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Milano, 18 settembre 2020

Convegno ASPA 2020

IL RUOLO DELLA ZOOTECNIA INTENSIVA NELLO SVILUPPO SOSTENIBILE

Sostenibilità ambientale delle produzioni animali: valutazione e nuove prospettive

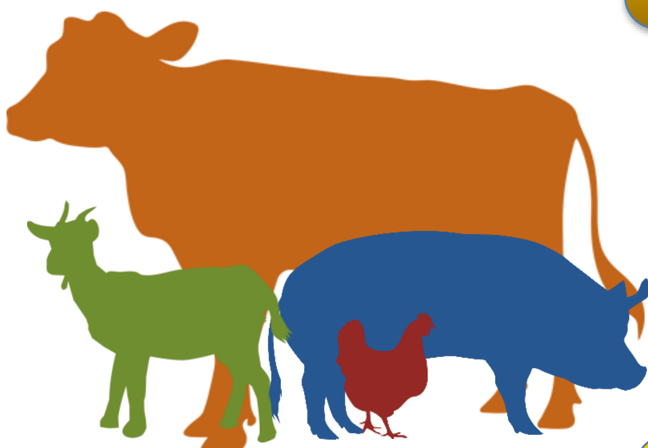
Anna Sandrucci

Environmental costs of animal productions

Land use

Soil compaction & erosion

GHG emissions



Biodiversity loss

Water depletion

Eutrophication

Particulate matter emissions

Acidification

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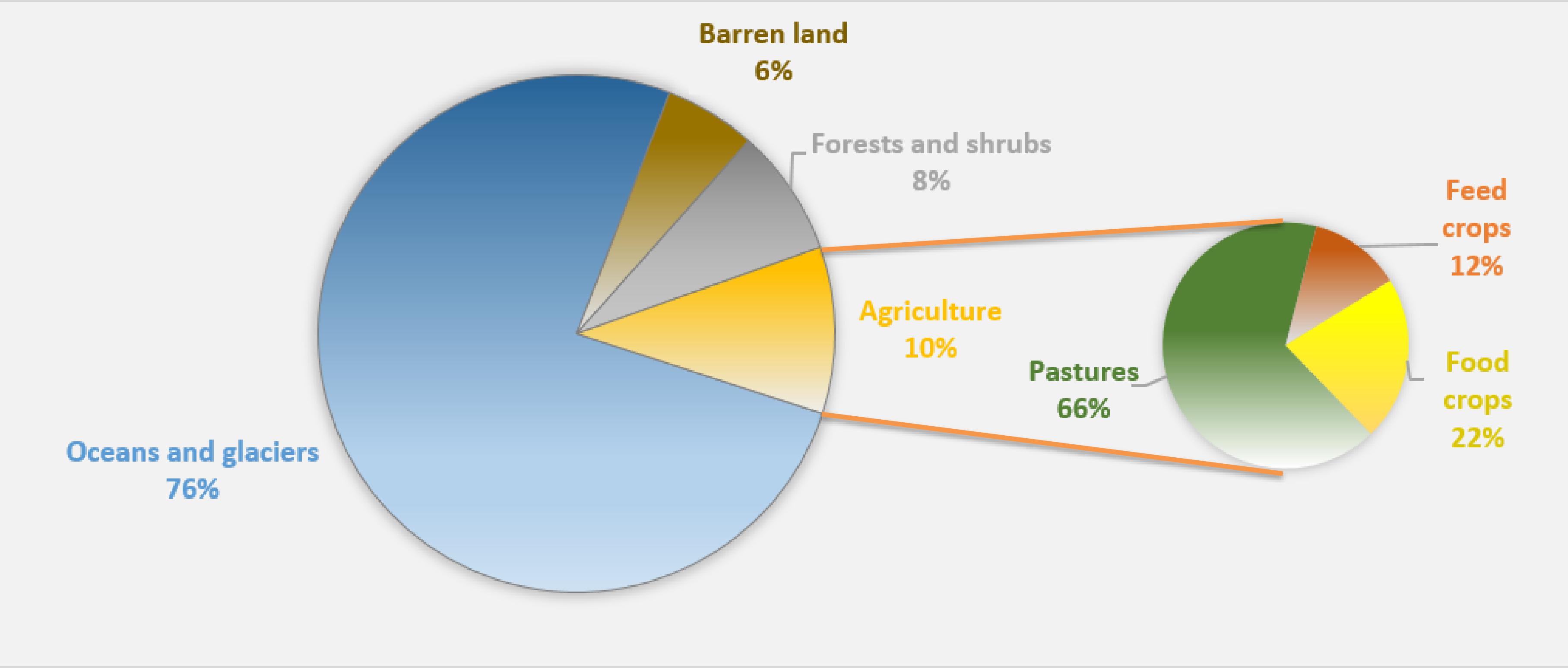
Global land use



Livestock productions occupy ~77% of agricultural land *(FAO 2019)*

Ruminants occupy the largest area of land worldwide compared with other livestock species (*Pulina et al 2016*)

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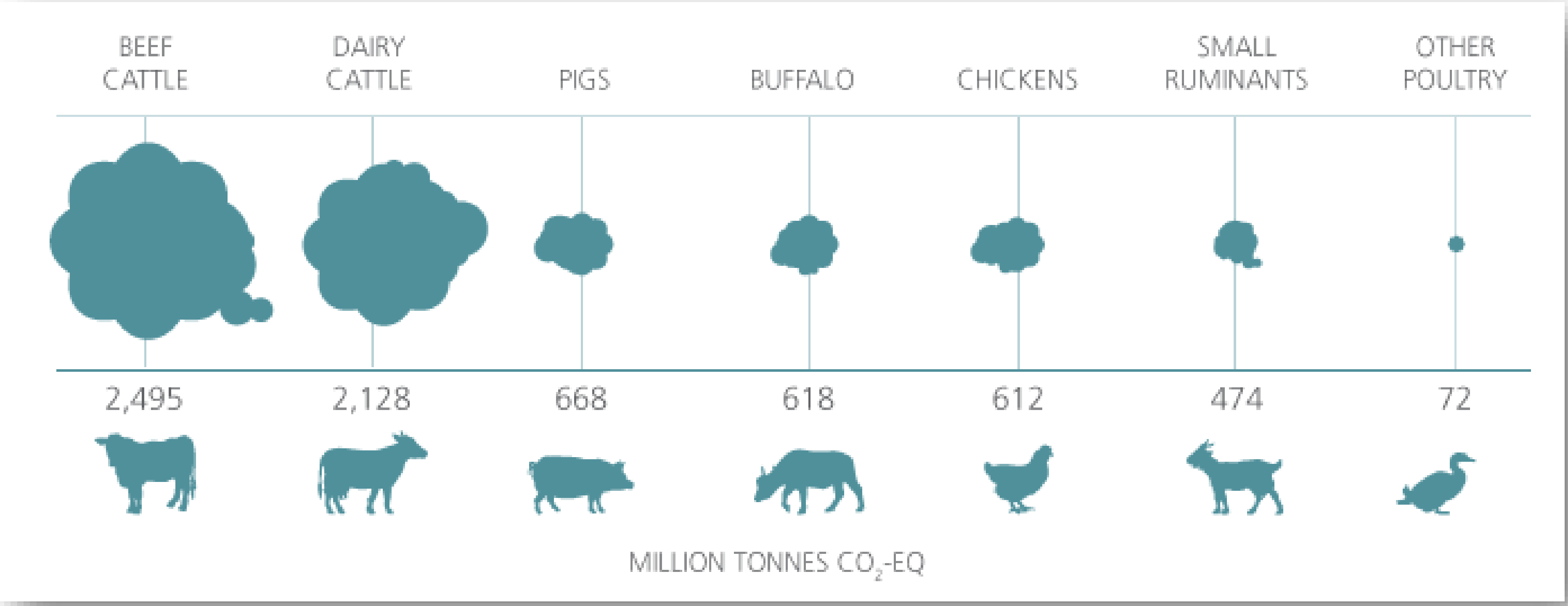
Global GHG emissions of different animal species



Livestock production contributes 14.5% of anthropogenic greenhouse gas emissions including land use change

Ruminant animals emit 80% GHG
Gerber et al. 2013

Animal-source food

Livestock production supplied 25% of protein consumed globally in 2016 *(FAOSTAT 2016-2018)*.

Compared to plant foods, animal derived food supply greater quantities of higher quality protein and more bioavailable vitamin A, vitamin D3, iron, iodine, zinc, calcium, folic acid and key essential fatty acids

Several of these nutrients are critical for neurological development *(Gupta 2016)*

Animal-source foods are the best available sources of high-quality nutrient-rich food for children aged 6–23 months *(WHO 2014)*.

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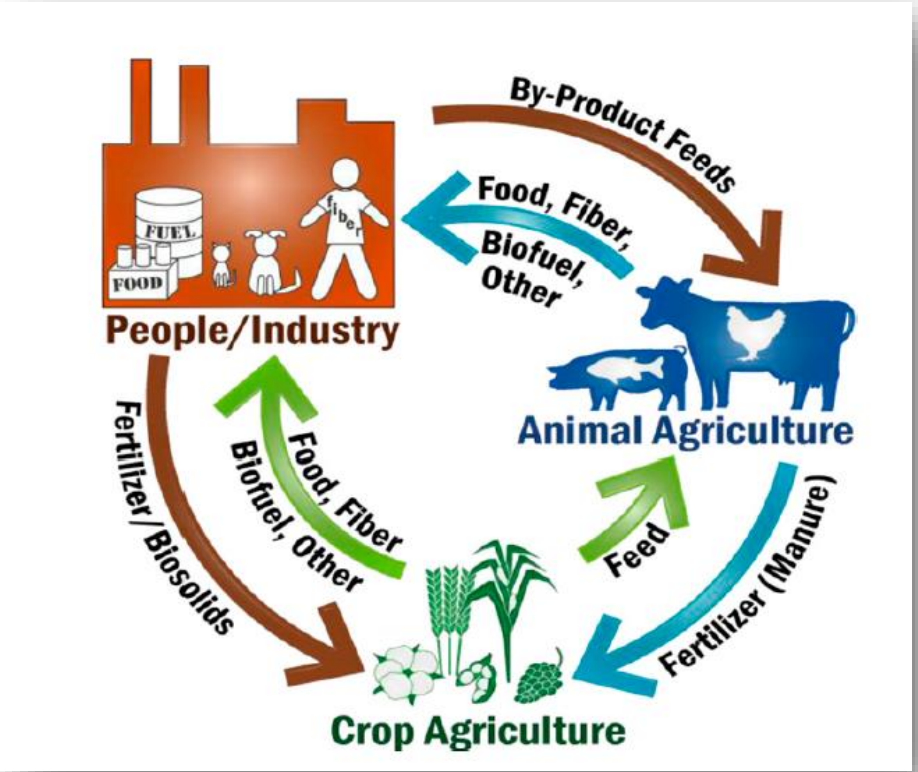
Services from livestock



White & Hall 2017

Livestock contribute to soil fertility with organic matter and nutrients, providing organic fertilizer for over 50% of the world's croplands *(Bruinsma 2003; FAO 2018)*.

