KEY MESSAGES OF CHAPTER 5

- The potential to reduce the sector's emissions is large. Technologies and practices that help reduce emissions exist but are not widely used. The adoption and use of best practices and technologies by the bulk of the world's producers can result in significant reductions in emissions.

- Emission intensities (emissions per unit of animal product) vary greatly between production units, even within similar production systems. Different agro-ecological conditions, farming practices and supply chain management explain this variability. In the gap between the production units with the lowest emission intensities and those with the highest emission intensities is potential for mitigation.

- The emissions could be reduced by between 18 and 30 percent (or 1.8 to 1.1 gigatonnes CO_2-eq), if producers in a given system, region and climate adopted the practices currently applied by the 10 to 25 percent of producers with the lowest emission intensity.

- Better grazing land management holds additional promises for mitigation. It can contribute to carbon sequestration of up to 0.4 to 0.6 gigatonnes CO_2-eq.

- The mitigation potential can be achieved within existing systems; this means that the potential can be achieved thanks to improving practices rather than changing production systems (i.e. shifting from grazing to mixed or from backyard to industrial).

- A reduction of emissions can be achieved in all climates, regions and production systems.

- The adoption of more efficient technologies and practices is key to reducing emissions. Possible interventions to reduce emissions are to a large extent based on technologies and practices that improve production efficiency at animal and herd levels. They include better feeding practices to reduce enteric and manure emissions, better husbandry and health management to reduce the unproductive part of the herd (fewer animals means fewer inputs, fewer rejections and fewer emissions for the same level of production).

- Manure management practices that ensure the recovery and recycling of nutrients and energy contained in manure and a more efficient use of energy along supply chains are also mitigation options.

- Most of the technologies and practices that mitigate emissions also improve productivity and can contribute to food security and poverty alleviation as the planet needs to feed a growing population.

- The major mitigation potential lies in ruminant systems operating at low productivity, for example, in Latin America and the Caribbean, South Asia and sub-Saharan Africa. Part of the mitigation potential can be achieved through better animal and herd efficiency.

- Mitigation potential is also important in intermediate pig production systems of East and Southeast Asia.

- The most affluent countries, where emission intensities of ruminant production are relatively lower but the volumes of production and emissions remain important, also offer an important potential for mitigation. In these areas where herd efficiency is often already high, mitigation can be achieved by on-farm efficiency, such as better manure management and energy saving devices.

SCOPE FOR MITIGATION

Reducing the sector's emissions may be achieved by reducing production and consumption, by lowering emission intensity of production, or by a combination of the two.

This assessment does not investigate the potential of reduced consumption of livestock products. Several authors have, however, assessed the hypothetical mitigation potential of different dietary change scenarios (see, for example, Stehfest *et al.*, 2009; Smith *et al.*, 2013); their work demonstrates the substantial mitigation effect, and its relatively low cost, compared with alternative mitigation strategies. Positive effects of reducing animal protein consumption on human health are also reported among populations consuming high levels of animal products (McMichael *et al.*, 2007; Stehfest *et al.*, 2009).

Many technical options exist for the mitigation of GHG emissions along livestock supply chains. They fall into the following categories: 1) options related to feed supplements and feed/feeding management (for CH_4 only); 2) options for manure management which include dietary management, but with a focus on "end-of-pipe" options for the storage, handling and application phases of manure management; 3) animal husbandry options which include animal and reproductive management practices and technologies. The practices and technologies recommended by (FAO, 2013c) for their effectiveness are reported in Box 2.

5.1 MITIGATION POTENTIAL

Earlier sections have described the high variability of emission intensity on a global and regional scale, identifying a wide gap in emission intensity between the producer with the lowest emission intensity and the producer with the highest emission intensity. This gap is also found within discrete sets of commodity, production system, regions and agro-ecological zones, as illustrated in Figures 25 and 26.

This gap provides room to mitigate emissions within existing systems.

