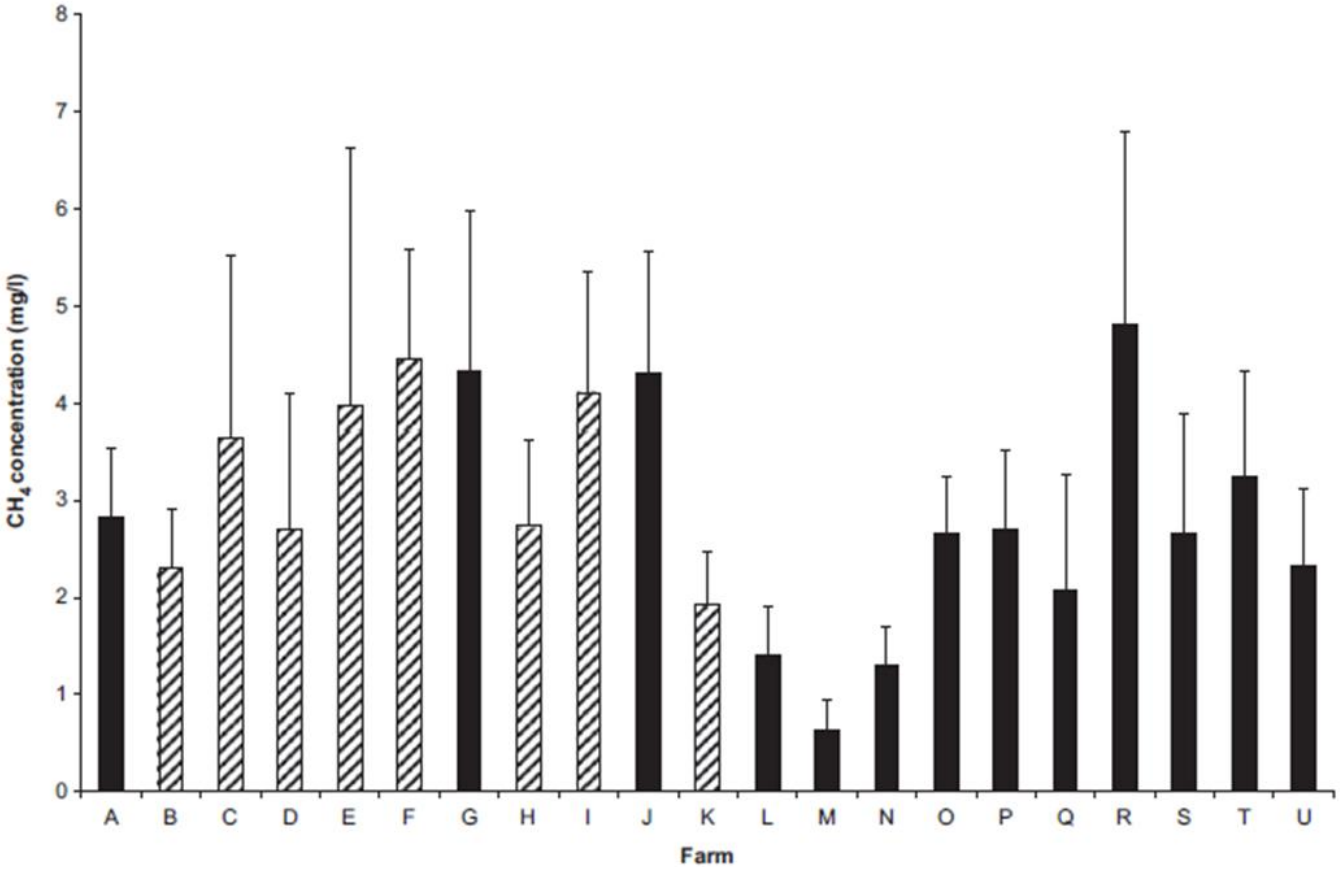


Reading University
report for DairyCo

Variation in methane on commercial dairy farms

defra
Department for Environment Food and Rural Affairs

