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Five practical actions
towards low-carbon livestock

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Contents

Acronyms and abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
ASF	Animal-source food
CCAC	Climate and Clean Air Coalition
CFS	Committee on World Food Security
CO_2	Carbon dioxide
CO_2 eq.	Carbon dioxide equivalence
CH_4	Methane
CSIRO	Commonwealth Scientific & Industrial Research Organisation
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Databases
GASL	Global Agenda for Sustainable Livestock
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHG	Greenhouse gas
GLASOD	Global Assessment of Soil Degradation
GLC-SHARE	Global Land Cover-SHARE
GLEAM	Global Livestock Environmental Assessment Model
GEF	Global Environment Facility
GRA	Global Research Alliance on Agricultural Greenhouse Gases
GWP	Global warming potential
HICs	High-income countries
IARC	International Agency for Research on Cancer
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
ISRIC	International Soil Reference and Information Centre
KJWA	Koronivia Joint Work on Agriculture
LCA	Lifecycle assessment
LEAP	Livestock Environmental Assessment and Performance
LMICs	Low- and middle-income countries
MRV	Monitoring, reporting, verification
N_2O	Nitrous oxide
NCD-RisC	NCD Risk Factor Collaboration
NDCs	Nationally determined contributions
NZAGRC	New Zealand Agricultural Greenhouse Gas Research Centre
SOC	Soil organic carbon
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Technical terms

- **Carbon dioxide equivalence** (CO_2 eq.) is a measure used to compare the emissions of various greenhouse gases (GHGs) based on their global warming potential (GWP). In this document this always refers to GWP_{100}
- **Circular bioeconomy** involves recycling resources at every possible step (where waste from one process becomes a resource input for another) as well as "closing" systems to minimize resource and nutrient loss
- **Emission factor** is the average emission rate of a given greenhouse gas for a given source relative to units of activity
- **Emission intensity** represents the rate of greenhouse gas emission relative to a unit of output, such as a kilogram of milk or protein, or a unit of value
- **Global warming potential** (GWP) is an index measuring the radiative forcing of a unit mass of a given substance (such as nitrous oxide or methane), accumulated over a chosen time horizon, relative to the radiative forcing of the reference substance, carbon dioxide. The GWP thus represents the combined effect of the differing times these substances remain in the atmosphere and their effectiveness in causing radiative forcing. GWP is typically estimated at 20 years after an emission (GWP_{20}), and after 100 years (GWP_{100})
- **Radiative forcing** is a measure of the influence a given climatic factor has on the amount of downward-directed radiant energy impinging upon Earth's surface, with "positive forcing" exerted by climatic factors such as greenhouse gases contributing to warming of the Earth's surface

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What is low-carbon livestock and why do we need it?

Livestock provide valuable nutritional benefits as well as supporting livelihoods and the resilience of families and communities. Demand for animal products is expected to scale up with a growing global population. However, worldwide livestock production is also ramping up in response to demands from an increasingly affluent and urbanized population that is seeing a spike in overconsumption. Demand for animal-source foods (ASF) in low- and middle-income countries (LMICs) more than quadrupled from 1970 to 2012 (FAOSTAT). Though growth has slowed, demand is still predicted to increase by 35 percent from 2012 levels by 2030, and by 50 percent by 2050 (FAO 2018).

In spite of gains in production efficiency, greenhouse gas (GHG) emissions from livestock are on the rise. The Intergovernmental Panel on Climate Change (IPCC) special report this year (IPCC 2019) flags considerable emissions originating from the Agriculture, Forestry, and Other Land Use (AFOLU) sectors, and from livestock in particular, which generate nearly 15 percent of global anthropogenic GHG emissions, with cattle contributing nearly two thirds of this (FAO 2013). National commitments to reduce GHG emissions are therefore expected to include livestock agrifood systems in climate change mitigation and adaptation plans.

Successful action on climate change through practical action in livestock agrifood systems is an urgent priority, but it must not come at the expense of other sustainability objectives, particularly those relating to ending poverty and achieving zero hunger by 2030. Hence there is a need to balance the benefits of ASF and livestock keeping for nutrition, health and well-being, with the urgent need to reduce GHG emissions to tackle the climate crisis, which also threatens food security.

"Low-carbon livestock" can help countries achieve a balance whereby ASF, such as meat, milk, eggs, cheese and yogurt – sources of essential nutrients – feed the hungry and malnourished, yet are produced in a way that minimizes the overall output of greenhouse gases into the atmosphere. And while there are many opportunities to reduce livestock-related emissions, this brief outlines five key areas for practical action towards low-carbon livestock to help focus global efforts in achieving this goal.

The three main GHGs emitted from livestock systems are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) – making emissions of these three gases priority targets for reduction. Methane is an especially important target as it is an extremely potent (though short-lived) GHG, and so in the race to manage global warming, reducing methane emissions can provide fast returns.

The Food and Agriculture Organization (FAO) estimates that improved management practices alone could reduce net emissions from livestock systems – methane in particular – by about 30 percent (FAO 2013). For an even greater global benefit, better results can be achieved, and more quickly, through an integrative approach by improving multiple action areas at the same time. This means supporting countries and stakeholders throughout the agrifood system to design integrated solutions to reduce emissions from livestock, and helping them set and meet targets.

Key messages

- Despite production efficiency gains, emissions from livestock are still on the rise so national commitments need to include livestock agrifood systems in plans for climate change mitigation and adaptation
- Successful action on climate change in livestock agrifood systems is an urgent priority, but must not come at the expense of ending poverty and achieving zero hunger by 2030
- Low-carbon livestock can help countries achieve a balance whereby animal-source foods feed the hungry and malnourished, yet are produced in a way that is minimizing the overall output of greenhouse gases
- Shaping a sustainable future depends on understanding the diversity and complexity of livestock agrifood systems and the challenges stakeholders face during transformative change
- Achieving better results, more quickly, means supporting stakeholders throughout the agrifood system to design integrated solutions to reduce livestock emissions, and helping them set and meet their targets
- In the race to manage global warming, reducing methane emissions can provide fast returns

Countries party to the Paris Agreement are expected to raise their ambitions for reducing national GHG emissions and adapting to the effects of climate change post-2020, and to report these intentions in their Nationally Determined Contributions (NDCs; UNFCCC 2015). But this scale of reporting is a challenge, especially for LMICs, given the difficulty in establishing baseline estimates of livestock-related GHG emissions and in tracking changes in these emissions (see Appendix A). This is necessary, however, to help establish concrete targets and a roadmap of practical actions to achieve these targets in an economically and environmentally sustainable way.

Shaping a sustainable future will depend on understanding the diversity and complexity of livestock agrifood systems (see Appendix B) and the particular motivations and challenges stakeholders face in periods of transformative change. What works for a producer in a capital-intensive system can be very different from what works for a pastoralist or a mixed crop-livestock smallholder. Sustainable action means respecting these differences, and working closely with these diverse stakeholder groups to develop relevant and practical actions for everyone.

The following five practical actions can be widely implemented for measurable and rapid impacts on livestock emissions:

Action 1: Boosting efficiency of livestock production and resource use.

Action 2: Intensifying recycling efforts and minimizing losses for a circular bioeconomy.

Action 3: Capitalizing on nature-based solutions to ramp up carbon offsets.

Action 4: Striving for healthy, sustainable diets and accounting for protein alternatives.

Action 5: Developing policy measures to drive change.

Action 1
Boosting efficiency of livestock production and resource use

Agriculture, Forestry, and Other Land Use stands apart from other sectors because it is organic, so carbon can never be eliminated from it, as it could for example from the transport or energy sectors. Rather the key to promoting "climate smart" practices in the face of increasing demand is to improve productivity and resource use efficiency.

Within-system comparisons reveal large variations in GHG emission intensities (see Appendix B), and so there is still work to be done for improving efficiency through broader adoption of best practices. Notably, the variability of emission intensities is greatest for ruminant species, which also generally have higher average emission intensities. A considerable proportion of the variability is due to differences in management practices that could be improved through various forms of intensification.

The ongoing process of increasing productivity in livestock systems can make them more GHG-efficient. In many parts of the world, improved organizational strategies and technological innovations – such as improved feeding, genetics, animal health, general husbandry and information technology – are driving up productivity, making resource use more efficient with potential to reduce environmental impact, relative to the amount of livestock product (see Figure 1 as an example in dairy systems). There is also considerable scope for higher efficiency in fertilizer production and use in growing feed; for example, by using renewable energy and precision application.

Productivity growth has mostly responded to increasing consumer demand, rather than to climate considerations. This provides ample opportunity for intensification to be steered towards low emissions. The opportunity is particularly striking where livestock serve social and economic purposes other than production (e.g. asset building in the form of stock accumulation, particularly in Africa and parts of Asia, and land speculation, as occurs in Latin America).

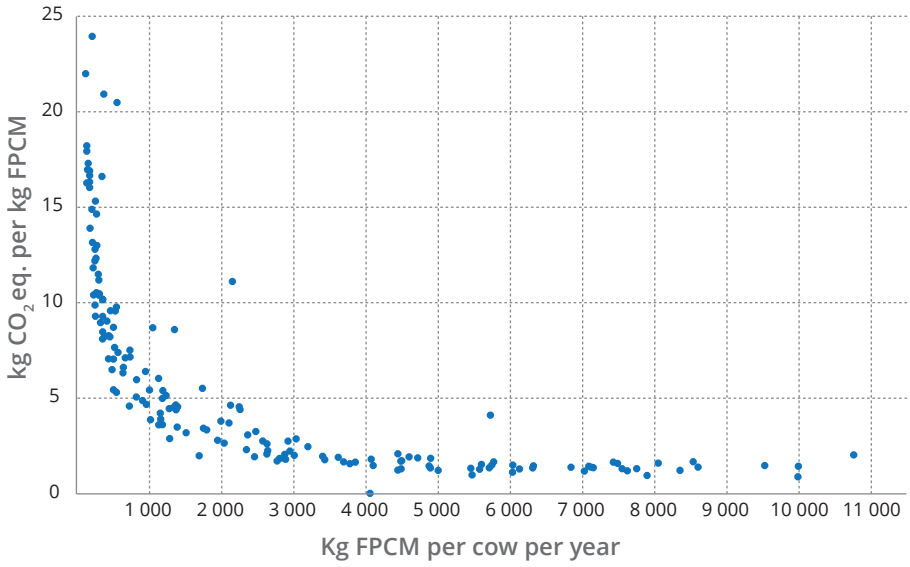
Key messages

- The key to promoting climate smart practices in the face of increasing demand is to improve productivity and resource use efficiency
- Emission intensities vary widely within and across livestock systems – particularly for ruminants – showing that better management practices can be adopted more widely to boost production efficiency
- Extensive and labour-intensive ruminant systems with low productivity are targets for low-carbon investments
- Technological innovations such as improved feeding, genetics, animal health, general husbandry and information technology are driving up productivity, making resource use more efficient with potential to reduce environmental impact

Intensification also needs to be sustainable – avoiding negative impacts on other sustainable development objectives. Intensification comes with an inherent risk of disrupting natural cycles, such as separating animal production from feed and fodder production, resulting in nutrient imbalances; for example when animal units are established close to markets rather than close to feed supplies. There are also animal health and welfare considerations that must factor into productivity optimization plans (Llonch *et al.* 2017); for instance, the extent to which animals can be contained in spaces without serious restrictions on natural behaviour. Potential animal and public health risks linked to the emergence of virulence and drug-resistance in pathogens in high-density, genetically homogenous animal populations are also a factor, requiring the right balance between optimizing productivity and managing animal and public health risks. There are also livelihood concerns that need to be managed.