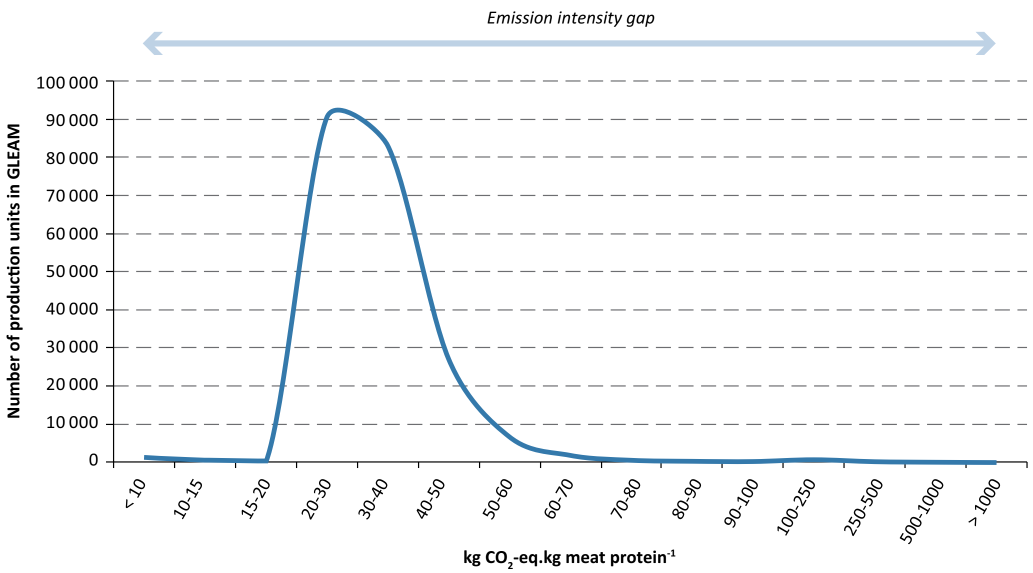
Order of magnitude

The sector's potential to mitigate GHG emissions is important, and significant reductions could be obtained by closing the gap in emission intensities among producers in the same region and production systems.

Mitigation potential within existing production systems

It is estimated that the sector's emissions could be reduced by approximately 30 percent (about 1.8 gigatonnes CO_2-eq) if producers in a given system,

FIGURE 25. Example of emission intensity gap – distribution of broiler production units in GLEAM according to their emission intensity in temperate zones of East and Southeast Asia



Source: GLEAM.

region and agro-ecological zone were to apply the practices of the 10 percent of producers with lowest emission intensity (10th percentile)[18] (Table 10), while keeping the overall output constant. If producers were to apply the practices of the 25 percent of producers with lowest emission intensity (25th percentile), the sector's emissions could be reduced by 18 percent (about 1.1 gigatonnes CO_2-eq). These estimates are based on several assumptions, including that conducive policies and market signals are in place to overcome barriers to the adoption of the most efficient production practices. These numbers should be taken as an order of magnitude only and need to be considered in view of the many assumptions and simplifications that this aggregated gap analysis entails (Box 3).

This mitigation potential does not imply any farming system change and is based on existing and already applied technologies.

[18] Average emission intensity of each unique combination of commodity, production system, region and agro-ecological zone set to the level of the lowest 10th (25th) percentile.