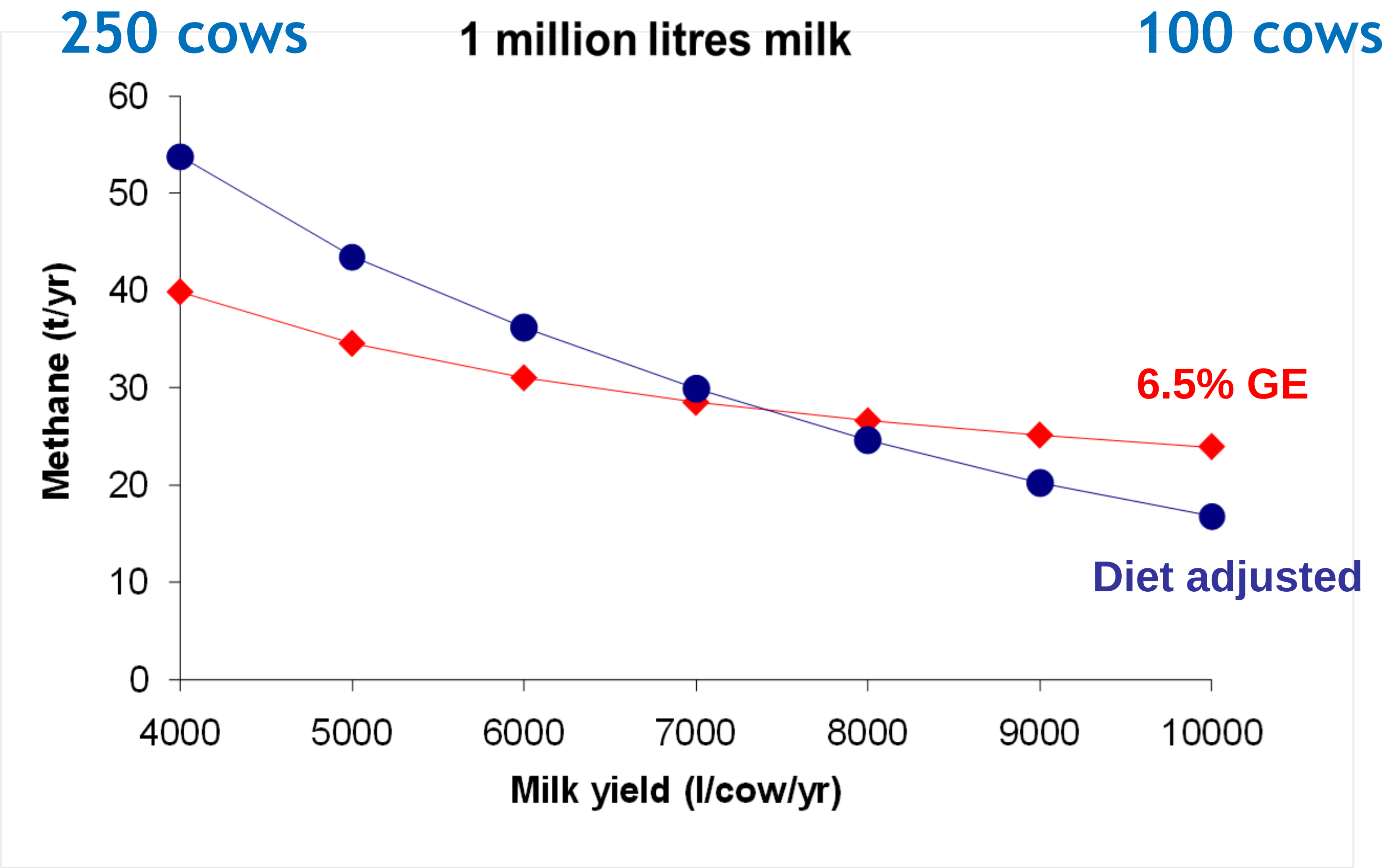
Agricultural UK GHG PLATFORM



- 2,000 cows, 21 farms
- Variation between and within farms
- Due to diet, milk yield and individual cow