Figure 1

Relationship between average emission intensities of greenhouse gases from national dairy systems (each point represents a country) and average productivity of those dairy systems. Dairy emission intensities are vastly higher in countries with low average productivity, and these tend to be the lower-income countries. This suggests that significant gains could be made through targeted investment to improve efficiency in systems producing less than 2000 kg of Fat and Protein Corrected Milk (FCPM) per year.
Sources: emission intensities, GLEAM 2, productivity, FAOSTAT.

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Action 2

Intensifying recycling efforts and minimizing losses for a circular bioeconomy

Agrifood systems rely on natural resources as primary inputs. However, the future of food is under threat as resources are used at a speed and level of inefficiency that compromises natural cycles of replenishment. To support increases in production to meet global food demand in a sustainable way, there are key recycling and loss reduction mechanisms available that can be more widely implemented, and there is ample opportunity for innovations in resource re-use.

Promoting a "circular bioeconomy" (as opposed to a linear process of extraction, production, use and disposal) involves recycling resources at every possible step in agrifood systems, as well as "closing systems" to minimize the loss of resources and nutrients. Increased circularity in food systems – where waste from one process becomes a resource input for another – offers ways to increase the efficiency of food production. Countries implementing mechanisms that better use the biomass they are already generating are thus expected to see better economic and environmental returns over time.

Globally an estimated one third of all food produced is either lost or wasted (FAO 2015). A first priority to tackle both hunger and GHG emissions is to cut food waste and losses as far as possible in livestock systems. In spite of their perishability, the high value of livestock products tends to act to minimize waste, nevertheless, there is still room for improvement. As an example, milk – a highly under-costed commodity – sees one in five litres lost or wasted globally (FAO 2015). Food waste can be reduced by the use of suitable packaging, for example, but a trade-off with single-use plastics must be managed.

Food waste itself can also be put to better use. "Clean" sources of food waste from restaurants and supermarkets can be valuable sources of livestock feed, as long as the food is tested and treated for pathogens to ensure feed safety. With the right incentives, legislation, and systems in place for feed safety, some countries

Key messages

- The future of food is under threat as resources are used at a speed and level of inefficiency that compromises natural cycles of replenishment
- Promoting a circular bioeconomy involves recycling resources at every possible step in agrifood systems and closing systems to minimize the loss of resources and nutrients
- Countries better using the biomass they are already generating are expected to see better economic and environmental returns over time
- Unused crop residues, food waste, and agro-industrial by-products are lost opportunities to recycle and optimize resource use efficiency and can be repurposed for animal feed
- Manure and slaughterhouse waste can be used to generate fertilizer and biogas as a source of renewable energy

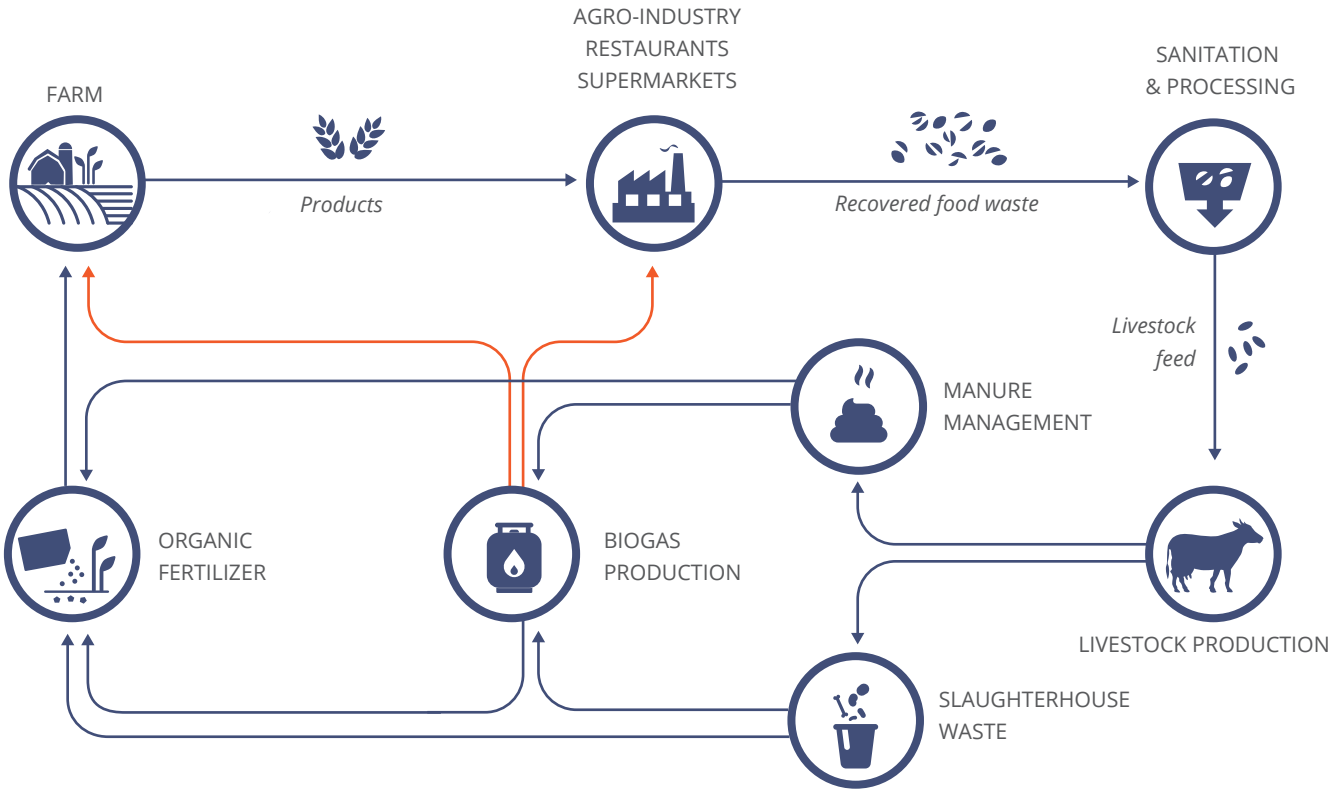


Figure 2

This diagram illustrates some of the recycling opportunities available in livestock systems towards creating a circular bioeconomy. Food recovered from waste streams in the retail, catering, agrifood and biofuel industries can be sanitized and converted into high-value, nutritious feed. The manure from livestock, and the waste from slaughterhouses, can be recycled first as biogas (and used to help fuel the agrifood industry), and then converted into organic fertilizer that can in turn be applied back to crops. Carbon savings are made at all stages of the recycling. In this scenario, improvements in manure management and adoption of lower carbon energy sources could help reduce greenhouse gas emissions by up to 25 percent and provide more than 2 million tonnes of CO_2 eq. savings from biogas production (FAO 2013). Feeding food waste to livestock in this way can also improve nitrogen use efficiency (and reduce nitrogen losses in feed and animal production), reduce N_2O emissions, and could release millions of hectares of agricultural land currently dedicated to feed production (Uwizeye *et al.* 2019).

manage to recycle half of their food waste into high-value "green" livestock feed (see Figure 2 as an example of a circular bioeconomy for livestock production).

While there are considerable differences in recycling practices within and between countries, large amounts of potential feed, such as crop residues, food waste, and agro-industrial by-products, are often unused, and this waste can contribute directly to adverse environmental impacts. These are lost opportunities to recycle and optimize resource use efficiency.

Crop residues, as an example, can be used as livestock feed, and made more digestible through the addition of various supplements. Burning of crop residues results in unnecessary GHG emissions and contributes to air pollution, when instead these could be fed to animals and thus transformed into nutritious ASFs.

The particular feed sources vary with priority crops of given countries, but as examples, soybean cake (a by-product of oil production) has for a long time been used as a feed supplement, and cake from other crops such as cottonseed and sunflower – as well as peels from crops such as potato and cassava – can be recycled as feed. Likewise, whey, a protein-rich by-product of cheese-making can be and has been traditionally fed directly to pigs. Dregs from biofuel production and brewing can make excellent livestock feed. And slaughterhouse waste can be converted to bone meal fertilizer, or used to generate biogas. Research on animal nutrition and production optimization, as well opportunities for cross-sectoral collaboration, provide much scope to expand such practices.

The livestock sector can also benefit from restorative and regenerative practices, for more resource-efficient production to maintain and enhance natural capital. Ties between production systems become increasingly severed in the ongoing processes of intensification, with livestock operations concentrating in areas with limited cropland on which to apply manure. However, net emissions can be reduced by re-integrating livestock and crop agriculture as a way to better recycle nutrients and energy and "close" these systems. At present, only a fraction of the nutrients contained in animal waste are being returned to the land in a

useful way. This is disrupting nutrient cycles, depleting resources upstream and leading to nutrient overloads downstream. But the mobility of livestock facilitates relocations (where possible) to areas better suited to recycling; for example, closer to areas where crops are grown.

Thoughtfully integrating livestock production into the wider circular bioeconomy hinges on developing livestock systems that make new and more efficient use of wastes, residues and by-products. This will help global society reap environmental and economic benefits by making better use of the biomass generated.