Livestock, particularly ruminants, consume substantial amounts of byproducts and fiber production that are not edible by humans

They use untillable pasture and grazing lands not suitable to produce crops for human consumption

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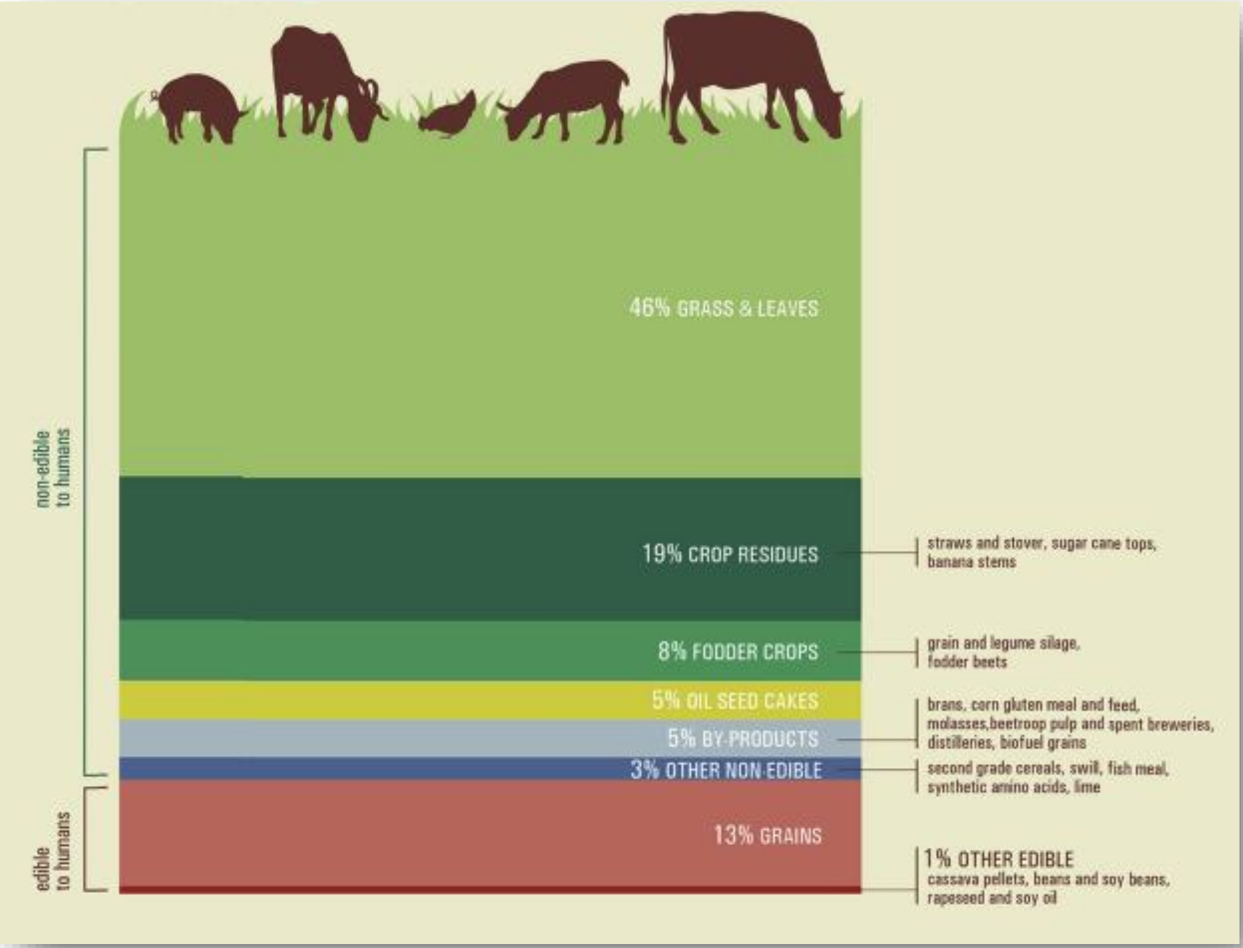
By-products, co-products, non human edible resources

Livestock converts over 432 billion kg of food by-products/fibrous inedible food for humans into edible food for humans, pet food and industrial products annually, plus 4 billion kg of N usable as fertilizer

White & Hall 2017



Adesogan et al 2020

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Ban of animal husbandry

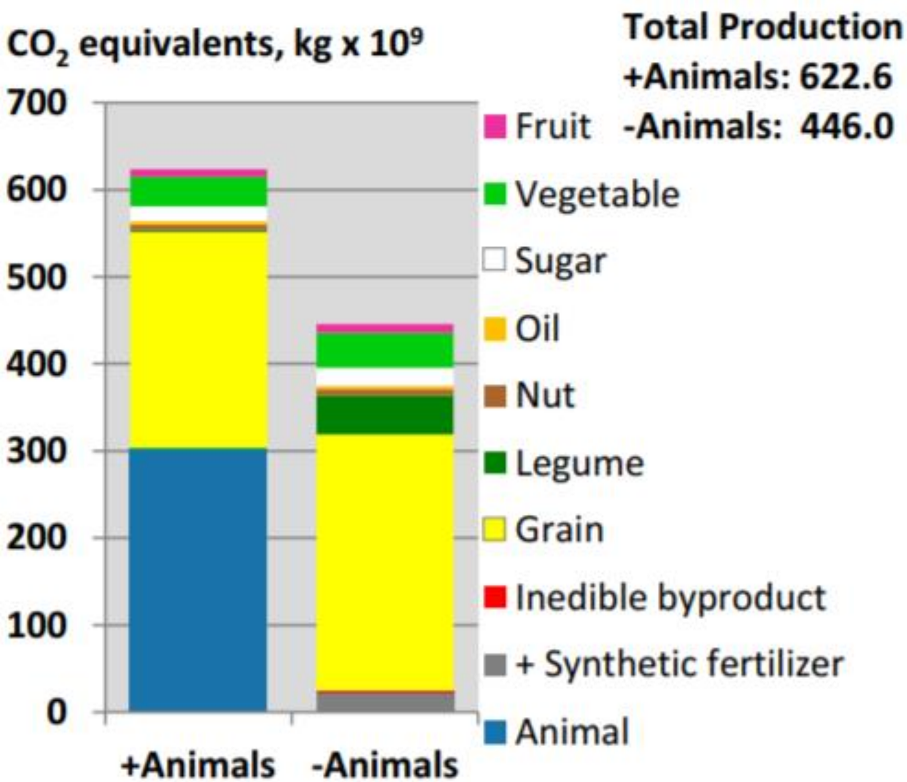

Fig. 5. GHG emissions associated with food production in a system representative of the current United States and a modeled system in which animal-derived food inputs are eliminated.

The GHG produced by the US agricultural system would decrease by 28% with the elimination of animal husbandry and not by 49% (estimated impact of animal husbandry) due to the need to synthesize fertilizers to replace animal fertilizers, to dispose of inedible by-products for previously used as animal feed and produce additional crops on land previously used by animals. In total, the elimination of animal husbandry would reduce total US GHG emissions by only 2.6 percentage units

White & Hall, 2017

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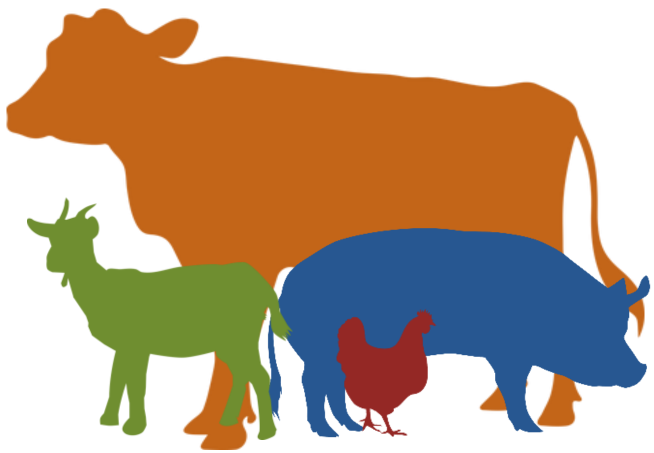
Mitigation strategies

Shift to extensive/organic livestock farming

Increasing C sequestration

Lowering enteric methane emissions



Increasing animal/feed crop efficiency

Changing animal diets

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Organic production

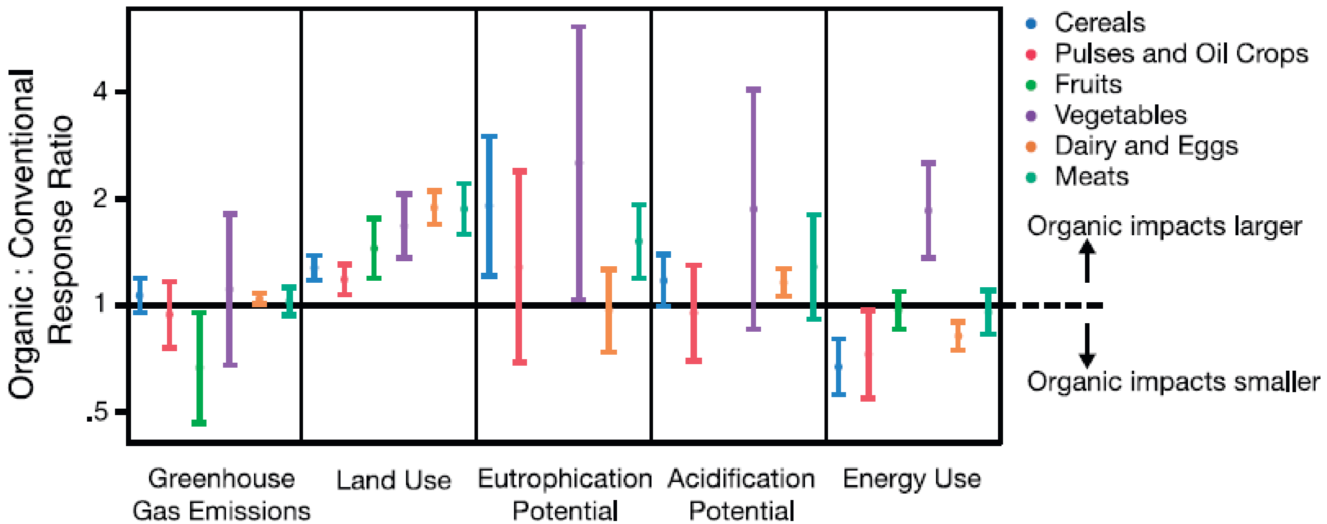

Figure 1. Response ratio of the environmental impacts of organic and conventional food production systems. Comparisons were made within publication to control for agronomic and environmental differences between publications. Plotted on a log base 2 scale, where a ratio greater than one indicates organic systems have higher impacts; a ratio less than one indicates organic systems have lower impacts. Bars are means and standard errors.