Bell et al. (2014) Animal, 8:9, pp 1540–1546

Methane and Milk Yield

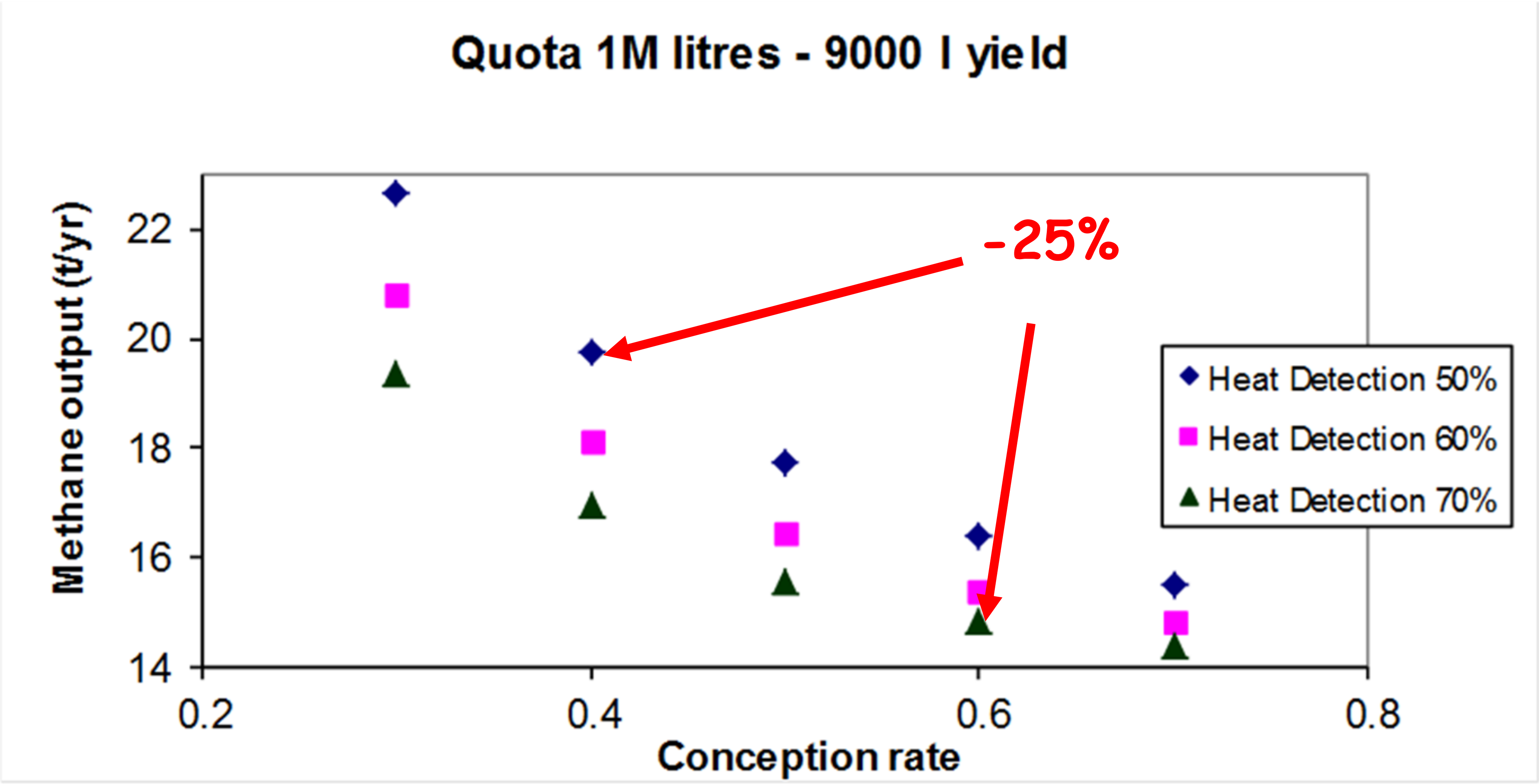


Higher milk yield reduces methane by diluting maintenance and needing fewer replacements