Action 3

Capitalizing on nature-based solutions to ramp up carbon offsets

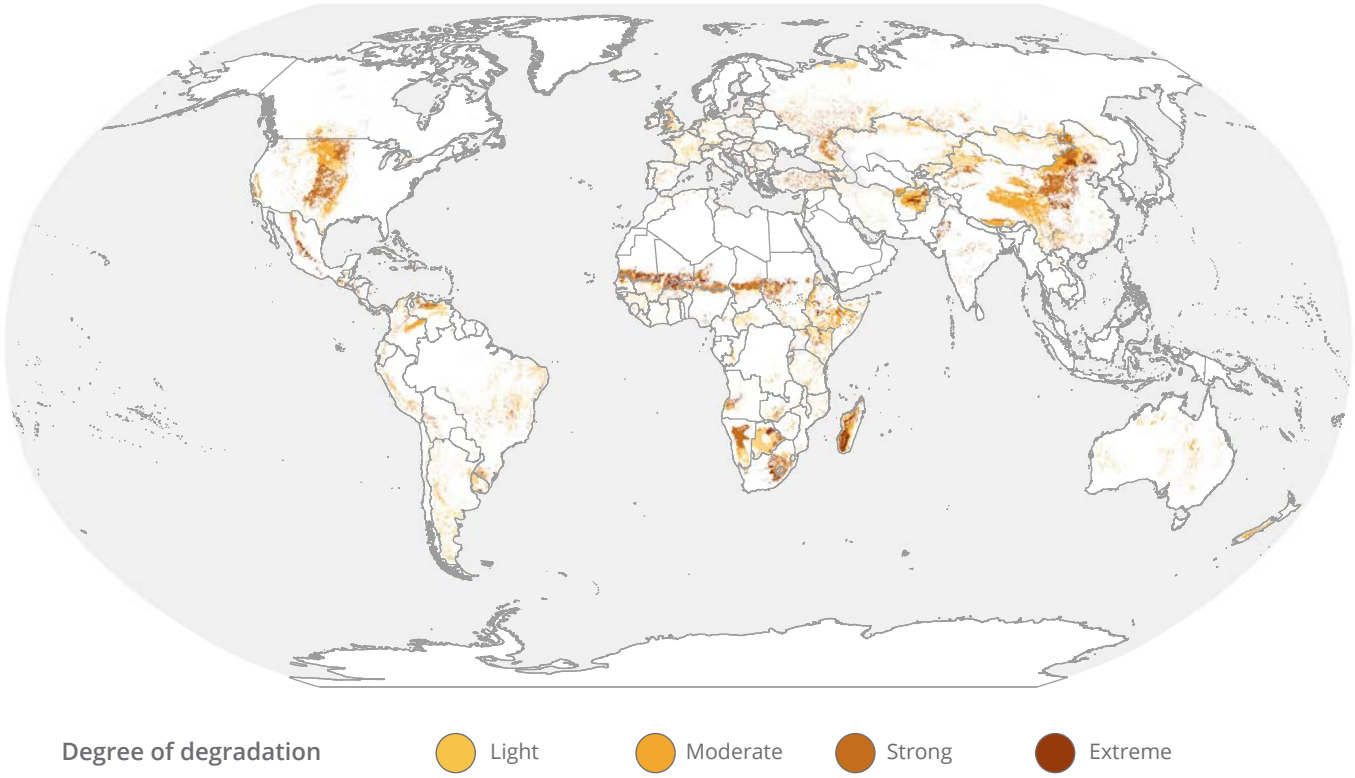
Key messages

- Agriculture is the largest direct driver of deforestation globally but nature-based solutions like carbon sequestration can help offset emissions
- Halting expansion into forests for feed production and pasture is an effective way for livestock systems to tackle climate change
- Soil carbon sequestration through regenerative grazing practices and restoring degraded land can help put carbon back in the ground
- Livestock farms can contribute to renewable energy production through biogas, solar and wind power

The AFOLU sector differs from others in that it removes carbon from the atmosphere and sequesters it, as well as emitting it. This uniquely positions the sector to directly offset its own emissions, and requires accounting for emissions net of sequestration. Livestock is one component of AFOLU but it is difficult to consider in isolation from the wider sector because of the many interactions and interdependencies across these areas. Notably, 30 percent of all crops are grown to feed livestock (Mottet *et al*. 2017), and most livestock are raised in mixed crop-livestock systems among trees, with silvo-pastoral systems including fodder trees, among others. However, agriculture is the largest direct driver of deforestation globally (FAO 2016). In Latin America, for example, cattle and livestock feed production are the dominant drivers of deforestation. These intersections need to be considered in national roadmaps for reducing net carbon emissions from livestock.

Halting expansion into forests for feed production and pasture is an urgent priority and remains one of the most effective ways for grazing systems to contribute to climate change mitigation. Bluntly, the global livestock sector can ill afford to be assigned the carbon losses associated with deforestation. Therefore, commitments to reshape forest management are essential.

Forests tend to be top of mind in discussions about nature-based solutions for carbon sequestration, but vast quantities of carbon are also sequestered in the cropland used to produce feed, and the grazing lands on which ruminant livestock are raised. In fact, a large proportion of the world's rangelands are degraded (Figure 3) and could capture far more carbon in soil organic matter (Figure 4), if restored. Regenerative forms of grazing can provide needed carbon offsets. Well-adapted grazing systems – with improved pasture and optimized grazing regimes – have the potential to stimulate plant growth and capture carbon in the soil, particularly in areas where degradation is not yet severe. The introduction of



trees in tropical pastures on previously forested land (silvo-pastoralism) can help stabilize productivity and generate many social, economic and environmental benefits. Regenerative grazing can also contribute to improved biodiversity and water use efficiency, as well as making the land more resilient to a changing and more variable climate.

While the potential for carbon sequestration, and the permanence of such capture, is subject to debate, the extent of pasture degradation and loss of productivity is such that urgent action is required even if large carbon gains take more time.

Another area with great potential for creating offsets is in the generation of renewable energy on livestock farms. This includes using manure and other waste to generate biogas, prior to recycling as a source of nutrient replenishment that can offset the use of energy-intensive chemical fertilizers. There is also scope for more widespread use of the land and buildings linked to livestock farms to install solar and wind power facilities. Solar panels can even be used to shade livestock from the sun. The economics of such offsets would need to be made favourable to livestock keepers, and appropriate carbon-accounting mechanisms put in place, for the resulting emission savings to be offset against those produced by livestock. This is a promising area that warrants attention.

Figure 3

This map shows the extent of human-induced soil degradation in grasslands around the world. Extensive areas of high degradation can be seen for example in the African Sahel, North America, East Asia and Central Europe.
Sources: soil degradation, GLASOD; Oldeman *et al*. 1990; grassland distribution, GLC-SHARE; FAO 2014; international boundaries conform to the United Nations world map; UN 2019.

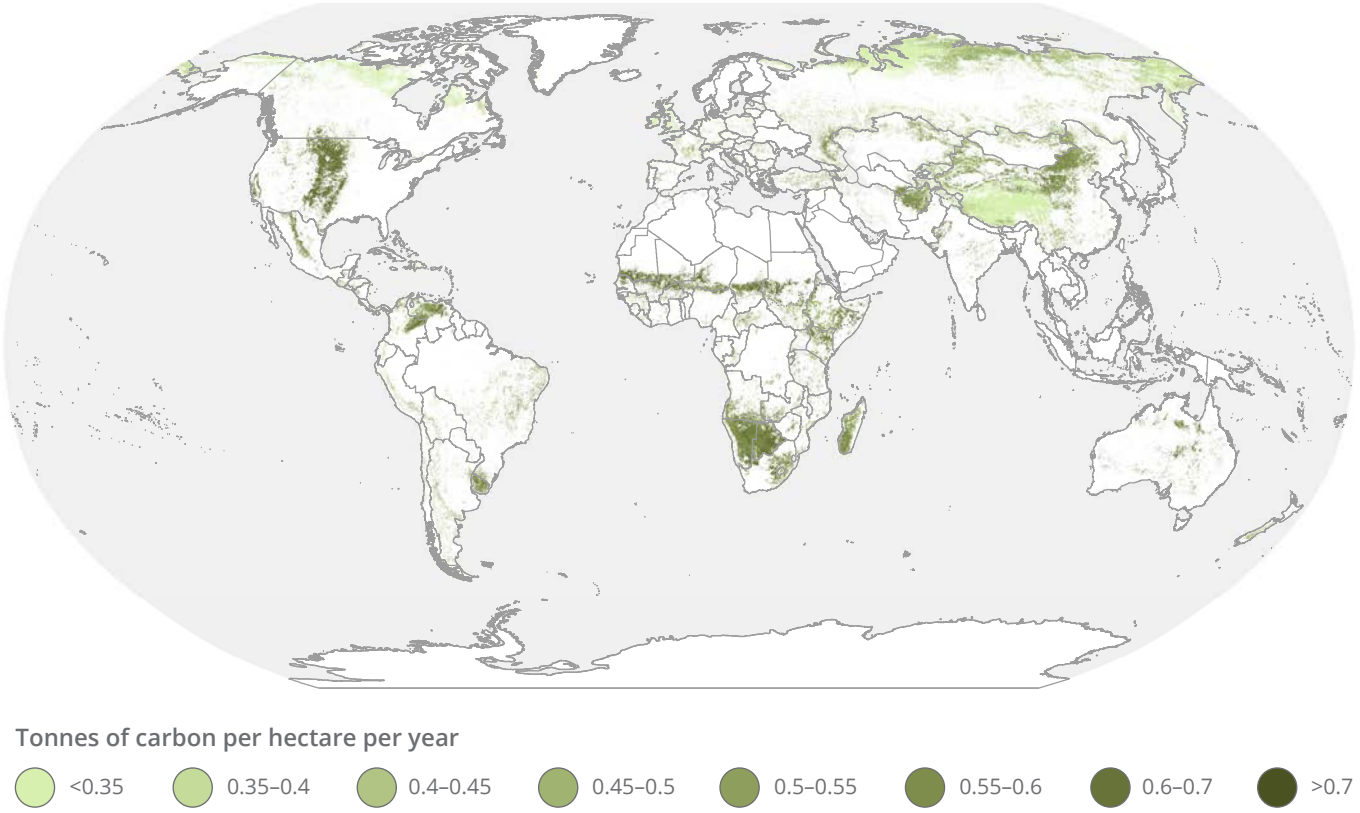


Figure 4

This map shows the potential attainable increase of soil organic carbon (SOC) on grasslands. The map was produced by applying the methodology of Sommer and Bosio (2014) to a global soil database providing data on SOC, bulk density and sand content at 0-30 cm soil depth (Hengl *et al*., 2017). High carbon soils, as well as sandy soils have been excluded from the analysis as they have little sequestration potential. The heavily degraded areas shown in Figure 3 have a high potential for SOC sequestration, as do other areas such as Southern Africa and parts of Latin America. *Sources:* SOC sequestration potential, Dondini *et al*., unpublished; grassland distribution, GLC-SHARE; FAO 2014; international boundaries conform to the United Nations world map; UN 2019.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Action 4

Striving for healthy, sustainable diets and accounting for protein alternatives

Malnutrition is unacceptably high across all regions of the world, with about a third of women below the age of 50 anaemic, at least one in five children under five years old suffering from stunted growth, and nearly a third of these children wasting (UNICEF, WHO and World Bank Group 2019). Healthy nutrition is particularly critical during the first 1000 days of life – during pregnancy, lactation and early childhood – as deficiencies in zinc, vitamin A and iron severely restrict growth, cognitive development, and proper immune function. Animal-source foods are dense in these and other essential micronutrients, such as vitamin B_{12}, riboflavin, calcium and various essential fatty acids. These nutrients are difficult to obtain in adequate amounts from plant-based foods alone, and including even modest amounts of ASF in diets adds much-needed nutritional value for better health outcomes.

Overconsumption is also a problem, with 40 million children under five years old reportedly overweight, and if current trends continue, more children and adolescents will be obese than moderately to severely underweight by 2022 (NCD-RisC 2017; UNICEF, WHO and World Bank Group 2019). Explicit links between overconsumption of livestock products and overweightness and obesity are still being investigated, and some studies have examined a possible link between consumption of red meat and processed meat and certain cancers (Bouvard *et al*. 2015; IARC 2018; Han *et al*. 2019).

Overall protein consumption, and the contribution from livestock products, are closely linked to wealth (Figure 5) with people in high-income countries (HICs) generally consuming far more animal-source foods than in LMICs. While some segments of society are under-nourished and others over-consume, there must be a convergence on healthy, nutritious diets for all in order to meet the 2030 Agenda for Sustainable Development.