Organic systems require 25%–110% more land use, use 15% less energy, have 37% higher eutrophication potential, do not significantly differ in their GHG emissions or acidification potential than conventional ones per unit of food.

(Clark & Tilman, 2017)

Organic production

The average organic yield gaps of 19–25%, which would mean additional land requirements of 23–33%.

Large-scale conversion to organic would likely require bringing more natural habitats into agricultural production, with a net negative impact on biodiversity and soil organic carbon at larger spatial scales because of the greater land clearing

It is largely agreed that the biodiversity gains from organic production cannot offset the biodiversity loss associated with additional land-use change

Organic agriculture heavily depends on the livestock sector for fertilization *(Nowak et al. 2013)*. Completely replacing synthetic fertilizers would mean significantly increasing the number of farm animals kept.

Meemken and Matin Qaim 2018

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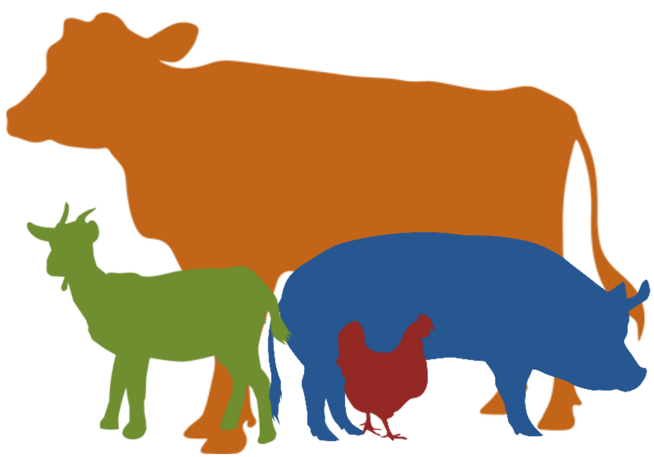

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Land use change and carbon sequestration

FAO estimates livestock induced land use change for feed production to be responsible for almost 10 percent of total livestock emissions (FAO, 2013).

By reducing the use of high LUC feed ingredients (e.g. soybean meal) and sequestering CO_2 in soil, farmers can help mitigate climate change: conversion from arable crops to permanent grasses, managing pastures, silvopastoral systems

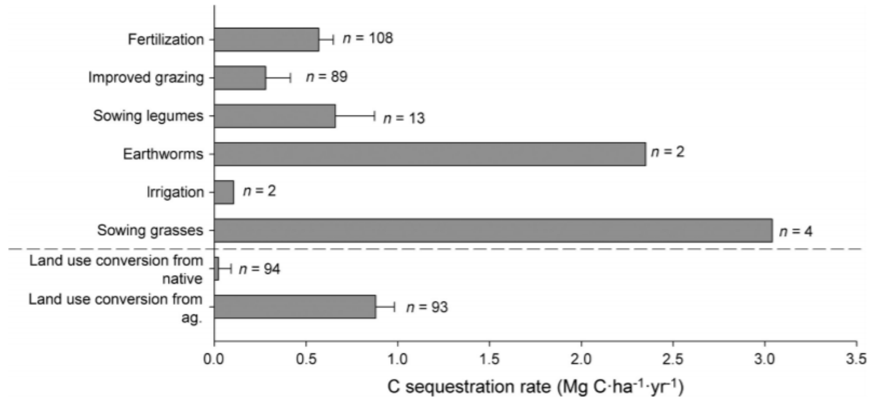

FIG. 3. Changes in soil C stocks driven by grassland management improvements. Bars represent average across all studies containing soil C stock change information, error bars represent SEs calculated using meta-analysis across all studies containing information on treatment SEs. The number of studies used to calculate the average is indicated for each type of management change.

Conant et al 2017

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Carbon sequestration in silvopastoral systems

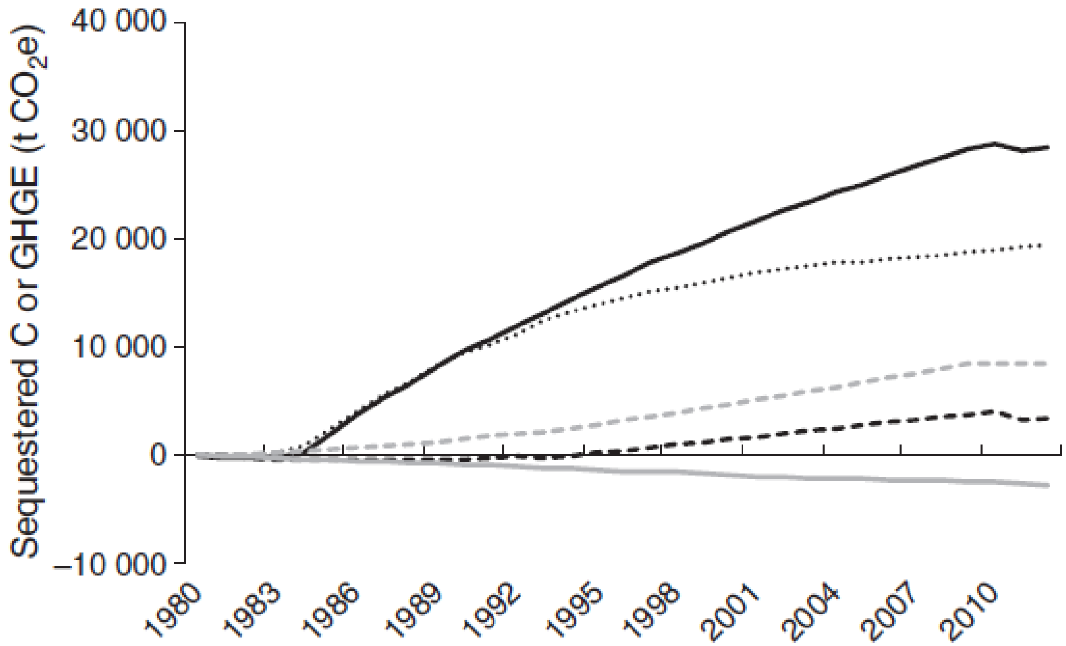

Fig. 1. Cumulative carbon balance from 1980 to 2012 (▬▬) including farm emissions (on-farm methane, nitrous oxide, carbon dioxide and pre-farm emissions) (▬▬), tree carbon sequestration (••••••) and soil carbon sequestration under pastures (▬ ▬ ▬) and on the slopes (▬ ▬ ▬).

Doran-Browne et al 2016

Silvopastoral systems are defined as the intentional integration of livestock, trees, shrubs and grasses on the same land unit (*Jose et al. 2017)*

The carbon uptake and storage potential of silvopastoral systems have been studied, in recent years, with the aim of offsetting livestock sector GHG emissions
(Steinfeld et al 2019)

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Silvopastoral systems

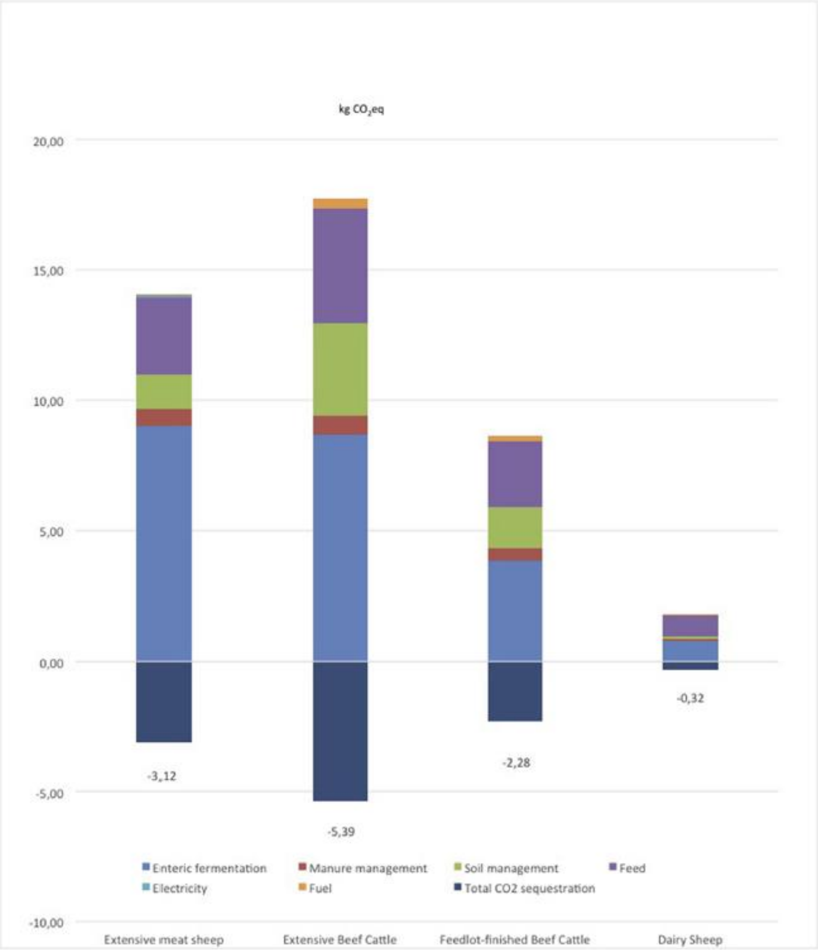

Fig. 3. Compensated CF per functional unit (kg of CO_2eq per FU).