But, higher milk yield may reduce fertility, leading to more replacements

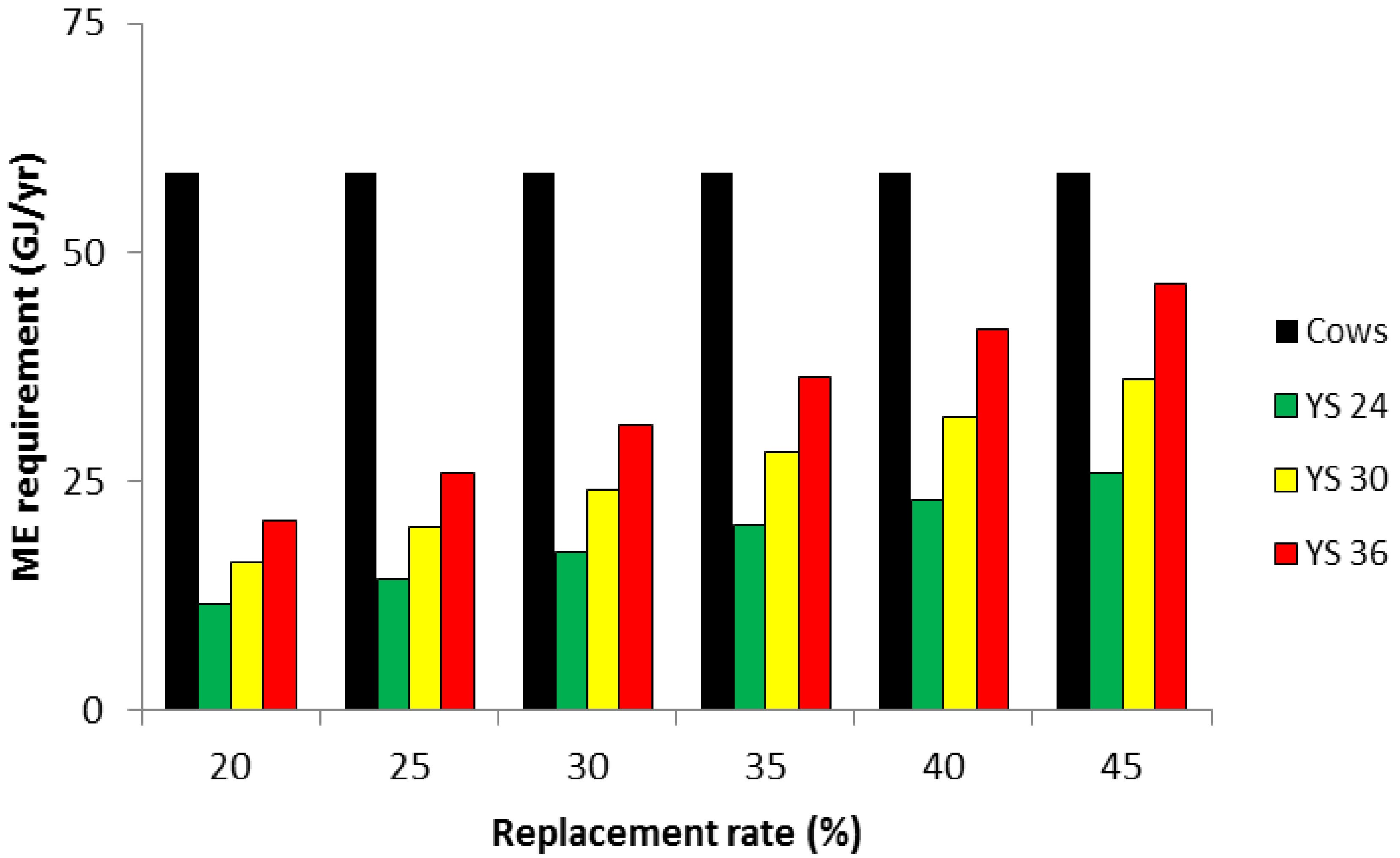
Garnsworthy, 2004. Anim Feed Sci Technol, 112, 211-223

Fertility affects methane per herd



Garnsworthy, 2004. Anim Feed Sci Technol, 112, 211-223

Replacement rate, age at first calving and energy requirements



Feed energy required for heifers ranges from 16 to 44% of total feed energy for herd

Feed energy ≡
Diet CFP
Methane
N excretion
P excretion
Profit

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Can we breed for low methane?

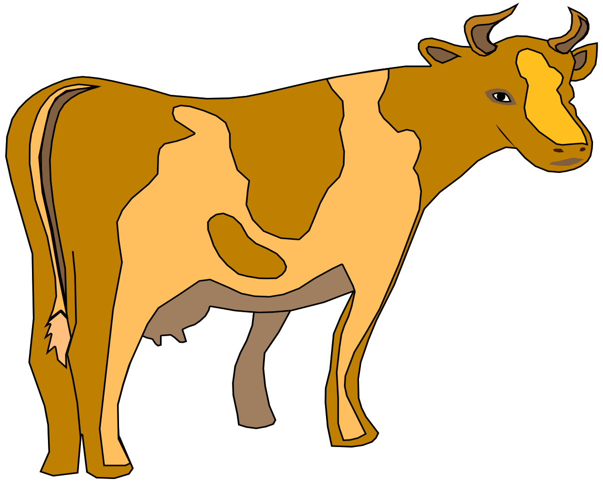
- Heritability of methane emissions is 0.1 to 0.3
- There is a lot of genetic and phenotypic variation (CV 10-30%)
- Methane ranges from 2 to 12% of Gross Energy Intake
- Reducing methane should save energy for use in milk synthesis
- Breeding could be a win-win solution