Key messages

- The prevalence of malnutrition and overconsumption is unacceptably high with livestock protein consumption tied to wealth
- Convergence on healthy diets for everyone means higher income countries can benefit from reduced consumption of animal-source foods and lower income countries can benefit from improved access
- Biotechnological innovations are transforming the way proteins are produced for consumers and how they can be used for feeding livestock
- New alternative proteins coming to market could potentially present consumers with climate smart choices with less environmental impact

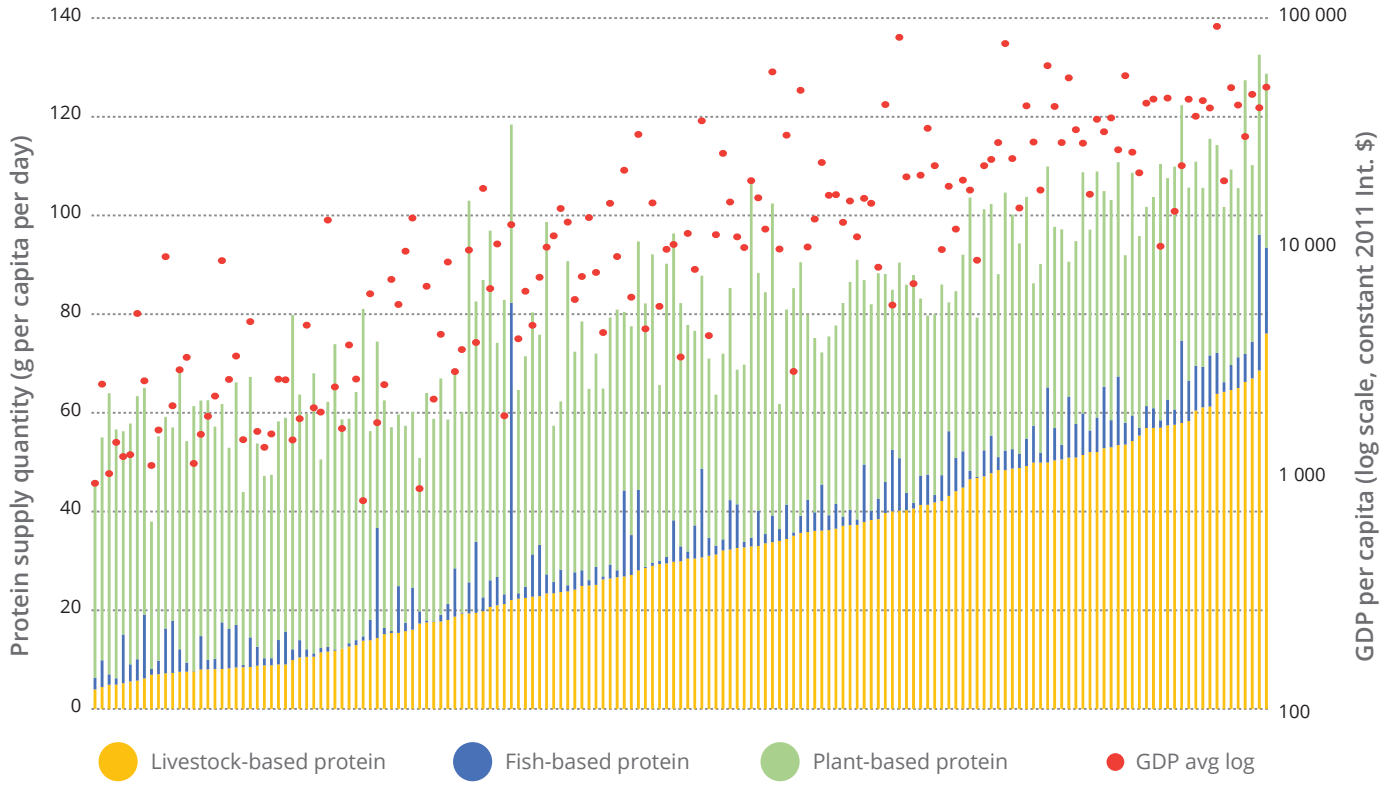

Figure 5

This graph shows average per capita protein supply (2011-2013), disaggregated by source (livestock-, plant- or fish-based). Each bar represents a country, ranked left to right based on the amount of dietary protein derived from livestock. The overlain red circles show the average per capita Gross Domestic Product (GDP) for each of the countries (on a log scale) for the same time period. Despite the inherent variability, there is a clear trend of higher total protein consumption and higher per capita GDP, and this trend is driven by livestock-derived protein. In the highest-income countries (to the right), more than half of all protein comes from livestock, while in countries with the lowest incomes (to the left), this proportion is down to less than 10 percent. In some countries, low levels of livestock protein are compensated for by fish-based protein.
Sources: protein supply, FAOSTAT; GDP data, World Bank 2019.

With heightened awareness, there is growing consumer interest (particularly in HICs) in lower-emitting ASF, such as poultry meat and eggs, and plant-based alternative protein sources. Such alternatives appeal to consumer concerns about their personal diets, environmental footprints and animal welfare. These trends are expected to spawn market expansions in some areas and potentially contractions in others, which may impact on emissions from livestock, and need to be factored into national planning.

Consumer demand tends to drive rapid innovation, and these growing trends represent unique opportunities for expansion of the agrifood system. Cellular agriculture (where animal proteins and whole cells are generated in bioreactors) is being further developed. The phenomenon is not new – human insulin has been produced in yeast cells since the 1970s – and relatively simple milk (i.e. casein and whey) and egg (i.e. ovalbumin) proteins can already be produced, but the construction of cell complexes for in vitro meat is more challenging, and relies on culturing stem cells. While it may be some time before replica meat cuts can be made in this way, protein supplements, and alternatives to powdered milk, powdered eggs and ground beef for the agrifood industry seem already to be in reach.

Another area of rising demand is for alternatives to conventional livestock feed. Biotechnological innovations are revolutionizing the way that protein can be produced and used for feeding livestock. This includes established practices like the addition of synthetic amino acids to feed rations, as well as newer approaches involving algal, fungal and microbial protein replacing conventional feed protein (such as soy), as well as the use of insects. Some feed additives particularly target reductions in methane emissions.

As new products cross regulatory hurdles and enter the market, there will be a clear need for proper environmental accounting to help chart the way forward for the continually evolving agrifood system vis-à-vis health and climate goals.


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Action 5
Developing policy measures to drive change

Public policy interventions are needed to implement the above action areas by engaging stakeholders with appropriate incentives to drive change. Policies and technical approaches will undoubtedly vary across regions, livestock systems, agroecological and socioeconomic contexts – reflecting different priorities. Thus, policy approaches will need to be self-correcting in order to avoid unintended impacts on other objectives, such as food security and nutrition, livelihoods, public health and animal welfare.

Successful policies using an evidence-based and people-centred approach will reflect the concerns of multiple stakeholder groups, involving them early in the process of policy development. This participatory approach is vital for better understanding (and predicting) how people can and will respond to change in the context of feasibility constraints, power structures, beliefs and sociocultural values. Policy approaches will likely achieve the best results in complementary combinations. "Action 5" presents a range of potential policy options (see examples in Table 1) warranting consideration for an integrative approach conducive to transformative practices while helping to reduce stakeholder risk. These options span market-based instruments (e.g. pricing, taxes, incentives), investments in infrastructure and support for research and development, and direct regulatory interventions.

"Pull incentives" can help to generate market demand in support of shifts towards best practices. Incentives and market-based approaches, incorporating consumer concerns, and indeed raising consumer awareness, would depend on reliable certification schemes for farms and other agrifood system components, with rigorous traceability and appropriate labelling systems for livestock commodities at the point of sale. As an example, governments, regulatory bodies, professional societies and co-operatives can respond to consumer pressure on markets by developing and implementing "climate smart" certification schemes that entail benchmarking and ongoing monitoring and evaluation to deter poor practices and incentivize practices that will help countries meet national targets.

Key messages

- Public policy interventions are needed to drive change
- Policy approaches will vary across regions, livestock systems, agroecological and socioeconomic contexts, reflecting different constraints, opportunities and priorities for sustainability
- Policy approaches will need to be self-correcting to avoid unintended impacts on other domains of sustainability
- Integrating different types of policy approaches may yield best results to support transformative practices while helping to reduce stakeholder risk
- Subsidies can be better aligned with climate action priorities through public payments for public goods, in coordination with climate smart pricing, regulation and certification schemes

To discourage unsustainable practices (which put agrifood stakeholders themselves in jeopardy), the prices of livestock commodities could also be allowed to reflect the presence of GHG emissions and other environmental impacts. Alongside water, forests and common grazing land, a more stable climate is a common property resource that can be costed for in commodities that take advantage of these resources. The subsidies currently provided for livestock production could be repurposed to help incentivize farmers to adopt better practices that reduce emissions and help future-proof their businesses. Subsidies currently at odds with environmental priorities could be improved through cross-compliance regulation, under which conditions direct payments can be made to farmers and other agrifood system stakeholders for reducing emissions by adopting good practices. Failure to respect the compliance conditions would lead to the loss – in whole or in part – of the direct payments. The idea of direct payments being replaced by "public money for public goods" is currently being investigated by some countries.

"Carbon taxes" are an example of a pricing instrument that has already been applied in some countries for select sectors – transport and energy in particular. Carbon taxes are calculated for different fuels to compensate for the social cost of carbon though GHG emissions. Applying a carbon tax in the livestock sector would be complex as emissions occur upstream and downstream of production, as well as on the farm itself. Emissions also vary from farm to farm, so the implementation of a carbon tax for livestock would require careful consideration, as well as monitoring and evaluation mechanisms. The application of a "meat tax" is another price instrument that has been proposed, but may also suffer from variable performance among farms and would fail to incentivize good practices along the agrifood system unless it were linked to complex certification schemes. Notably, such Pigouvian taxes have been applied in attempts to mitigate health effects of tobacco and sugary drinks. A taxation approach could present an opportunity to re-invest funds back into low-carbon livestock research and support programs to expedite progress towards meeting climate targets.

Regulation as a policy instrument can be effective in certain contexts, and is already in place for animal health, welfare, environmental pollution, and food safety in many countries. Similar regulations and enforcement mechanisms could be trialled for reducing livestock-related emissions. Such regulations would act at specific points in livestock agrifood systems to enable feedback, and/or enforcement, and/or rewards for emission-reducing practices. Managing manure correctly is an example of a practice that would lend itself to regulation. Soft law, in the form of normative guidance, can also be effective and quicker to implement.

While "top-down" interventions are useful, they tend to be more successful when applied in combination with "bottom-up" behaviour change initiatives. Stakeholder assessments, including vulnerability and risk assessments, are a key part of this process for developing a sound theory of change. Government and industry-led support programs and awareness campaigns can be deployed to seed collective action. And farmer training programs and collaboratives can facilitate rapid changes in practice and knowledge transfer, as well as improving bargaining power for pricing their products. Advances in practices can be transmitted through social and professional networks by stakeholders themselves for wider (and faster) uptake and better return on investment.