Soil sequestration has also been observed to range between 270.02 and 334.01 kg CO_2eq ha^{-1} y^{-1} in the extensive farms under study, which represents considerable carbon compensation.
But it should be noted that these systems cannot compete in product units with the more intensive ones

Eldesouky et al 2018)

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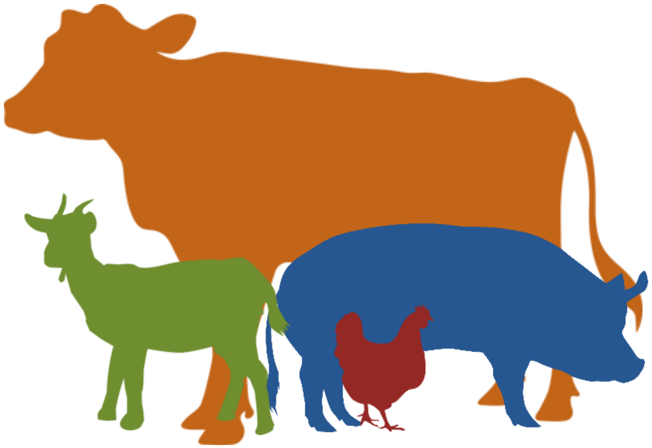

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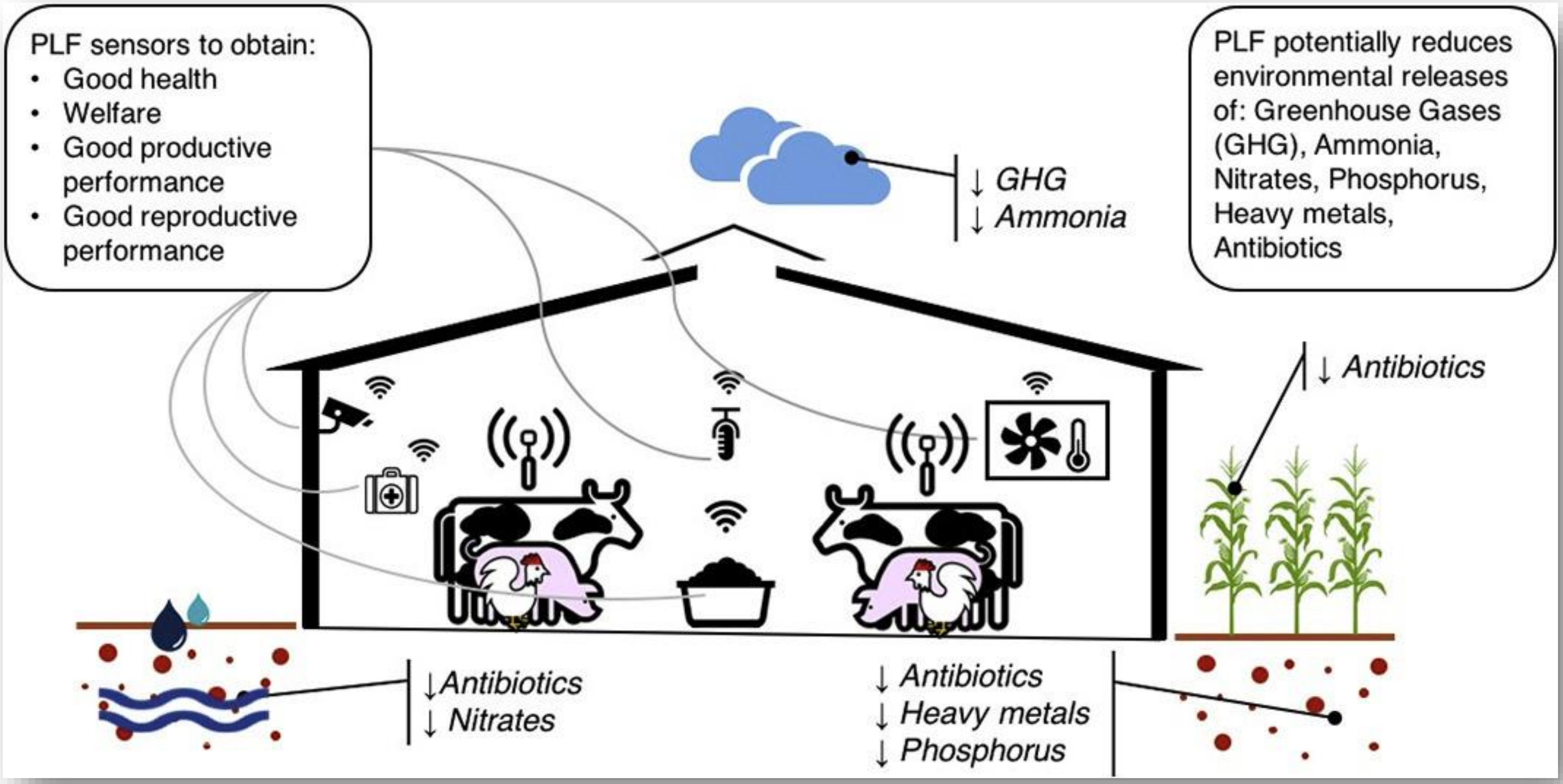
Precision Livestock Farming



Environmental impact can be reduced by limiting unwanted emissions that can occur when animals face health and stress problems *(Tullo et al., 2019)*

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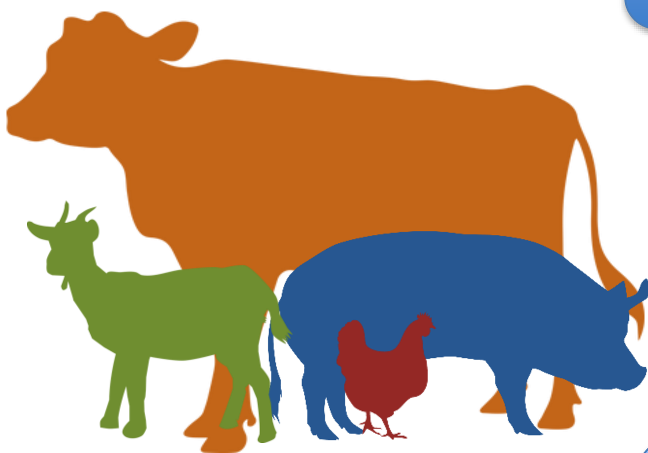
Health and welfare

Feed intake

Antibiotics and drugs

Feed conversion



Product quality and safety

Production

Longevity

Fertility

Energy requirements for maintenance

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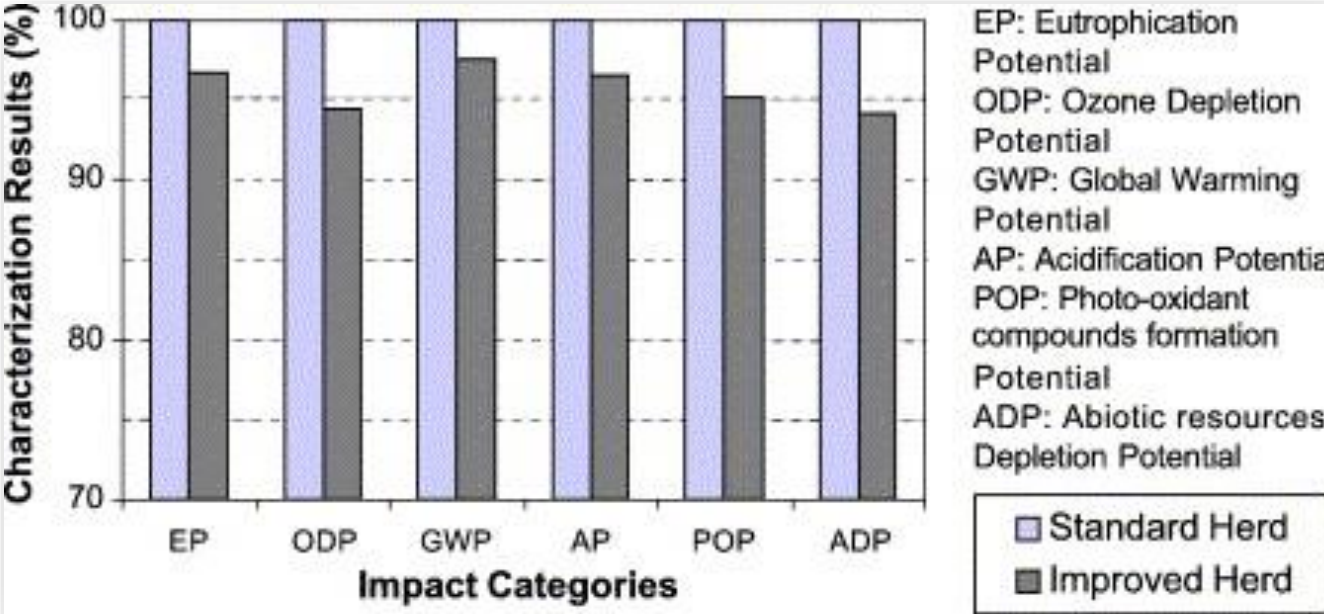
Mastitis



Hospido and Sonesson (2005) predicted a reduction of 2.5% (GWP) to 5.8% (depletion of abiotic resources) as a consequence of the decrease in clinical (from 25 to 18%) and sub-clinical mastitis rates (from33 to 15%)

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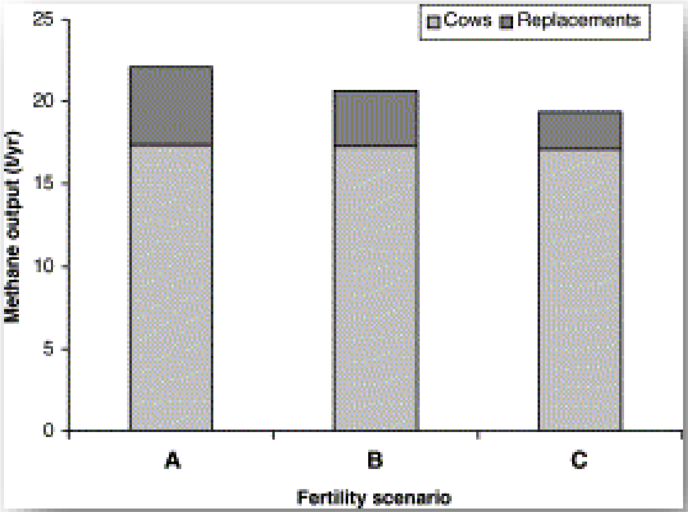
Fertility



Annual methane output per 100 cows in dairy herds with no milk quota and a mean annual milk yield of 6000 l per cow, and with current levels of fertility (A); 1995 levels (B); or ideal levels (C).