J. Dairy Sci. 102:7277–7281
https://doi.org/10.3168/jds.2018-15909

Short communication: **Heritability of methane production and genetic correlations with milk yield and body weight in Holstein-Friesian dairy cows**

I. S. Breider,[1,2] E. Wall,[2] and P. C. Garnsworthy[1]*
[1]School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough LE12 5RD, United Kingdom
[2]Department of Animal and Veterinary Sciences, Scotland's Rural College, Edinburgh EH25 9RG, United Kingdom

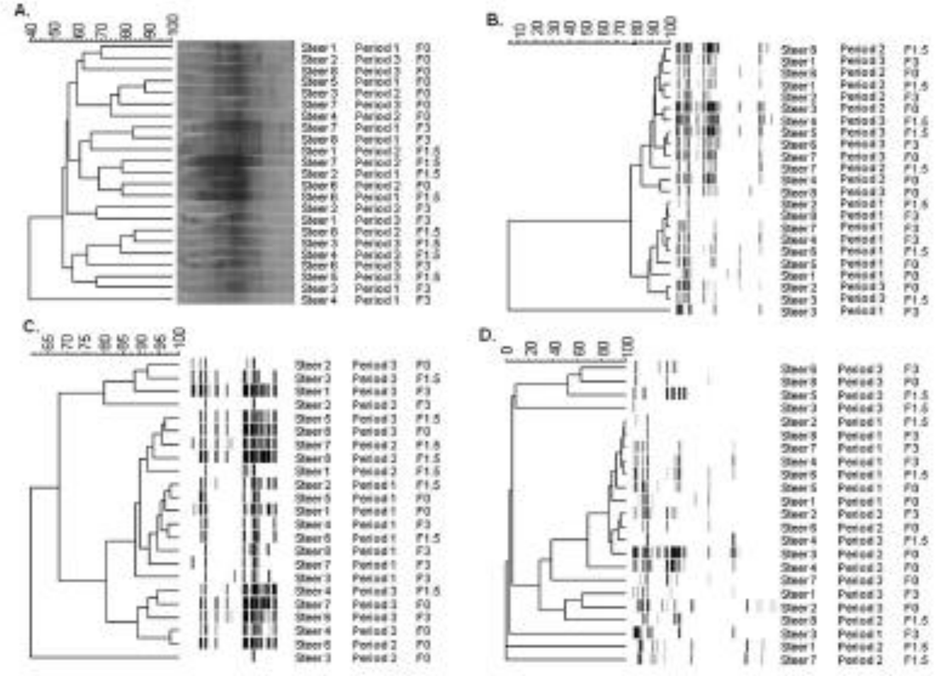
RuminOmics (EU-FP7 project)