Policies can also be put in place to ramp up research and development efforts in support of low-carbon livestock. Research and development is particularly salient for improving efficiency in livestock production, driving down methane emissions,

TABLE 1. Examples of potential policy measures towards low-carbon livestock and zero hunger

Policy approach example	Regulatory	Incentivisation	Pricing	Research and infrastructure
Pricing adjustments to account for externalities, such as taxes on carbon.			✓	
Producer support programs to help boost market competitiveness and risk mitigation schemes (e.g. insurance, subsidies) to protect the livelihoods of smaller, less efficient producers.		✓		
Enabling industry for technological innovations that boost productivity and resource efficiency. For example, more efficient fertilizer, better genetics, and developing information technology.		✓		✓
Policies promoting a circular bioeconomy, including benchmarks (with a monitoring and warning system) to motivate reductions in inefficiencies, and incentives for implementing mechanisms that reduce food waste and put it to better use (e.g. tax rebates, grants/ subsidies to help with the initial investment, interest-free loans, infrastructural investments to connect contact points in the cycle).	✓	✓		✓
Support for recycling research and development, creating new value-chains that make more efficient use of wastes, residues and by-products, and fostering cross-sectoral collaboration to close resource loops.	✓	✓		✓
Policies re-integrating livestock and crop agriculture to better recycle nutrients and energy (e.g. relocation grants, incentives for integrative production practices) to help global society make full use of the biomass already generated for environmental and economic benefit.	✓	✓		
Zero-deforestation commitments from governments and companies, increased supply chain transparency to reshape forest governance and reduce deforestation (e.g. land-tax breaks for silvo-pastoralism), and research on forest regeneration and management strategies.	✓	✓		✓
Incentives and/or subsidies for livestock holders investing in regenerative forms of grazing for carbon offsets. Regenerative grazing can also contribute to improved biodiversity and water use efficiency, as well as making the land more resilient to a changing and more variable use. Such positive externalities can be better recognized through payments for environmental services.		✓		✓
Subsidies for manure supply to generate biogas and installation of solar and wind power facilities.		✓		✓
Assessments of new alternatives to animal-source foods entering the market from an environmental (and health) perspective.	✓			✓
Enabling policies and incentives for biotechnological innovation for more sustainable food products as part of an expanding agrifood system.		✓		✓
Certification schemes for "climate smart" products, linked to product traceability and labelling.	✓	✓	✓	✓

recycling, capturing carbon, and developing alternatives to high-emitting livestock products.

Whichever combination of technical and policy interventions are trialled, special attention must be paid to impacts on prices for livestock commodities – whether they arise from efficiency gains, low-cost alternatives, subsidized production or taxation – to proactively guard against unintended consequences for livestock and other associated sectors.


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A call to action for integrated approaches to achieve low-carbon livestock

Key messages

- Tackling the climate crisis depends on strong and swift action
- Integrative approaches should be adopted as part of an ongoing process of continual improvement towards sustainable livestock agrifood systems
- Shifting burdens must be avoided, with a focus on preventing "virtual resource transfers", as climate change is a global problem that demands well-integrated solutions at local, national, and regional scales
- Successful action on climate change will harness synergies with other sustainability goals and manage trade-offs to achieve global prosperity in our lifetime and for generations to come

Tackling the climate crisis depends on strong and swift action. Each of these five actions alone has the potential to reduce livestock emissions. But there is great benefit to an integrative approach as part of an ongoing process of continual improvement towards sustainable livestock agrifood systems. Improving resource use efficiency can go hand in hand with restoring degraded grasslands through regenerative grazing, for example. Enabling policies and institutions can further enhance uptake of the appropriate practices. And such improvements can also harness synergies with other sustainability objectives – increased productivity and farm revenues, boosted nutrition and food security, enhanced soil health, improved human health, and greater resilience, are all positive outcomes that can be achieved together.

Making progress towards low-carbon livestock will depend on strong policies creating the right incentives, regulations, investments, and market responses. Appropriate systems will also need to be put in place for measuring baselines and tracking progress down to the level of the farm. There is currently limited capacity for implementing such policies and for monitoring emissions in many LMICs, as indicated by the absence of livestock from NDCs in many cases. These capacities must be built as a matter of urgency.

Climate change is a global problem that demands well-integrated solutions at local, national, and regional scales, so it is essential that burdens are addressed, rather than shifted. For example, improving ruminant production efficiency through increased use of feed, or shifts from ruminant livestock to monogastric species, can result in "virtual resource transfers", whereby negative impacts can occur far from the point of production or consumption, through land-use change and fertilizer use elsewhere in the world. Intensification may also threaten broader sustainability objectives, resulting in trade-offs in other aspects of environmental protection, or in food and nutrition security, livelihoods, human health, animal health and welfare. Therefore, safe and sustainable climate action in the livestock sector requires holistic approaches that harness synergies and manage trade-offs to achieve global prosperity in our lifetime and for generations to come.

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How FAO is helping countries approach zero hunger while tackling climate change

The Food and Agriculture Organization is a specialized agency of the United Nations leading international efforts to meet the Sustainable Development Goals with a strong focus on achieving #ZeroHunger by 2030. Access to healthy and nutritious food is a fundamental human right and a pre-requisite for all people to have the opportunity to lead a healthy, happy, and productive life. With 194 Member States, two associate members and one member organization, FAO is on the ground working with local partners in every region, championing change that is necessary, practical, sustainable and brings great benefit.

The Koronivia Joint Work on Agriculture (KJWA), adopted in 2017 (UNFCCC 2018), was a landmark decision by countries to work together so that agricultural development ensures both increased food security in the face of climate change and a reduction in emissions. This has been an important step forward for countries in the negotiations on agriculture with the United Nations Framework Convention on Climate Change (UNFCCC), and acknowledges the significance of agriculture and food security in the climate change agenda.

Through the KJWA, FAO is helping countries develop and implement new strategies for climate change adaptation and mitigation within the agriculture sector. The KJWA places livestock at a level of particular strategic importance, with priority areas including improved soil carbon sequestration in grazed grasslands, improved nutrient use and manure management, as well as improved livestock management systems. The Third Koronivia Dialogue was held at FAO headquarters in September 2019 to provide a supportive space for agricultural experts from Member States to identify ways to implement the KJWA and meet challenges and opportunities together.

FAO's convening role also extends to the Committee on World Food Security (CFS) – the foremost inclusive international and intergovernmental platform for stakeholders to work together to ensure food security and nutrition for all.

Key messages

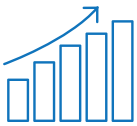
- Through the Koronivia Joint Work on Agriculture, FAO is helping countries develop and implement new strategies for climate change adaptation and mitigation in the agriculture sector
- FAO is providing countries with technical support – developing tools, methodologies, and protocols for measuring emissions – and support for developing and analysing technical and policy options
- FAO is helping countries assess different emission mitigation scenarios and access international climate finance to speed progress towards a more resilient and prosperous future
- FAO is committed to assisting Member States working towards low-carbon livestock as part of achieving the 2030 Agenda for Sustainable Development

Figure 6

Key ways in which FAO is supporting countries to develop low-carbon, sustainable livestock systems.

Strengthening the **knowledge and evidence base** by developing baselines, assessments and projections of emissions

Developing **tools, methodologies and protocols** to measure emissions and evaluate technical and policy options



Piloting and validating technical and policy options through projects and support to up-scaling and investments

Facilitating multistakeholder partnerships and better integration of broad sustainability objectives, promoting synergies and addressing trade-offs

Using a multi-stakeholder, inclusive approach, CFS develops and endorses policy recommendations and guidance on a wide range of food security and nutrition topics. Focusing on livestock, the FAO-hosted Global Agenda for Sustainable Livestock (GASL) is an important multi-stakeholder partnership aimed specifically at better integration of broad sustainability objectives across the global livestock sector.

In addition to FAO's convening work, the organization is providing countries with technical support, from developing tools, methodologies, and protocols for measuring emissions, to developing and analysing technical and policy options (Figure 6). To strengthen knowledge and evidence, FAO is generating baselines, conducting assessments and providing projections of emissions under different scenarios. Data sources and tools covering all sectors of agriculture and forestry include FAOSTAT, which provides data on agricultural emissions, and an ex-ante carbon-balance tool (EX-ACT) that provides estimates of the impact of agriculture and forestry development programs, projects and policies on carbon-balance. The Global Livestock Environmental Assessment Model (GLEAM; see Appendix A), including a simplified open-access, web-based version, GLEAM-i, focuses specifically on emissions from livestock systems.

While GLEAM provides a global assessment of livestock emissions it can also be applied using country-specific data to estimate national baselines and scenarios. FAO has already worked through GLEAM with 25 countries and welcomes even wider collaboration. GLEAM has also been used by organizations, research institutes and universities, such as the World Bank, Global Environment Facility (GEF), Green Climate Fund (GCF), Commonwealth Scientific & Industrial Research Organisation (CSIRO), International Livestock Research Institute (ILRI), Wageningen University and University of Central Asia. FAO GLEAM outputs are used by the IPCC to inform the development of guidelines relevant to livestock emissions, and GLEAM follows assessment methodologies and guidelines developed by IPCC and the multi-stakeholder Livestock Environmental Assessment and Performance (LEAP) partnership, which provides methodologies for monitoring the environmental performance of livestock agrifood systems.

The work of FAO also extends to piloting and analysing technical and policy options for sustainable livestock through targeted projects and investments. FAO is committed to helping countries meet their obligations to the Paris Agreement and the KJWA decision by building capacity for national measurement, reporting and verification (MRV). These capacity-building initiatives, such as the recently endorsed project, "Creating the enabling environment for enhanced climate ambition and climate action through institutional capacity building" – funded by the Climate and Clean Air Coalition (CCAC), the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) and the Global Research Alliance on Agricultural Greenhouse Gases (GRA) – help countries assess different mitigation action scenarios and access international climate finance to speed progress towards a more resilient and prosperous future.

FAO is committed to assisting Member States working towards low-carbon livestock as part of achieving the 2030 Agenda for Sustainable Development.

Appendix A
Estimating and reporting greenhouse gas emissions from livestock

Countries are expected to report their next round of NDCs (submitted every five years to the UNFCCC) in 2020, with agricultural contributions included. The typical process is for a given country to estimate their baseline GHG emissions (and what is driving them) as a first step, using one of the IPCC methodological approaches, and then after proposing specific mitigation targets, MRV methods are used to assess the impact of these mitigation approaches on emissions. Some LMICs have already noted livestock related emissions specifically, but a smaller subgroup has expressed explicit intentions to reduce livestock emissions, and relatively few countries have yet gone so far as to propose specific livestock mitigation policies and measures. However, there is an urgent need to raise ambitions in future NDCs by strengthening the focus on livestock, and building capacity for MRV of livestock emissions to track and demonstrate progress over time.

The IPCC issues guidelines and methodologies for estimating and reporting livestock emissions, with different types of approaches, or "tiers". Tier 1 methodologies use fixed emission factors per head of livestock (based on regional averages), which can only reflect changing emissions due to changes in livestock numbers. Tier 2 methodologies, on the other hand, use country-specific emission factors, and require much more detailed information, including herd and flock structures, and performance data, such as weight gain, digestibility of feed, and methods for manure management. Although Tier 2 approaches require more information, they are helpful in demonstrating the efficiency of a given system at national-, sub-national- and farm-level, and in capturing the early effects of changes in management practices on livestock emissions.