According to Garnsworthy (2004), CH4 emissions could be decreased by 10–11% and ammonia emissions by about 9% by restoring average fertility rates in dairy cattle to those in 1995.

According to Nguyen *et al*. (2013), decreased calving age seems a promising strategy to mitigate GHG emissions by an estimated 8 to 10%.

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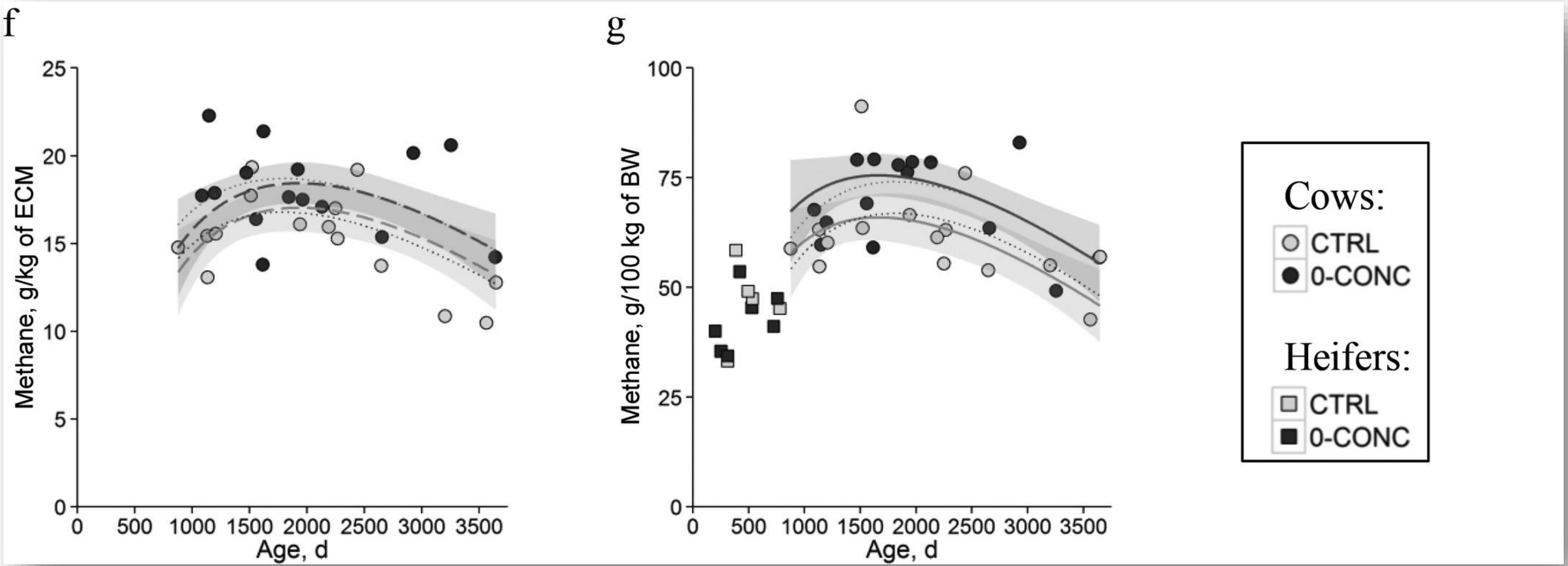
Longevity



Methane emissions per unit of intake, body weight, and milk yield were significantly related to age. Their development in the cows with age was characterized by an increase to maximum at around 2,000 d of age, followed by a decline *(Grandl et al 2016)*

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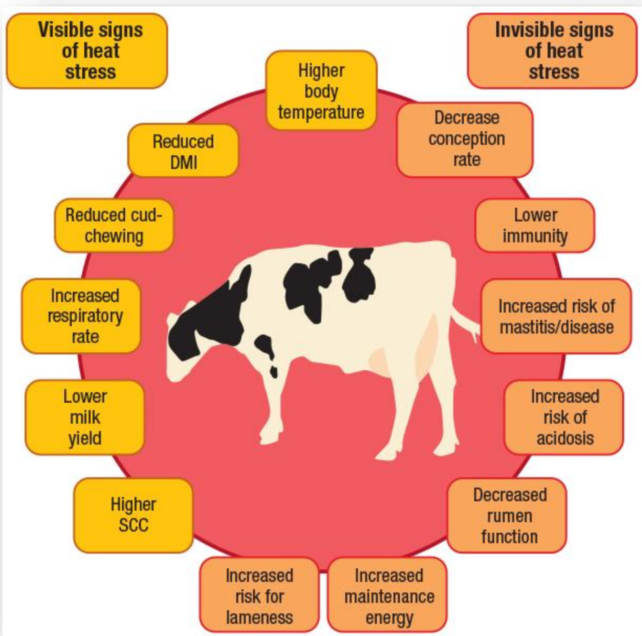
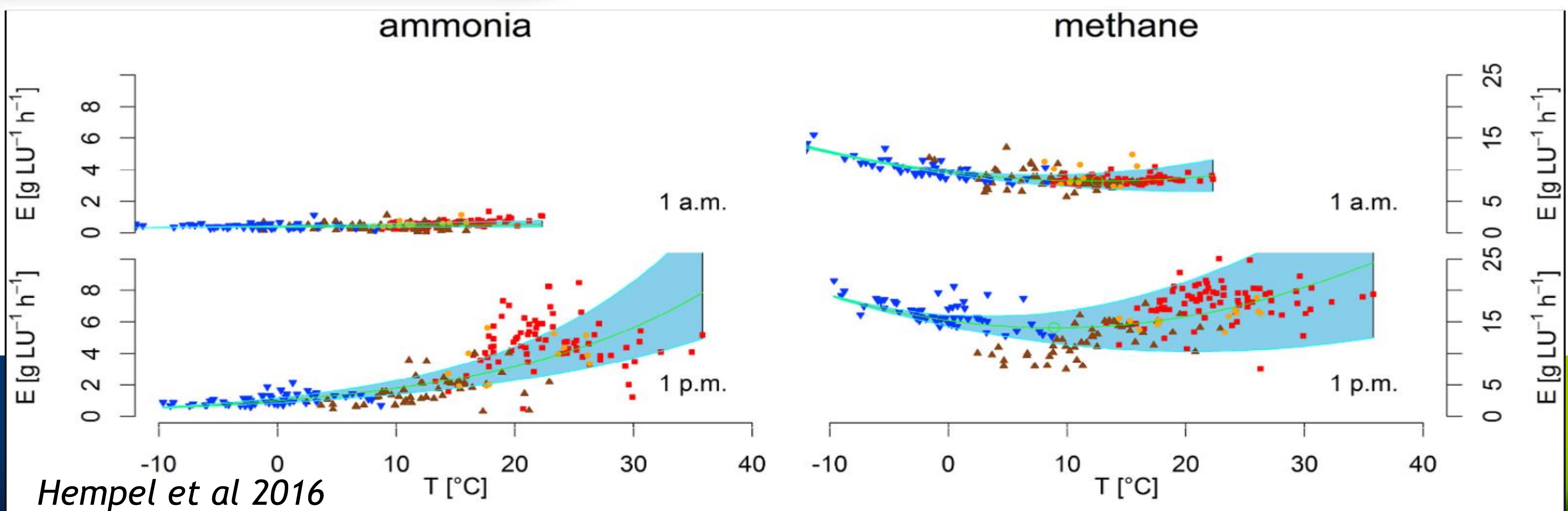
Heat stress



Need of rethinking environment control strategy of confined animal housing systems through precision livestock farming to reduce stress events

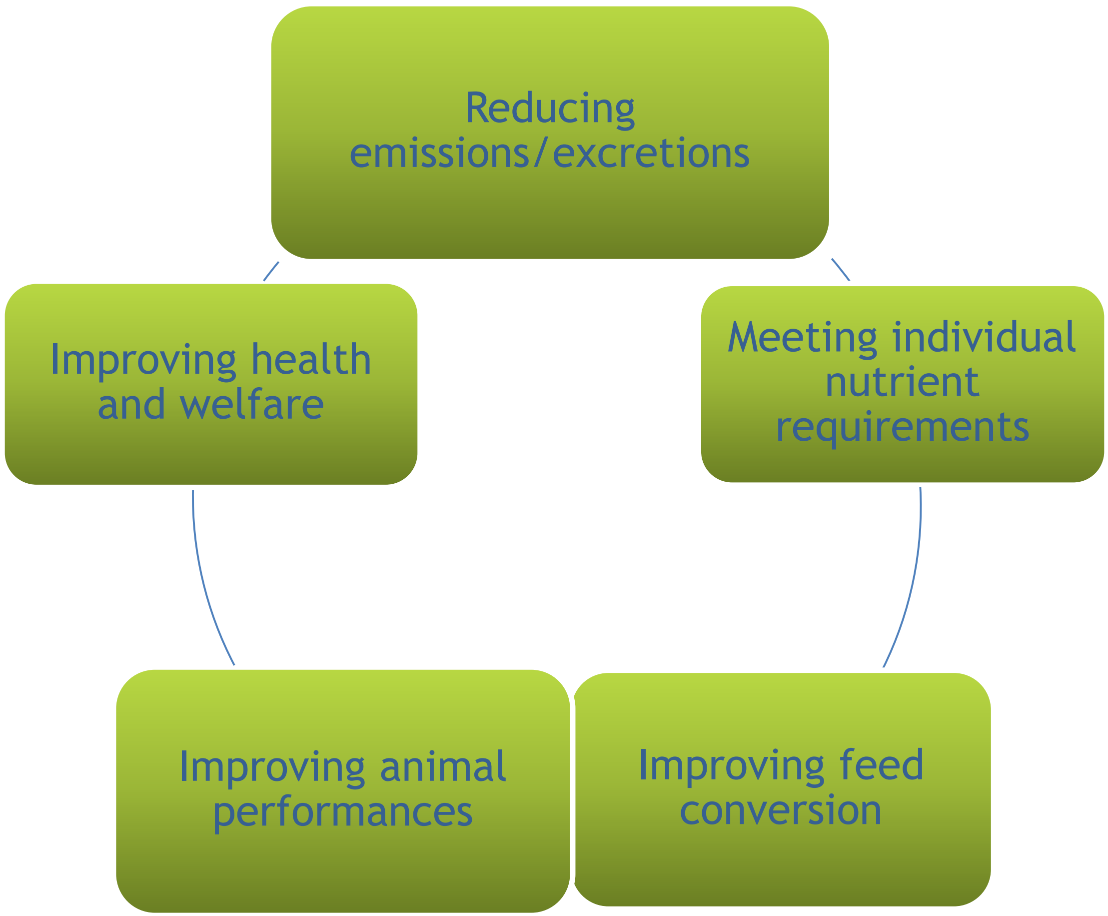
Enteric methane emissions rise with heat stress event *(Hempel et al 2016)*