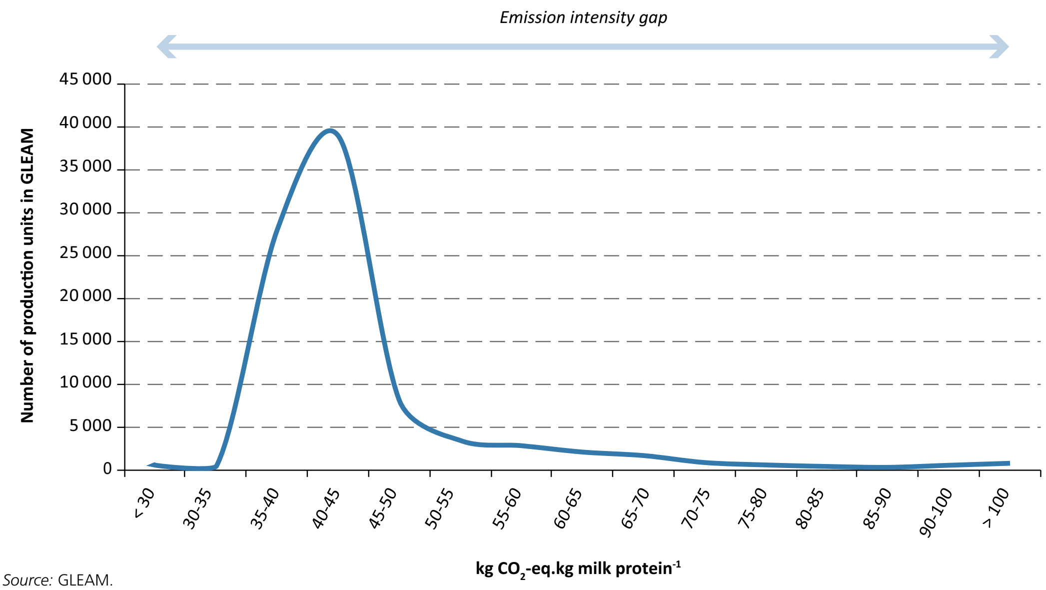
This large mitigation potential is observed for the various species. Emission reductions are roughly proportional to current emissions by different species: cattle offer the largest potential (65 percent) followed by chicken (14 percent), buffalos (8 percent), pigs (7 percent) and small ruminants (7 percent).

It should be noted that the mitigation potential is estimated at constant output. The sector is, however, growing and projected to further expand in the coming decades. Furthermore, disseminating the production practices of the 10th (25th) quantile in a given system, region and climate to all the producers in that region may well boost productivity. Net mitigation effect will be shaped by the combination of emission intensity reductions and output growth.

Mitigation potential allowing for changes between production systems

Allowing for moves between production systems (but not between commodity or region and agro-ecological zone), would achieve modest additional benefits (Table 10). Emissions would be

FIGURE 26. Example of emission intensity gap – distribution of dairy cattle production units in GLEAM according to their emission intensity in mixed systems in temperate zones of Western Europe



Source: GLEAM.

reduced by 32 percent if all producers in a given region and climate were to apply the practices of the 10th percentile,[19] and by 20 percent if they were to apply the practices of the 25th percentile.

This indicates that the heterogeneity of practices and resulting gap in emission intensities within the broad production systems used for this analysis are nearly as broad as the heterogeneity of practices between production systems.

If the mitigation potential identified in this assessment does not require any system change, nor any change in the mix of products generated by the sector (i.e. milk, eggs, beef, etc.), these changes are de facto taking place and affect the overall emission intensity of livestock. The two commodities currently showing highest growth rates are among those with lowest global average emission intensity, namely milk and poultry (FAOSTAT, 2013), which will tend to reduce average emission intensity per unit of protein. This is further accentuated by the fact that most of the growth is taking place among high productivity (dairy) and intensified (industrial broilers and layers) systems, which generally have the lowest emission intensity.

A conservative estimate

The emission reduction estimated through the statistical analysis of emission intensity gap reflects the hypothetical case of average emission intensities raised to the level of the 10 and 25 percent of best-performing production units, respectively. Despite the limitations of this statistical analysis and the assumptions on which it relies regarding policy context and availability of resources (see Box 3), it is probable that the resulting estimate is conservative.

First, it excludes mitigation technologies and practices that are available but not yet applied or adopted by more than a small share of producers and, thus, not included in the baseline. This is, for example, the case of biodigesters in ruminant production, energy saving devices on dairy farms or dietary supplements to reduce enteric CH_4 emissions.

[19] Average emission intensity of each unique combination of commodity, region and agro-ecological zone set to the level of the lowest 10th (25th) percentile.

BOX 2. A REVIEW OF AVAILABLE TECHNIQUES AND PRACTICES TO MITIGATE NON-CO_2 EMISSIONS

FAO recently initiated a comprehensive literature review of available mitigation techniques and practices for livestock (FAO, 2013c; Gerber *et al.,* 2013). The review focuses on mitigation options for enteric CH_4 and manure CH_4 and N_2O emissions. Tables A, B and C give a summary of this review.