As climate finance depends on a country demonstrating progress in reducing GHG emissions, the use of Tier 2 approaches, which provide greater transparency, can enhance access to resources from funds such as the GCF and GEF. Tier 2 methods are also helpful for advancing sustainable livestock development plans. At present, few LMICs are utilizing methods that can routinely show emission reductions resulting from changes in management practices and productivity. This is an area where FAO can provide strong support to improve access to climate finance for more countries.

FAO's GLEAM adopts a Tier 2 methodology, useful for developing detailed baseline and mitigation scenarios. GLEAM uses a lifecycle assessment (LCA) approach, which means that the assessment includes both direct emissions from animals as well indirect emissions upstream and downstream. This approach differentiates key stages within livestock agrifood systems, such as feed production, processing and transport; animal production, animal feeding and manure management; and the processing and transport of products (Figure 7). The model captures specific impacts at each step, offering a comprehensive and nuanced picture of livestock systems and how the sector is using natural resources. GLEAM also uses detailed geographic information on livestock distributions and production

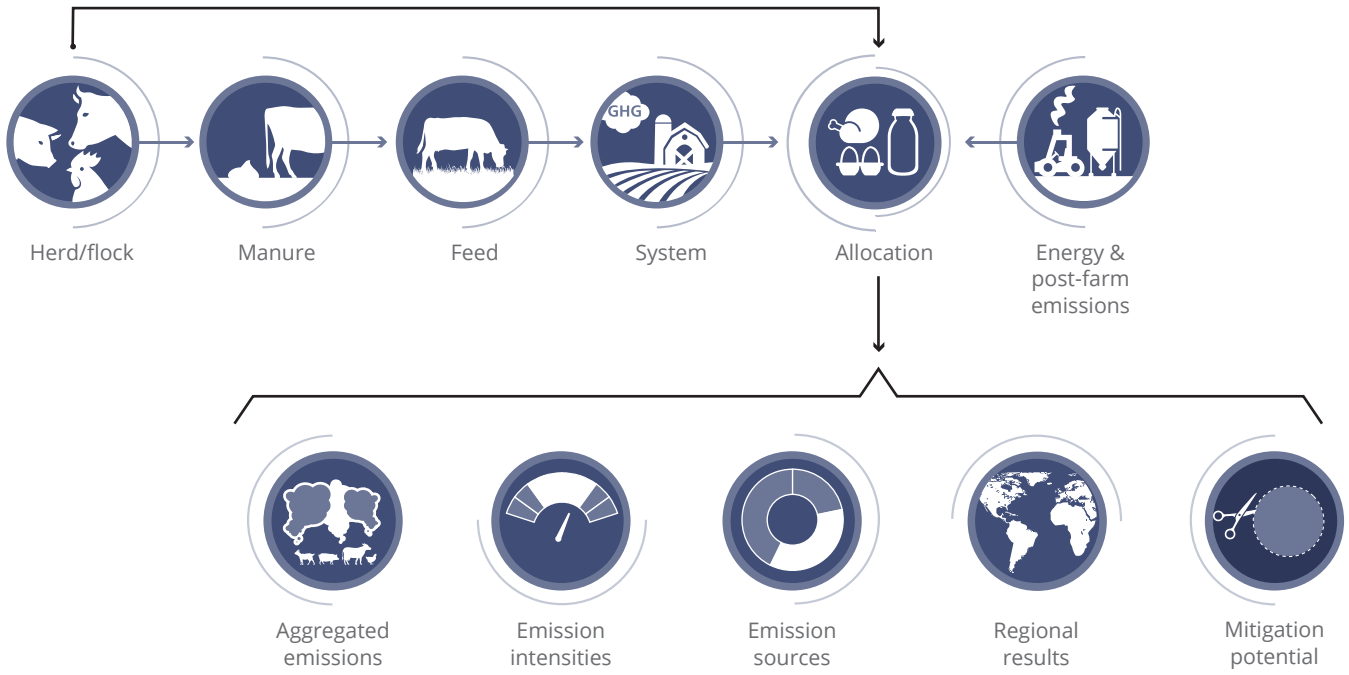


Figure 7

The Global Livestock Environmental Assessment Model (GLEAM) takes a lifecycle assessment approach to estimating emissions from livestock systems, following guidelines issued by the Intergovernmental Panel on Climate Change. Emissions from different stages of production are included, and emissions can be allocated geographically, according to where they originate in the systems, and by which types of gases are involved. Since a Tier 2 approach is used, the impacts of mitigation interventions at all stages of production can be simulated. GLEAM includes data for cattle, buffaloes, sheep, goats, pigs and chickens in its assessments.

systems, as well as on crop and feed production and distribution, which allows spatial variability to be accounted for and an analysis of livestock GHG emissions at different scales.

GLEAM 2 has a base year of 2010 and has already met its initial goal of providing a global inventory of livestock emissions (FAO 2013). The model has since been adapted in partnership with countries to generate national inventories, analyse different mitigation scenarios, and help countries chart a preferred plan of action.

GLEAM 3 is currently under development with a base year of 2015, and enhanced accounting of nutrient use and carbon sequestration in livestock systems. Future developments, in close collaboration with partner countries, will see GLEAM further adapted to meet the specific needs of programs designed for reducing livestock emissions and for NDC and MRV reporting.

The methodology and underlying data for GLEAM are continually updated and improved to reflect new information, such as updated livestock distribution data, revised guidelines from the IPCC and feedback from the multi-stakeholder LEAP partnership.

What analyses with GLEAM have made clear is that there is no “one-size fits all” solution and that progress towards low-carbon livestock will depend on tailored approaches that account for the diversity and complexity of livestock agrifood systems.

Appendix B
Livestock sector emissions explained

Livestock species, such as cattle, buffaloes, sheep, goats, camels, llamas, alpacas, horses and donkeys, form a group that can break down rough plant material, whereas pigs, chickens and other poultry species cannot. The first group of ruminant and pseudo-ruminant species are able to digest cellulose due to methane-producing bacteria undergoing a process called enteric fermentation in the gut. The second group of monogastric species have dietary needs more similar to our own so require relatively nutritious feed such as cereals and soybeans.

These species occur in a multitude of differently-adapted breeds and in a variety of production systems. Extensive systems, particularly associated with ruminants, are characterized by low labour and capital inputs and generally occur in marginal habitats. Labour-intensive systems can incorporate many livestock species, usually as mixed systems in combination with crops and trees, and are typically smallholder farms with low returns and a surplus of labour. Capital-intensive systems tend to be very specialized and are usually associated with highly modified environments where land and labour inputs have been substituted by capital investment through intensification and mechanization (Steinfeld *et al*. 2019). The relative distributions of these systems depend on climate, agroecology, cultural, historical, and socio-economic factors, among others. Different combinations of production approaches can occur side-by-side and intermediate forms also exist – often in transition from one to another. To illustrate this spectrum, dairy production occurs in extensive systems in the Sahel, in dual purpose or more specialized smallholder systems in the highlands of East Africa and in South Asia, in grass-fed systems in Europe, and in intensive, highly automated mega-dairy systems, incorporating large proportions of feed concentrate in their rations, in Europe, North America and East Asia.

Natural resource use efficiency and the environmental impacts of these different systems, including GHG emissions, vary considerably, as do constraints and opportunities to reduce emissions. It is therefore essential to include support for research to better understand different livestock systems and their dynamics in any analysis of emissions and plans to reduce them.

Overall, half of livestock emissions – expressed in CO_2 eq., a way to normalize the gases in standard units based on the radiative forcing of a unit of carbon dioxide over a given period of time – are in the form of CH_4, while N_2O and CO_2 represent almost equal shares – 24 and 26 percent, respectively. Notably, the relative proportions of emissions of these gases vary greatly depending on the production system, with a major distinction between ruminant and monogastric systems (Figure 8), so practical actions to manage emissions need to be tailored to different production systems and local contexts.

These three primary GHGs vary greatly in their ability to trap heat and in their persistence in the atmosphere, giving different GWPs at different time horizons. Table 2 shows that methane is relatively short-lived compared to CO_2 and N_2O, which persist in the atmosphere for much longer. This has a profound impact on the estimation of GWP, whereby the contribution of methane to GWP at 20

TABLE 2. Atmospheric duration and global warming potential of the priority greenhouse gases

Gas	Atmospheric duration (years)	After 20 years		After 100 years	
		GWP_{20}**	Livestock emissions (Gt CO_2 eq. per year)	GWP_{100}	Livestock emissions (Gt CO_2 eq. per year)
CO_2	*	1	2.1	1	2.1
CH_4	12.4	86	10.1	34	4.0
N_2O	121	268	1.7	298	1.9
Total livestock emissions	–	–	13.9	–	8.0

For standardized comparisons, the emissions of different greenhouse gases need to be brought into a common reference framework, based on their relative contributions to global warming. The three main greenhouse gases – CO_2, CH_4, and N_2O – differ considerably in their atmospheric duration and radiative forcing over given time periods following an emission, translating into different GWPs at 20 years (GWP_{20}) and 100 years (GWP_{100}), respectively, from the time of emission (IPCC 2013). The GWP values in the table have been multiplied by the actual emissions in 2010 of each gas from all livestock (estimated using GLEAM 2 without allocation) to calculate total emissions in CO_2 eq., resulting from each gas after 20 years and after 100 years. The GWP_{100} values are used to present GLEAM 2 outputs, and the GWP_{20} emissions illustrate the much higher short-term impacts caused by methane.

* The atmospheric lifetime of CO_2 cannot be represented with a single value because the gas is variably broken down among different parts of the ocean-atmosphere-land system. Some excess CO_2 is absorbed quickly (for example, by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments.

** The values of GWP_{20} and GWP_{100} presented here, and those used in GLEAM 2, include assumptions about climate-carbon feedbacks (see Table 8.7 in IPCC 2014).

years after an emission (GWP_{20}) is considerably greater than its contribution after 100 years (GWP_{100}) (Table 2 and Figure 8). For emission estimates derived from GLEAM 2 in this document, CO_2 eq. is calculated as GWP_{100}. There is ongoing scientific debate about the way that methane should be accounted for relative to carbon dioxide (e.g. Allen *et al*. 2018), but the quantity produced and high radiative forcing of the gas means that short-term impacts are considerable, and its shorter atmospheric duration means that actions to reduce methane can have a relatively quick impact on global warming, making methane a current priority for action.

About 55 percent of emissions from livestock are considered direct. These are associated with biological processes such as enteric fermentation in ruminants, which produces CH_4, and nitrification/denitrification of excreted manure and urine, as well as anaerobic decomposition, which produces CH_4 and N_2O. Direct emissions also include CO_2 emissions related to on-farm energy use. Indirect emissions account for the other 45 percent and come from the manufacture of fertilizers and pesticides for feed production in the form of CO_2, feed production itself (CO_2, N_2O and CH_4), manure deposition and application (N_2O and CH_4), and processing and transportation of feed, animals, and livestock products (CO_2), as well as CO_2 emissions related to land use change.