Ammonia and methane release from manure increases with temperature *(Amon et al 2007; Hempel et al 2019)*



Hempel et al 2016

Precision feeding



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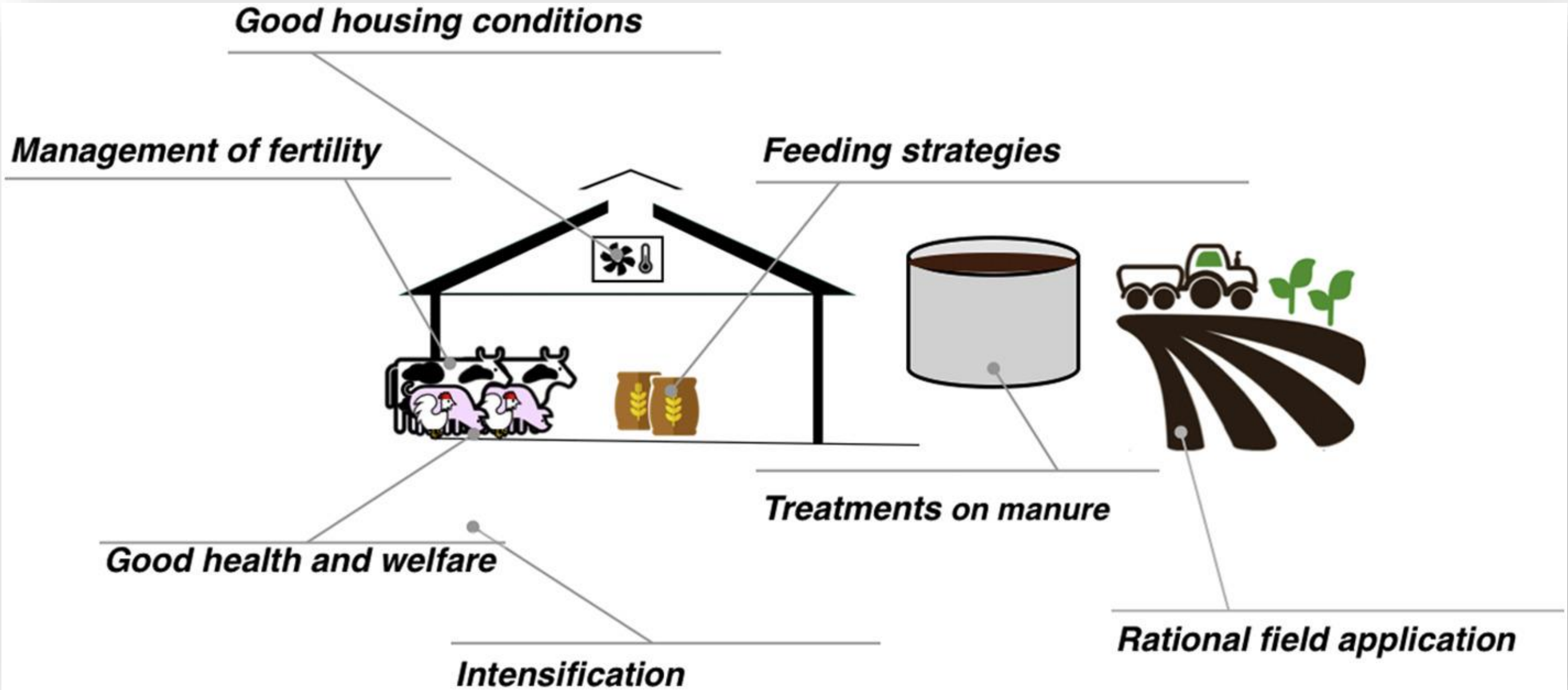
Precision agriculture



Tullo et al 2019

Feed crop productions must be as efficient as herd management, especially in terms of manure utilization and forage system

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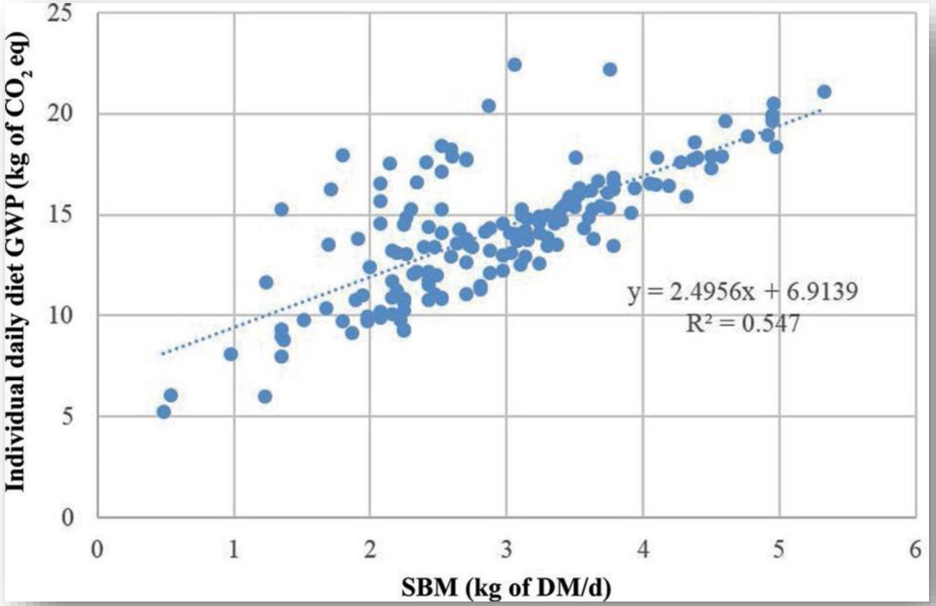
Feed crop production and forage systems

Improvement of forage systems in ruminant livestock farming:

1) to enhance biomass production, forage quality, digestibility and feed conversion efficiency
2) to contribute to soil C sequestration
3) to reduce the use of imported high LUC feed materials



Gislon et al 2020

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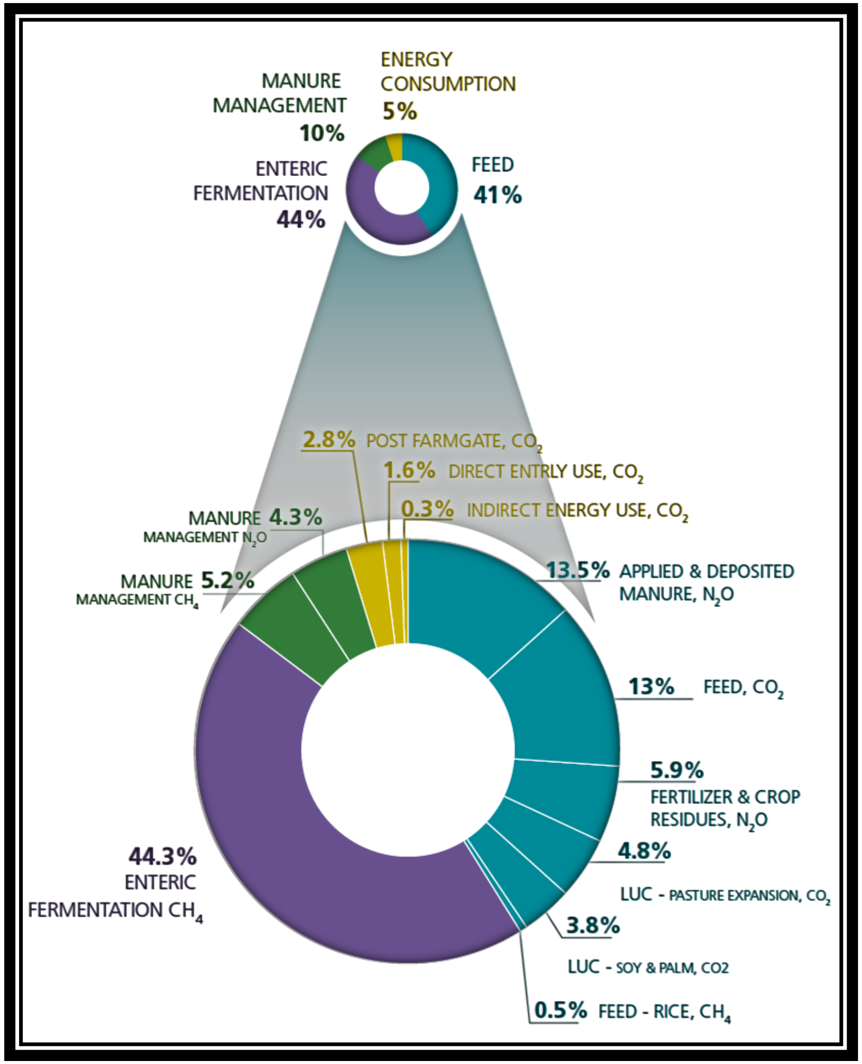
Feed efficiency



Feed production accounts for about 45% of the sector's GHG emissions
(Herrero et al., 2016)

Feed efficiency depends on:
- Diet digestibility
- Health and welfare
- Genetic characteristics
- Microbiota
- …