Linking the cow genome to the rumen microbiome, feed efficiency and impact

RUMINOMICS

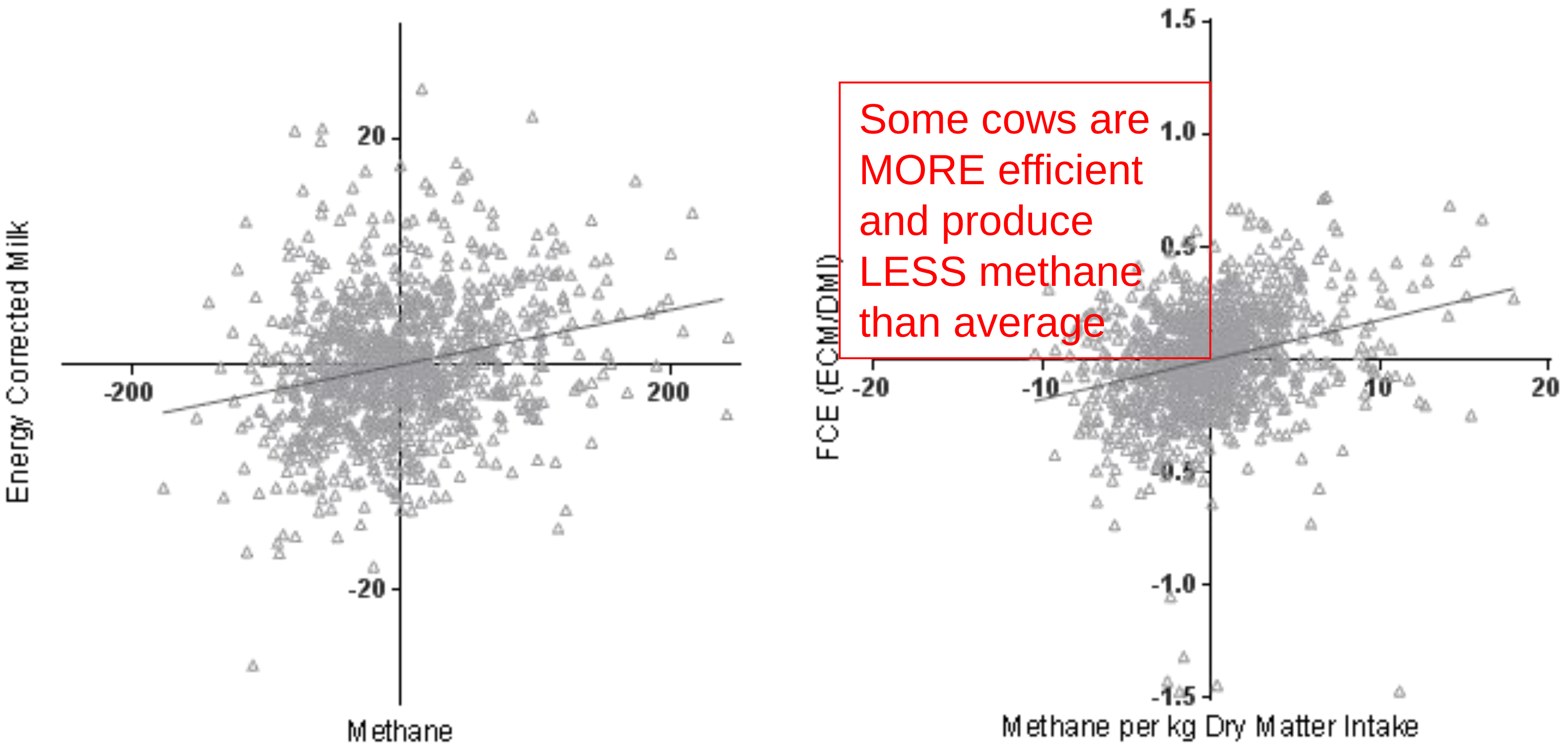
Measured CH_4 and sampled 1,000 cows



Wallace, R.J., *et al.* (2019) *Science Advances* 5, EAAV8391.

Should we breed for low methane?

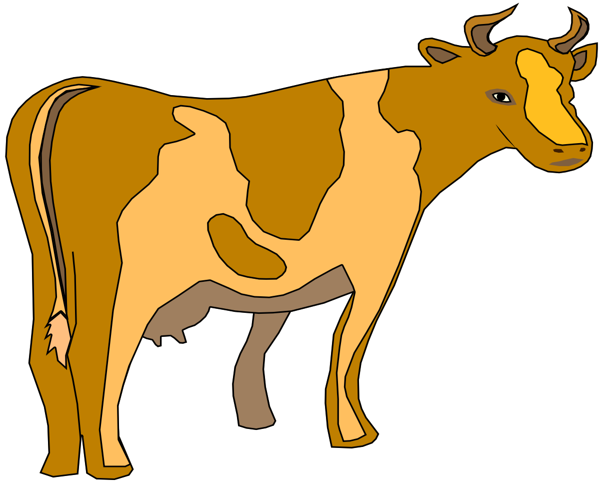
Methane is related to milk yield and feed efficiency



Reducing methane does NOT increase milk yield
High emitters generally digest forage more efficiently

Lower methane should not be the only breeding goal

RuminOmics (EU-FP7 project)



Linking the cow genome to the rumen microbiome, feed efficiency and impact

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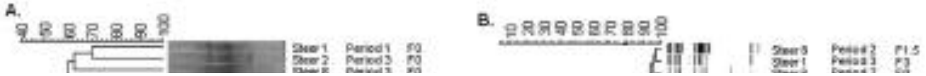
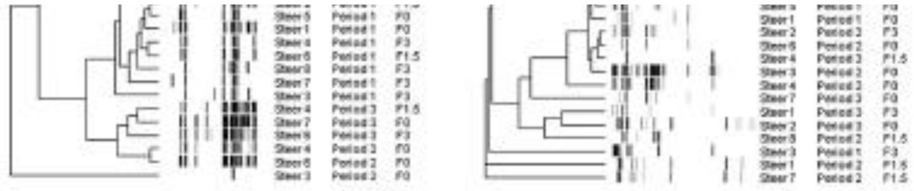


A core microbiome is heritable and is related to methane emissions and feed efficiency.