Looking across livestock species in GLEAM, cattle are the main contributors to GHG emissions, producing about 5 Gt CO_2 eq. per year, accounting for more than 60 percent of all livestock emissions. Pigs, chickens, buffaloes and small ruminants contribute much less, each representing between 7 and 10 percent of the sector's emissions (Figure 9). However, since animal production is a vital part of global efforts to reduce hunger and poverty, it is helpful to consider GHG emissions more specifically in the context of emission intensities – the rate of GHG emission relative to a unit of production, such as a kilogram of milk or protein, or a unit of value (Figure 10). This can help countries better assess improvements in the efficiency of livestock systems, and indicates that LMICs tend to have higher emission intensities due to greater inefficiencies.

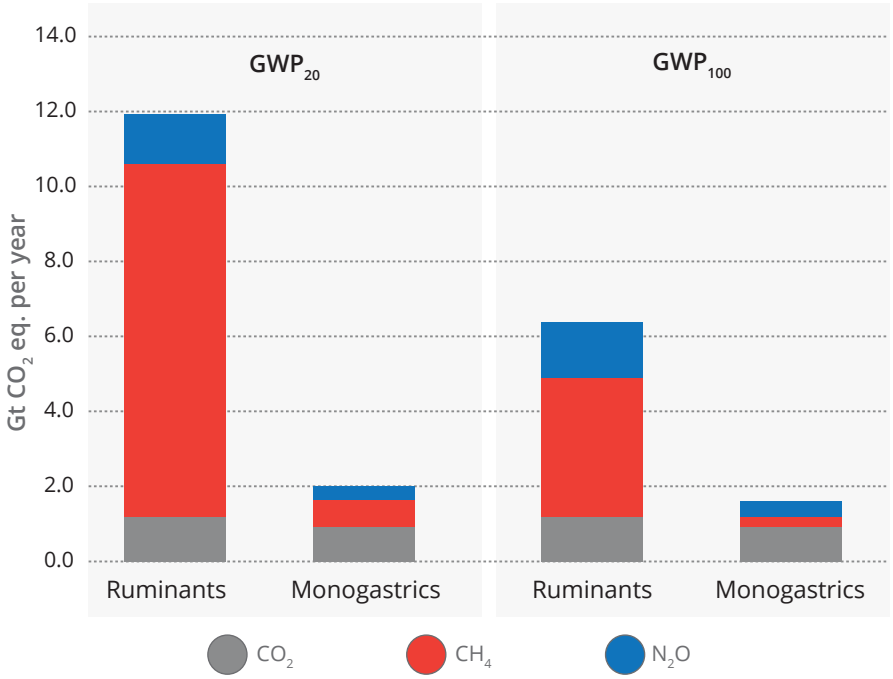


Figure 8

Total emissions from ruminant livestock species (buffaloes, cattle sheep and goats) and monogastric species (pigs and chickens), broken down by the three main contributing greenhouse gases – CO_2, CH_4 and N_2O – for GWP_{20} and GWP_{100}. The graphs reveal significantly greater overall emissions from ruminant species, particularly those arising from CH_4, and the much greater short-term impact of methane compared to the other gases. GWP_{100} is a more standard measure of global warming potential and is used throughout this document, and for all GLEAM 2 outputs.

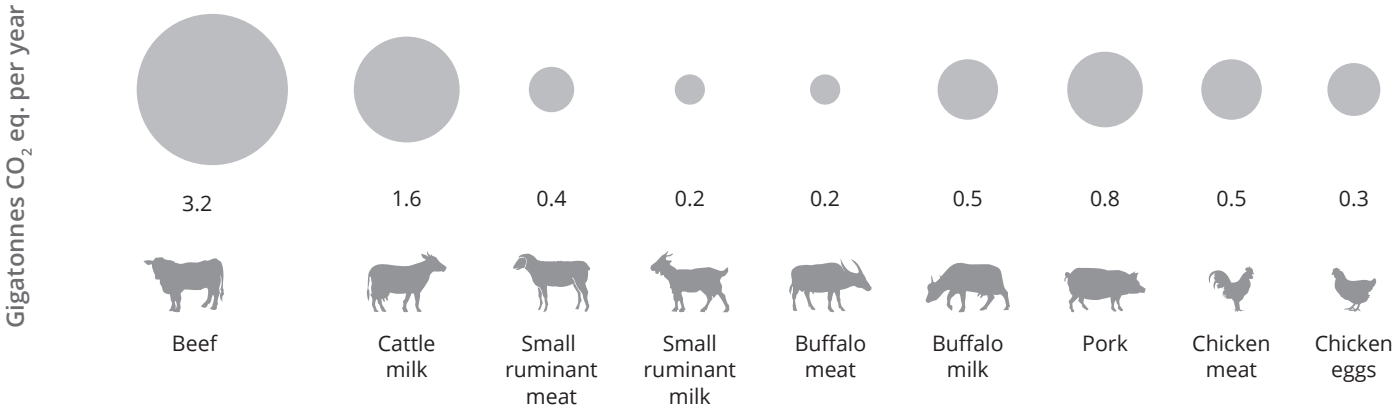
There are large differences in the productivity and associated emission intensities both within and between livestock systems. The monogastric species, with their higher feed conversion ratios, have lower emission intensities and less variability in emissions than do ruminants (Figure 10). As intensification of production tends towards greater efficiency, and a higher proportion of monogastric species, the proportions of N_2O and CO_2 increase relative to CH_4 (Figure 8). Such trends are important because they represent a shift from short-lived climate pollutants to much more persistent GHGs (Table 2).

Emission intensities also vary widely among different livestock commodities (Figure 10). On average, intensities are highest for ruminant products, particularly buffalo meat (404 kg CO_2 eq. per kg of protein), beef at 295 kg CO_2 eq. per kg of protein, and small ruminant meat at 201 kg CO_2 eq. per kg of protein. This is followed by cattle milk at nearly 87 kg CO_2 eq. per kg of protein, and pork at 55 kg CO_2 eq. per kg of protein, with the lower emission intensities for chicken products – eggs at 31 and chicken meat at 35 kg CO_2 eq. per kg of protein. Emission intensities can also be assigned to non-food livestock products, such as leather, wool and fibres.

Emission sources, and the specific gases involved, thus vary considerably between livestock species and production systems (Figure 11). Enteric methane

Figure 9

Total emissions (expressed in CO_2 eq.) vary considerably by commodity, with those from cattle far outstripping the combined impacts of all other livestock species, accounting for over 60 percent of all livestock emissions. Emissions from beef cattle are greatest, followed by those from dairy cattle. The areas of the circles are proportional to the total emissions.
Source: GLEAM 2.



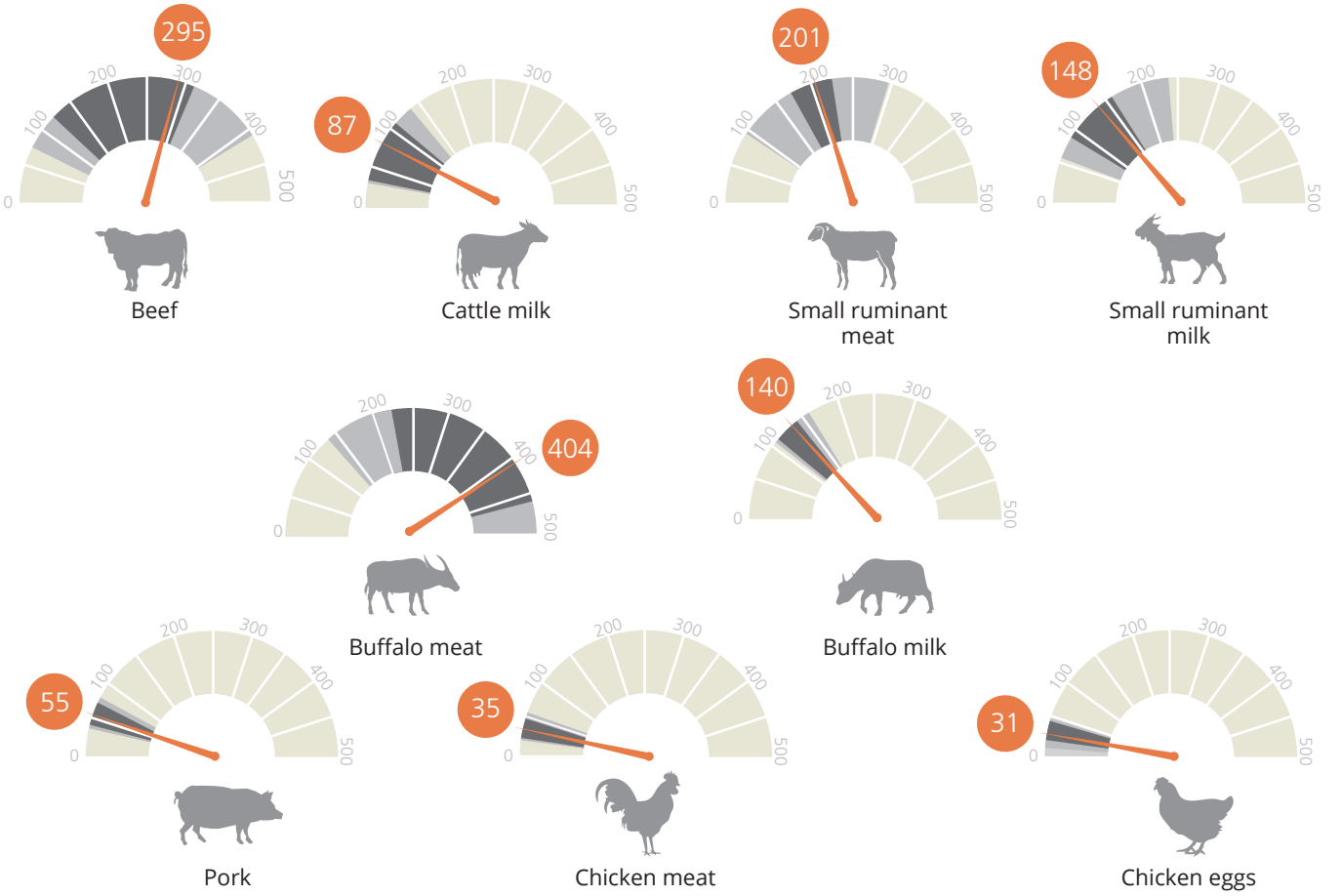
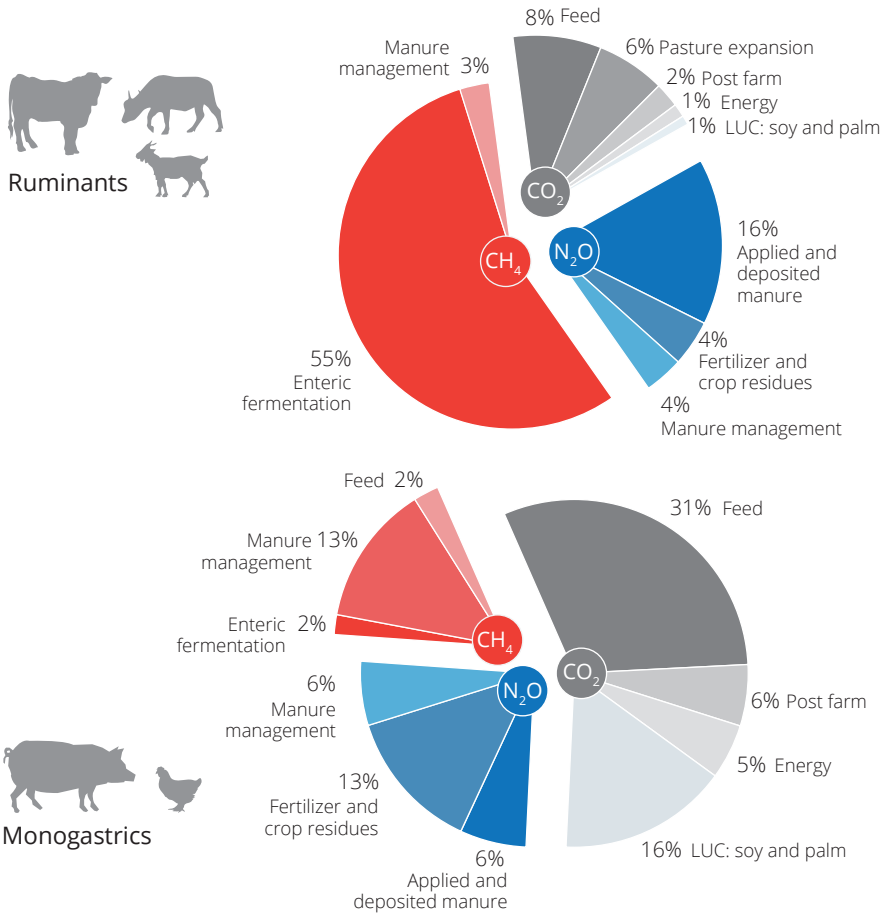