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Feed efficiency

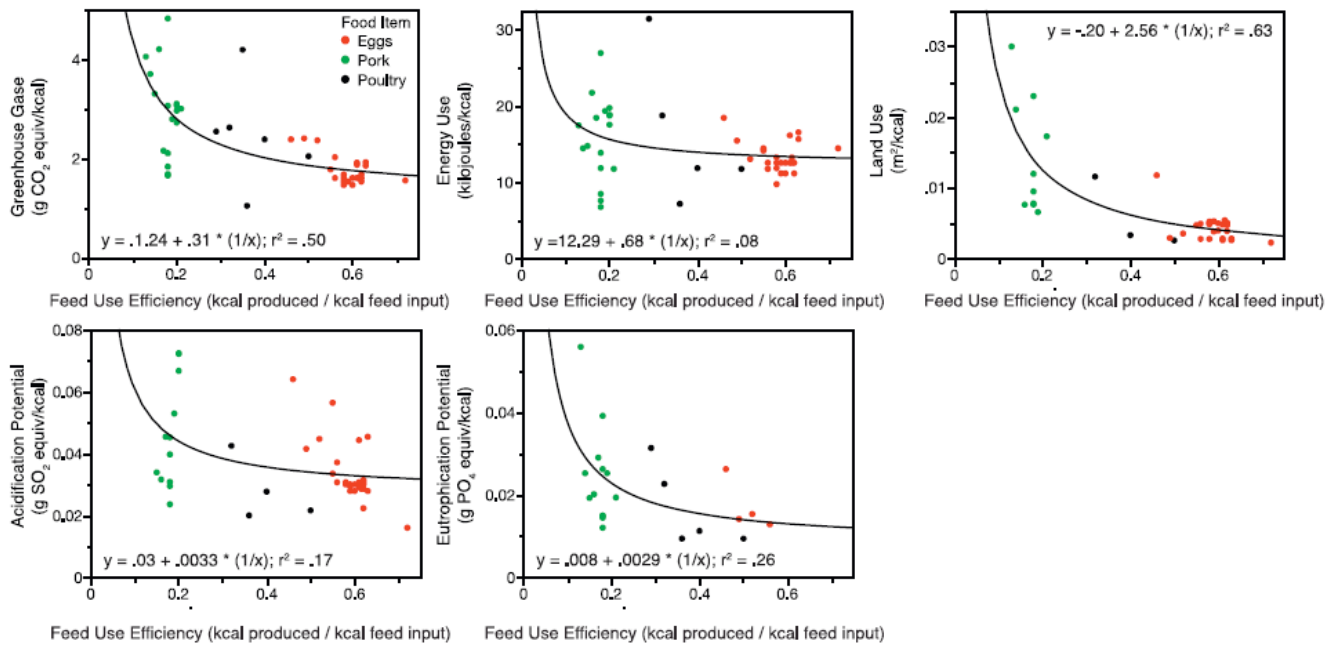

Figure 7. Correlations between feed use efficiency, or kcal of food produced per kcal of feed input, and environmental impacts in non-ruminant livestock systems. Regression lines are reciprocal fits between feed use efficiency and a food's environmental impacts. All relationships are significant at $p < .05$.

The environmental benefits of increasing agricultural input efficiency would not be equal across all systems, with improvements efficiency having the largest environmental benefit in the least efficient systems *(Clark & Tilman 2017)*

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Gene editing

Table 2 Examples of genome editing for disease resistance and other production traits

Genome editing			
Trait	Species	Genome-editing target	Reference(s)
Increased muscle growth (double-muscle phenotype)	Cow	Myostatin (GDF8)	[56]
	Sheep	Myostatin (GDF8)	[56, 57]
	Goat	Myostatin (GDF8)	[58]
	Channel Catfish	Myostatin (GDF8)	[59]
	Pig	Myostatin (GDF8)	[60–66]
Hornlessness (Polled)	Cow	Pc POLLED	[74]
Boretaint (Hormone release during sexual maturity leading to undesired meat taste)	Pig	KISS1R	[75]
Sterility	Salmon	Dead end protein (dnd)	[78]
Sterility/surrogate hosts	Pig	Nanos2	[79]
	Chicken	DDX4 (Vasa)	[80]
PRRSV resistance	Pig	CD163	[90–93]
ASFV resilience	Pig	RELA	[95, 96]
Mannheimia (Pasteurella) haemolytica resilience	Cow	CD18	[97]
Bovine tuberculosis resilience	Cow	NRAMP1	[99]
Xenotransplantation (removal of endogenous retroviruses)	Pig	Porcine endogenous retrovirus genes	[106, 107]

Abbreviations: *ASFV* African swine fever virus, *GDF* growth and differentiation factor, *PRRSV* porcine reproductive and respiratory syndrome virus

Muscle growth, infectious diseases resistence, production of enzymes such as phytases or xylanases in pigs, sterility in male pigs to avoid castration, hornlessness in cattle *(Burkard et al 2018)*

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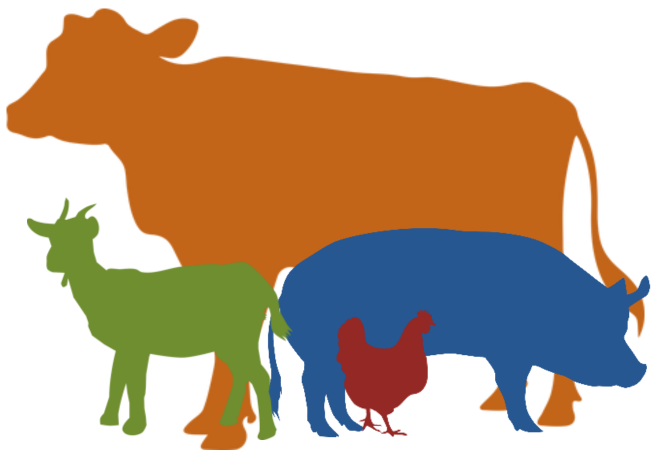

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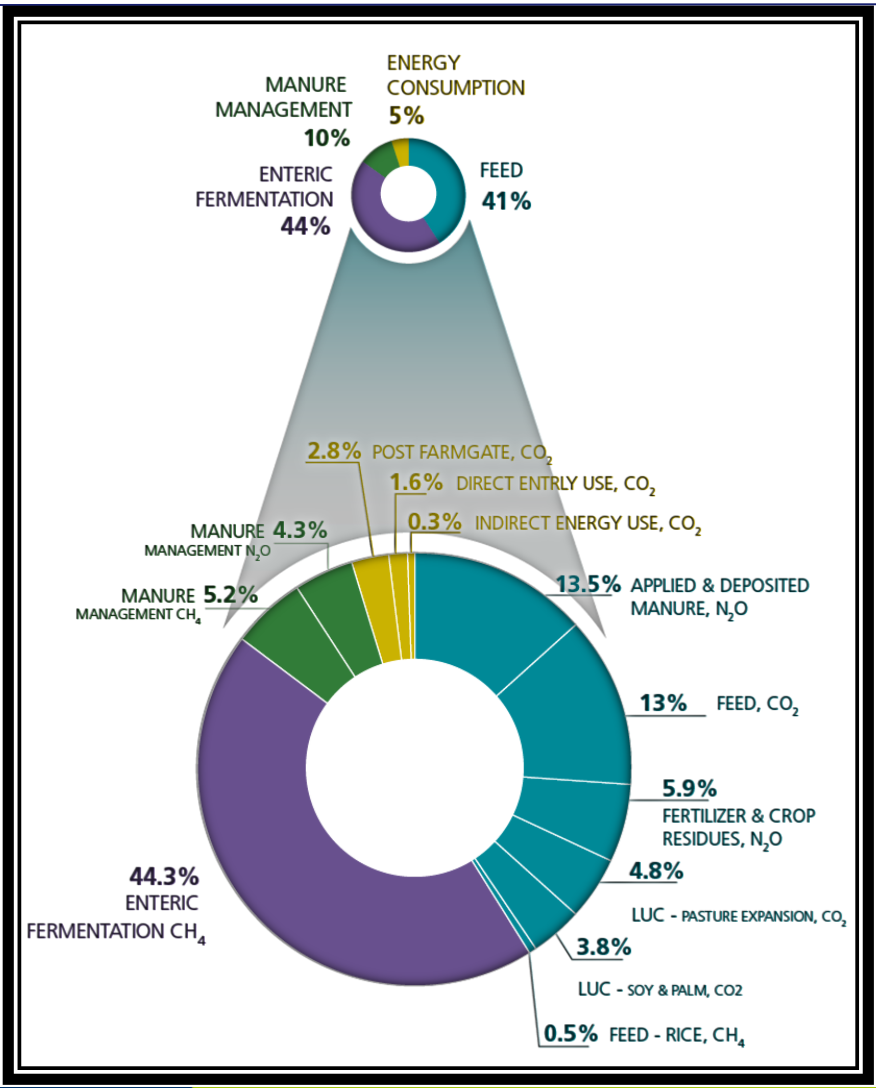
Enteric fermentations



Enteric fermentations accounts for about 40% of the sector's GHG emissions *(Herrero et al 2016)*

Strategies classified as antimethanogenic included chemical inhibitors, electron acceptors (i.e. nitrates), ionophores (i.e. monensin), dietary lipids, etc., each with limited success *(Hook et al., 2009)*.

Genetic selection for animals with less enteric CH_4 emission, on a daily or dry matter intake basis *(Knapp et al 2014)*.

The role of the microbiota

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Reducing rumen methane emissions

J. Dairy Sci. 103:8074–8093
https://doi.org/10.3168/jds.2019-17936

3-Nitrooxypropanol decreases methane emissions and increases hydrogen emissions of early lactation dairy cows, with associated changes in nutrient digestibility and energy metabolism

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[1]Wageningen Livestock Research, Wageningen University & Research, PO Box 338, 6700 AH, Wageningen, the Netherlands
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Feeding 3-nitrooxypropanol to dairy cattle in early lactation decreased CH_4 emissions by an average of 15.8%, without negatively affecting the apparent total-tract digestibility of DM, OM, NDF, and GE was higher with 3-NOP, energy and N balances, DMI, milk yield, milk component yield, or feed efficiency *(van Gastelen et al 2020)*

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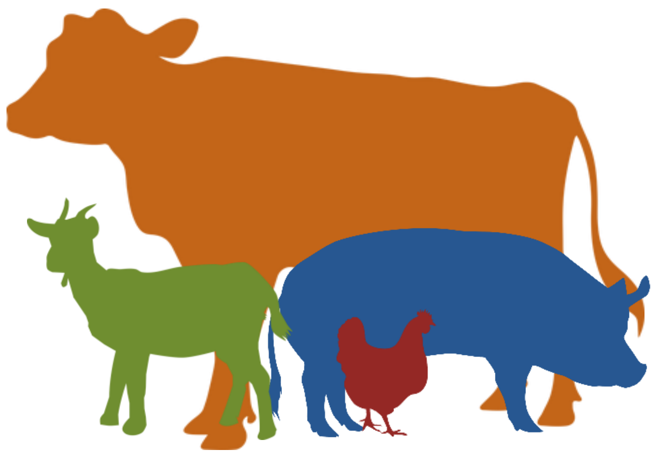

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Food wastes

- Food wastes can represent high-quality animal feed that requires no additional land with minimal or even positive environmental impact (disposal costs).
- Their use is limited in the European Union due to safety reasons
- Results from Ermgassen et al. (2016) suggest that the application of existing technologies could reduce the land use of EU by one fifth, potentially saving 1.8 million hectares of agricultural land.
- Despite the challenges of feeding by-products (i.e., risk of mycotoxin contamination, variation in nutrient composition between batches, etc.), studies have demonstrated that diets with relatively high proportions of by-products can maintain or even improve ruminant performance (Bradford and Mullins 2012).