Diet manipulation and feed additives have been identified as main avenues for the mitigation of enteric CH_4 production. Their effectiveness on absolute emissions is generally estimated to be low to medium, but some of these options can achieve substantially lower emission intensity by improving feed efficiency and animal productivity. Diets also affect manure emissions, by altering the content of manure: ration composition and additives have an influence on the form and amount of N in urine and faeces, as well as on the amount of fermentable organic matter in faeces.

Methane emissions from manure can be effectively controlled by shortening storage duration, ensuring aerobic conditions or capturing the biogas emitted in anaerobic conditions. However, direct and indirect N_2O emissions are much more difficult to prevent once N is excreted. Techniques that prevent emissions during initial stages of management preserve N in manure that is often emitted at later stages. Thus, effective mitigation of N losses in one form (e.g. NH_3) is often offset by N losses in other forms (e.g. N_2O or NO_3). These transference effects must be considered when designing mitigation practices. Numerous interactions also occur among techniques for mitigating CH_4 and N_2O emissions from manure.

More research is needed to develop practical and economically-viable mitigation techniques that can be widely practised. Efforts should target single practices with high potential (e.g. vaccination against rumen methanogens), but also take into account the interactions between practices, to develop suites of effective mitigation practices for specific production systems.

TABLE A. Available techniques and practices for non-CO_2 mitigation: feed additives and feeding practices

Practice/technology	Potential CH_4 mitigating effect[1]	Long-term effect established	Environmentally safe or safe to the animal
Feed additives			
Nitrate	High	No?	NK
Ionophores	Low	No?	Yes?
Plant bioactive compounds			
Tannins (condensed)	Low	No?	Yes
Dietary lipids	Medium	No?	Yes
Manipulation of rumen	Low	No	Yes?
Concentrate inclusion in ration	Low to Medium	Yes	Yes
Forage quality and management	Low to Medium	Yes	Yes
Grazing management	Low	Yes	Yes
Feed processing	Low	Yes	Yes
Macro-supplementation (when deficient)	Medium	Yes	Yes
Micro-supplementation (when deficient)	NA	No	Yes
Breeding for straw quality	Low	Yes	Yes
Precision-feeding and feed analyses	Low to Medium	Ye	Yes

[1] High = ≥ 30 percent mitigating effect; Medium = 10 to 30 percent mitigating effect; Low = ≤ 10 percent mitigating effect. Mitigating effects refer to percentage change over a "standard practice", i.e. study control that was used for comparison and based on a combination of study data and judgement by the authors of this document.

NK = Unknown.

NA = Not applicable.

? = Uncertainty due to limited research, variable results or lack of/insufficient data on persistence of the effect.

TABLE B. Available techniques and practices for non-CO_2 mitigation: manure handling

Practice/technology	Species[1]	Potential CH_4 mitigating effect[2]	Potential N_2O mitigating effect[2]	Potential NH_3 mitigating effect[2]
Dietary manipulation and nutrient balance				
Reduced dietary protein	AS	?	Medium	High
High fibre diets	SW	Low	High	NK
Grazing management	AR	NK	High?	NK
Housing				
Biofiltration	AS	Low?	NK	High
Manure system	DC, BC, SW	High	NK	High
Manure treatment				
Anaerobic digestion	DC, BC, SW	High	High	Increase?
Solids separation	DC, BC	High	Low	NK
Aeration	DC, BC	High	Increase?	NK
Manure acidification	DC, BC, SW	High	?	High
Manure storage				
Decreased storage time	DC, BC, SW	High	High	High
Storage cover with straw	DC, BC, SW	High	Increase?	High
Natural or induced crust	DC, BC	High	Increase?	High
Aeration during liquid manure storage	DC, BC, SW	Medium to High	Increase?	NK
Composting	DC, BC, SW	High	NK	Increase
Litter stacking	PO	Medium	NA	NK
Storage temperature	DC, BC	High	NK	High
Sealed storage with flare	DC, BC, SW	High	High	NK
Manure application				
Manure injection vs surface application	DC, BC, SW	No Effect to Increase?	No Effect to Increase	High
Timing of application	AS	Low	High	High
Soil cover, cover cropping	AS	NK	No Effect to High	Increase?
Soil nutrient balance	AS	NA	High	High
Nitrification inhibitor applied to manure or after urine deposition in pastures	DC, BC, SH	NA	High	NA
Urease inhibitor applied with or before urine	DC,BC, SH	NA	Medium?	High