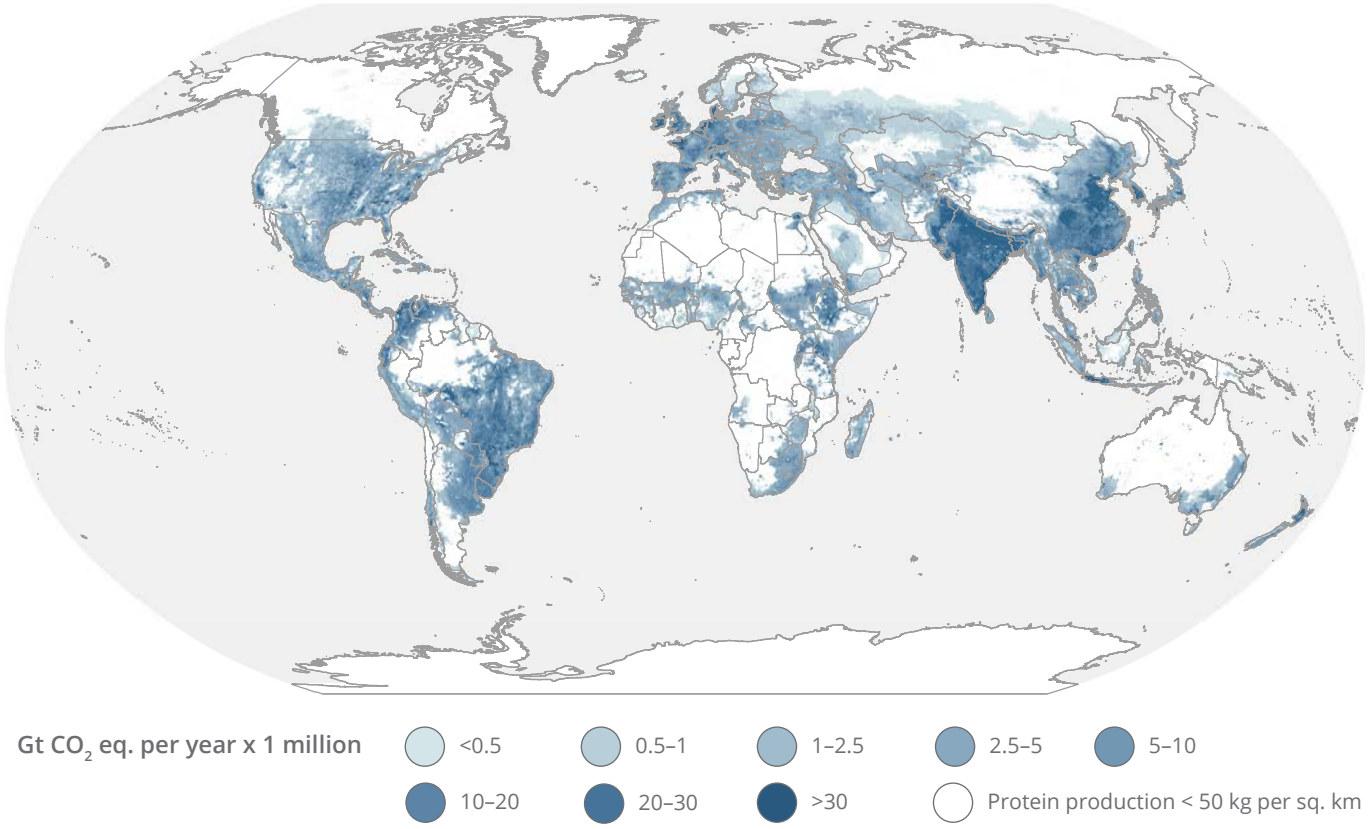
Figure 10

Emission intensities (expressed in CO_2 eq.) vary considerably by commodity. Ruminant species typically emit much more greenhouse gas per unit of protein compared to the more efficient monogastric species. Cattle milk, however, has a relatively low emission intensity, given high productivity. There is also high variability within commodities, particularly ruminant species, reflecting the diversity of systems in which they are raised.
Source: GLEAM 2.

Figure 11

GLEAM enables the sources of greenhouse gas emissions to be estimated and compared for different commodities. This high-level comparison between ruminant and monogastric species shows considerable differences in the sources of emissions between the two groups, and also in the gases responsible. Enteric methane accounts for more than half of ruminant greenhouse gas emissions, while feed production, land use change (LUC) and manure management are the main contributors to emissions in monogastric systems.
Source: GLEAM 2.





accounts for 55 percent of ruminant emissions, while feed production (46 percent), land use change (16 percent) and manure management (19 percent) are the main contributors in monogastric systems.

Total GHG emissions (Figure 12) and emission intensities (Figure 13) vary greatly geographically too, with regional differences reflecting livestock densities and different production systems, particularly the relative proportions of ruminant and monogastric systems. Typically emissions are higher in high-income countries (HICs), but also in LMICs with high livestock densities, especially where ruminant farming is prevalent.

Figure 12

This global map of total greenhouse gas emissions from livestock systems shows high overall emission levels in high-income countries. High emission levels also occur in low- and middle-income countries in areas with high livestock densities, particularly where ruminant livestock are abundant, such as significant parts of Latin America and South Asia, and in the highlands of East Africa. Densely populated areas in South East Asia also show high emissions, but this is associated with high-density monogastric production. This map points to areas where overall reductions in the production of high-emitting livestock products could make a significant positive impact.
Sources: emission data, GLEAM 2; international boundaries conform to the United Nations world map; UN 2019.

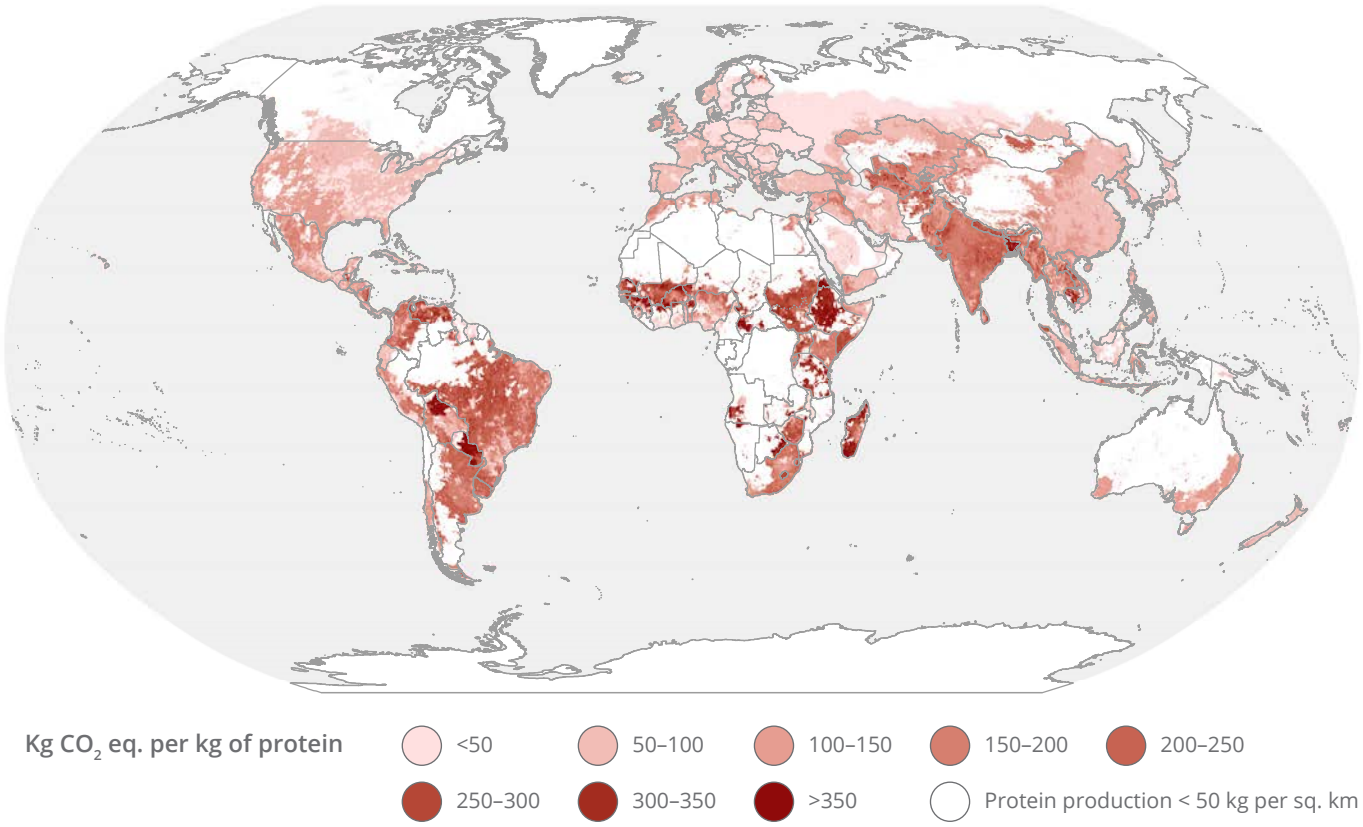


Figure 13

This global map of greenhouse gas emission intensities from livestock systems shows a very different picture from Figure 12. High-income countries, with more efficient livestock production systems, exhibit lower emission intensities on the whole. Low- and middle-income countries, especially those in which ruminant livestock production systems predominate, tend to have much higher emission intensities. This map points to areas where investments in efficiency improvements could lower emission intensities.
Sources: emission data, GLEAM 2; international boundaries conform to the United Nations world map; UN 2019.

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