Food wastes

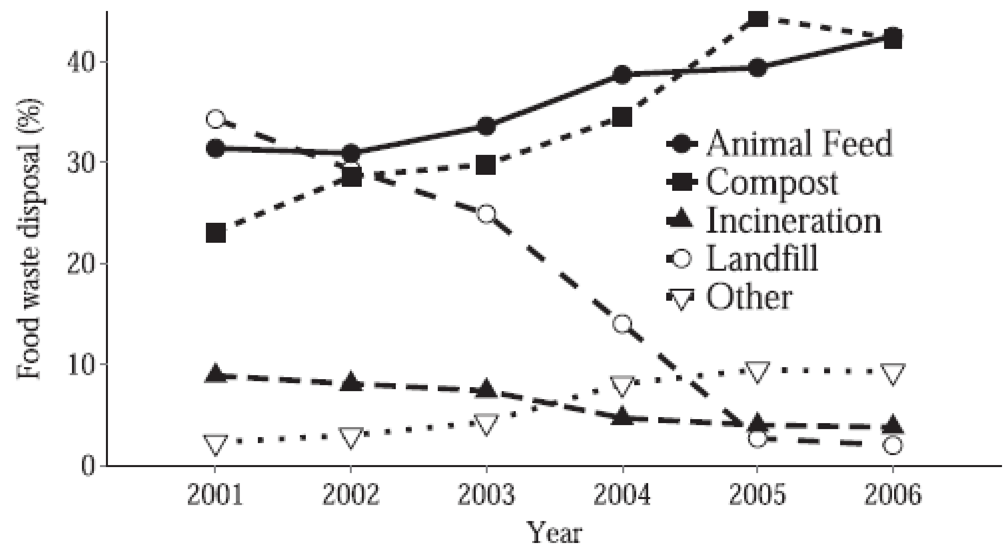

Fig. 1. The end-uses of food waste in South Korea 2001–06, the most recent available data (Kim and Kim, 2010). After the introduction of food waste recycling legislation in 1997, South Korea achieved substantial increases in food waste recycling. The recycling of food waste for animal feed is shown as a solid line.

In 2006–07 Japan and South Korea respectively recycled 35.9% and 42.5% of food waste as animal feed *(Kim and Kim, 2010; MAFF, 2012, 2011)*.

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Food wastes, by-products, non human edible feeds

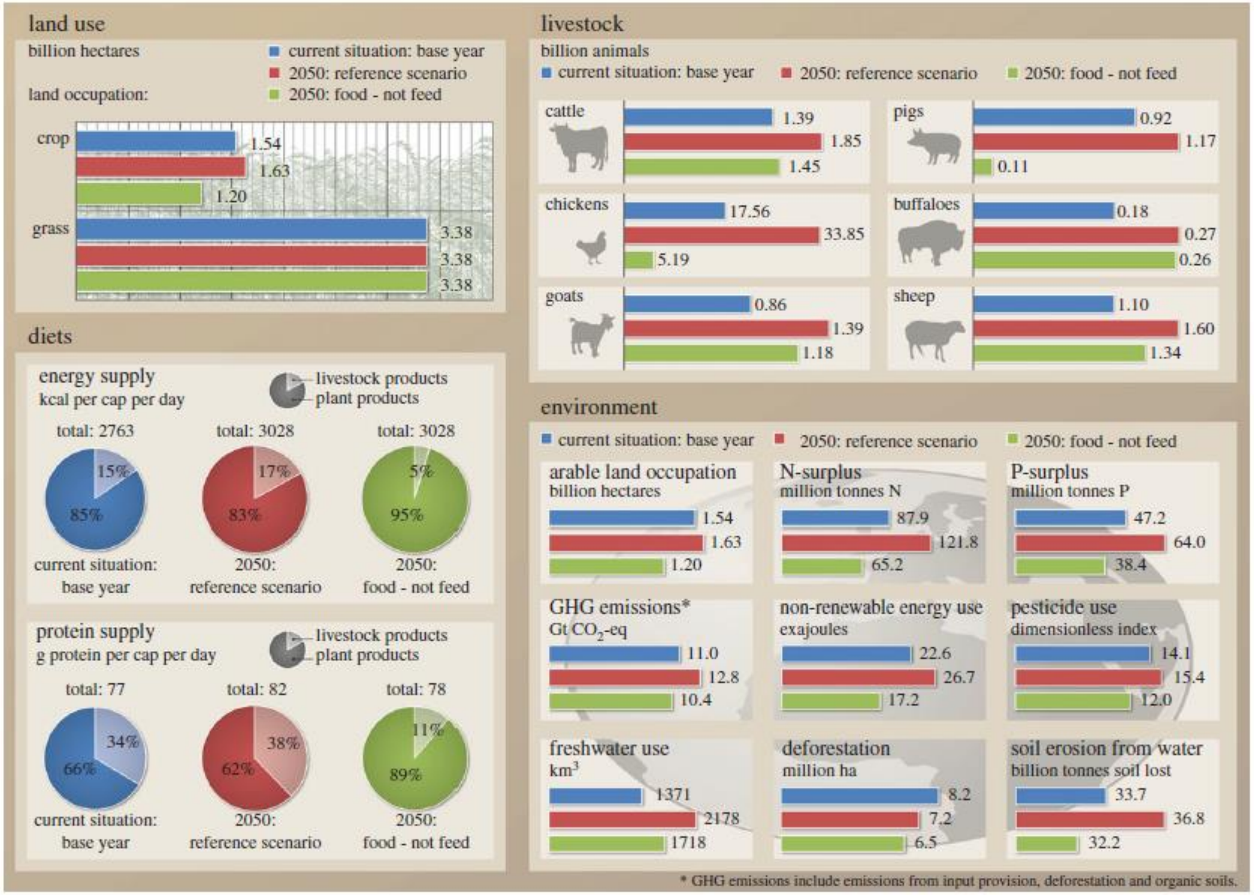

Figure 1. Impacts of feeding less food-competing feedstuffs to livestock ('food - not feed') on land use, livestock numbers, human diets and the environment in 2050.

Shader et al 2015

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Strategies

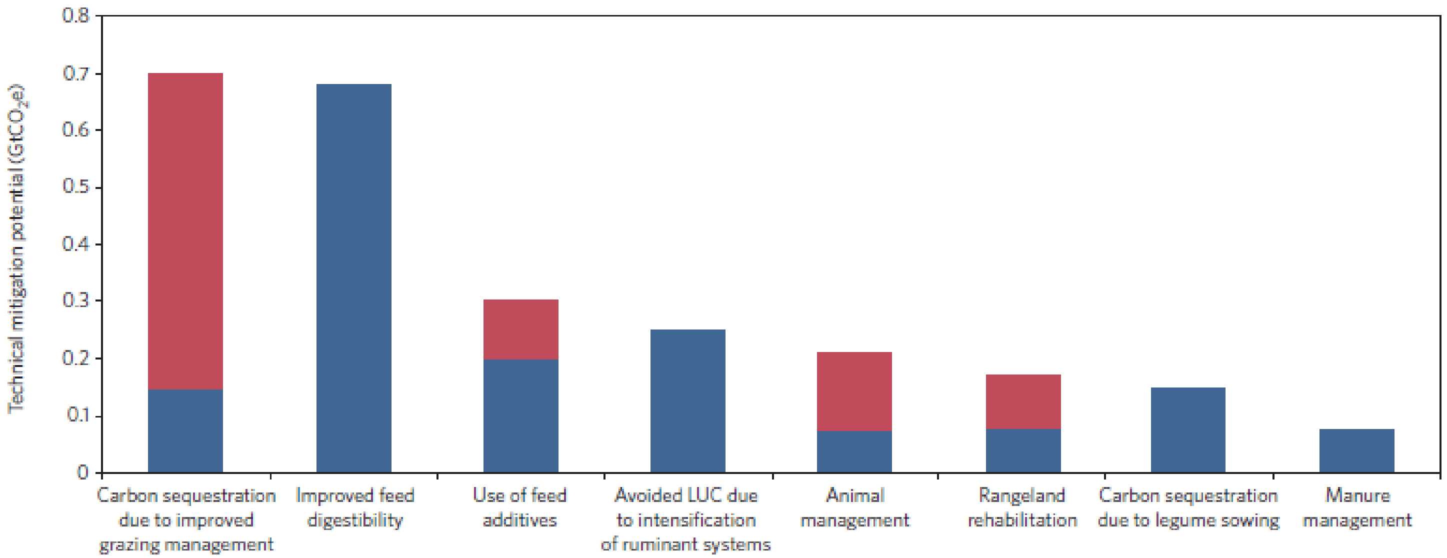

Figure 3 | Technical mitigation potentials of supply-side options for reducing emissions from the livestock sector. Red represents the range for each practice, where available. The range of mitigation potentials for carbon sequestration due to improved grazing management is defined by refs 41,56. The mitigation potentials for 10% improved digestibility in all ruminants in the developing world are shown, obtained by up-scaling values from ref. 37. Direct application of this option to developed country situations was assumed to be too small to be considered. Full adoption of the practice across all ruminants was assumed to obtain the technical mitigation potential for this practice, hence no range is presented . The mitigation potentials for use of feed additives are from ref. 32, and include inhibitors, ionophores, electron receptors, enzymes, plant bioactive compounds, lipids and manipulation of rumen microflora. These potentials are applied to breeding herds of cattle globally with effects on E_{CH_4} as described in ref. 32. The mitigation potentials of avoided land-use change from transitions from grazing to mixed crop–livestock systems are from ref. 79. The mitigation potentials for animal management practices such as improved health and reduced mortality are from ref. 32, and the effects applied as for feed additives. Rangeland rehabilitation mitigation potentials are from ref. 56. Manure management mitigation potentials are from ref. 41.

Herrero et al 2016

Conclusions

Addressing the challenges faced by the livestock sector requires an evaluation of synergies and trade-offs between different sustainability domains (environment, animal welfare and health, human health, food security and other functions) and within the domain itself.

Specific sustainability outcomes are often interlinked with other outcomes, leading to trade-offs, even within and across the sustainability domains themselves.

Steinfeld et al 2019

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Conclusions

Meeting the sustainability objectives identified by the United Nations Sustainable Development Goals (2016) will be achieved with sound science, broader implementation of current technologies, and more deployment of new technologies in the near future.

Investment in agricultural research is more critical than ever.

Research must be free from prejudices and external/internal conditioning

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