The cow controls her own rumen microbes – or the microbes control the cow.



RUMINOMICS

Wallace, R.J., *et al.* (2019) A heritable subset of the core rumen microbiome dictates dairy cow productivity and emissions. *Science Advances* 5, EAAV8391.

Welfare in intensive systems

Nottingham University Dairy Centre (NUDC)

Centre for Dairy Science Innovation (CDSI)

- Opened 2008
- Cows housed all year
- Robotic milking
- Slatted floors
- Space = 8.8 m^2 per cow
- Milk yield 10,500 L/cow/y

- Opened 2018
- Sand bedded cubicles
- Excellent ventilation
- Feeding
- Space ratio 8.8 to 14.1 m^2 per cow
- Cubicle dimensions
- Good ventilation
- Passage ways 1.5 - 2 times recommended
- Partial mixed ration
- Concentrate in robot
- Milk yield increased from 10,500 to 12,500 L/cow/y
- Somatic Cell Count went down from 180 to <100
- Lameness decreased
- Fertility improved

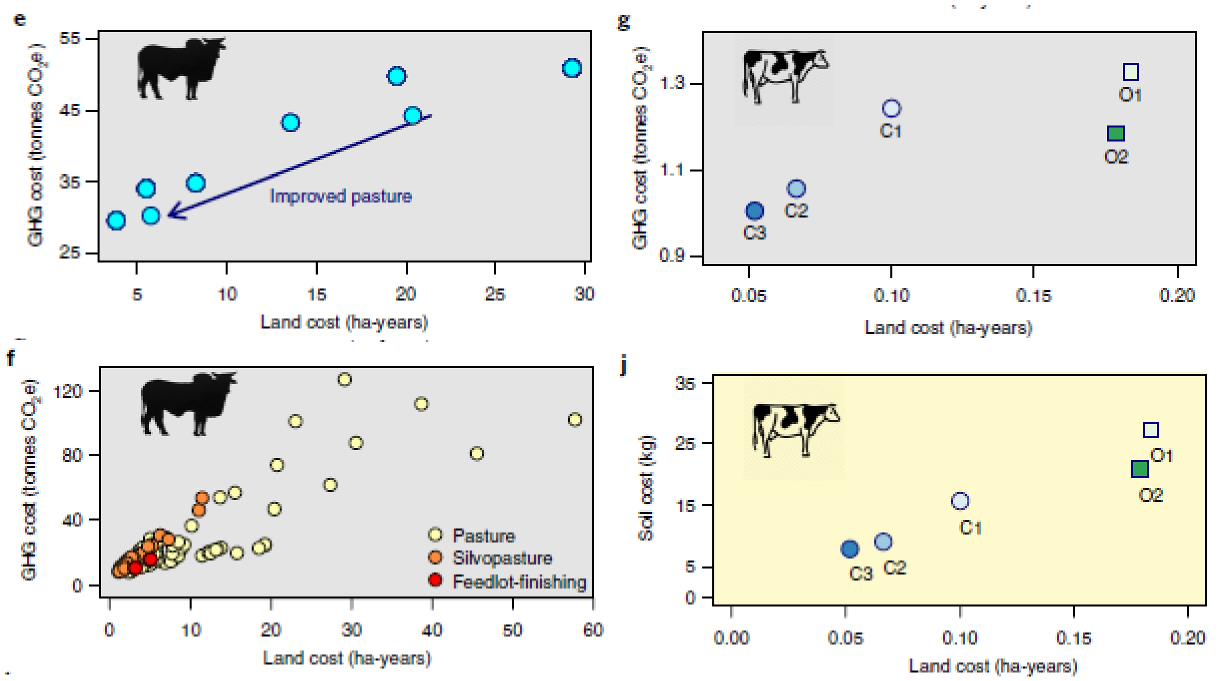
Animal intensification and Biodiversity

nature sustainability ARTICLES
https://doi.org/10.1038/s41893-018-0138-5

The environmental costs and benefits of high-yield farming

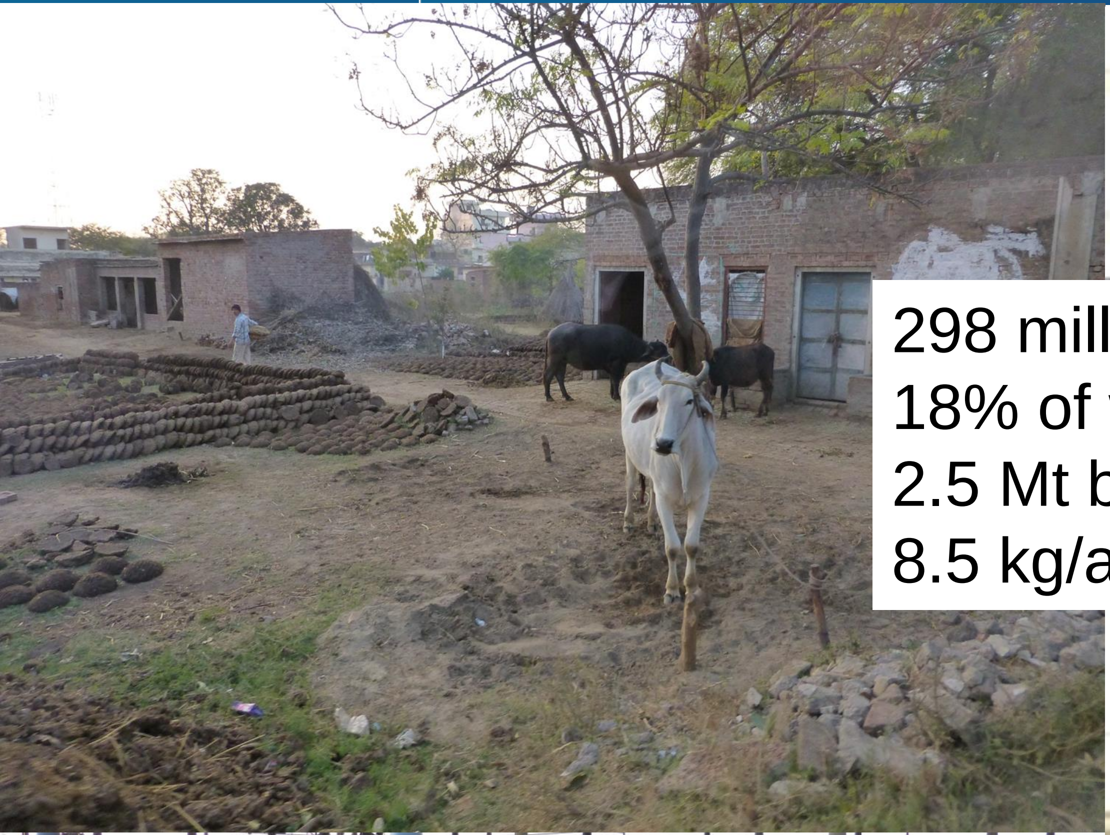
Andrew Balmford[1*], Tatsuya Amano[1,2], Harriet Bartlett[1], Dave Chadwick[3], Adrian Collins[4], David Edwards[5], Rob Field[6], Philip Garnsworthy[7], Rhys Green[1], Pete Smith[8], Helen Waters[1], Andrew Whitmore[9], Donald M. Broom[10], Julian Chara[11], Tom Finch[1,6], Emma Garnett[1], Alfred Gathorne-Hardy[12,13,14], Juan Hernandez-Medrano[15], Mario Herrero[16], Fangyuan Hua[1], Agnieszka Latawiec[17,18], Tom Misselbrook[4], Ben Phalan[1,19], Benno I. Simmons[1], Taro Takahashi[4,20], James Vause[21], Erasmus zu Ermgassen[1] and Rowan Eisner[1]

Detailed field data from five continents and almost 1,800 species reveal that for most species the impacts of agriculture are best limited by farming at high yields alongside sparing large tracts of intact habitat.



- Externality and land costs can covary positively: per unit production
- Land-efficient systems often produce lower externalities
- Farming at high yields (production per unit area) has considerable potential to restrict humanity’s impact on biodiversity.

Special case - India



298 million cattle
18% of world pop.
2.5 Mt beef/year
8.5 kg/animal

Silvo-pastoral systems – Yucatan, Mexico

Conclusions

Sustainable intensification of animal production means:

- Increasing efficiency of converting feed into animal products
- Reducing environmental impacts
- Increasing profit
- All with high standards of animal welfare

- Production efficiency can be increased at all scales
- Often there are hidden inefficiencies at the system level

- Emissions, Profit and Efficiency are all linked

- **Animal Production is vital to Future Food Security**

Thank you for your attention