[1] DC = dairy cattle; BC = beef cattle (cattle include *Bos taurus* and *Bos indicus*); SH = sheep; GO = goats; AR = all ruminants; SW = swine; PO = poultry; AS = all species.

[2] High = ≥ 30 percent mitigating effect; Medium = 10 to 30 percent mitigating effect; Low = ≤ 10 percent mitigating effect. Mitigating effects refer to percentage change over a "standard practice", i.e. study control that was used for comparison and based on combination of study data and judgement by the authors of this document.

NK = Unknown.

NA = Not applicable.

? = Uncertainty due to limited research, variable results or lack of/insufficient data on persistency of the effect.

(cont.)

BOX 2. *(cont.)*

TABLE C. Available techniques and practices for non-CO_2 mitigation: animal husbandry

Practice/technology	Species[1]	Effect on productivity	Potential CH_4 mitigating effect[2]	Potential N_2O mitigating effect[2]
Animal management				
Genetic selection (Residual feed intake)	DC, BC, SW?	None	Low?	NK
Animal health	AS	Increase	Low?	Low?
Reduced animal mortality	AS	Increase	Low?	Low?
Optimization of age at slaughter	AS	None	Medium	Medium
Reproductive management				
Mating strategies	AR, SW	High to medium	High to medium	
Improved productive life	AR, SW	Medium	Medium	
Enhanced fecundity	SW, SH, GO	High to medium	High to medium	
Periparturient care/health	DC AR, SW	Medium	Medium	
Reduction of stress	AR, SW	High to medium	High to medium	
Assisted reproductive technologies	AR, SW	High to medium	High to medium	

[1] DC = dairy cattle; BC = beef cattle (cattle include *Bos taurus* and *Bos indicus*); SH = sheep; GO = goats; AR = all ruminants; SW = swine; PO = poultry; AS = all species.

[2] High = ≥ 30 percent mitigating effect; Medium = 10 to 30 percent mitigating effect; Low = ≤ 10 percent mitigating effect. Mitigating effects refer to percentage change over a "standard practice", i.e. study control that was used for comparison and based on combinations of study data and judgement by the authors of this document.

NK = Unknown.

? = Uncertainty due to limited research, variable results or lack of/insufficient data on persistence of the effect.

Second, the gap analysis does not capture the potential offered by practices for which GLEAM uses average input data over entire combinations of production systems, regions and agro-ecological zones. For example, several parameters related to herd performance that characterize animal husbandry practices and animal health are defined at regional or farming system levels.

And third, the analysis excludes postfarm emissions and emissions related to pasture expansion that are not calculated at pixel level. Together, they represent about 10 percent of the 7.1 gigatonnes.

5.2 CARBON SEQUESTRATION

Reduced land-use change

Reducing land-use changes can further contribute to mitigation. Emissions from pasture and soybean area expansion result in an estimated 9 percent of the sector's emissions (Chapter 2). While no formal analysis was done to estimate global abatement potential from land-use change, it is plausible that land-use conversion rates related to livestock production could be halved over the medium term (one to two decades), mitigating about 0.4 gigatonnes CO_2-eq of the sector's annual emissions. The feasibility of this target is demonstrated by comparison with the Brazilian Government's pledge in 2010 to reduce emissions by 0.7 gigatonnes CO_2-eq, by reducing deforestation rates by 80 percent in the Amazon and by 40 percent in the Cerrado by 2020.[20] In the mitigation case study for the specialized beef sector in Brazil presented later, animal and herd efficiency improvements were estimated to reduce grazing land use and associated land-use change emissions by up to 25 percent.

[20] http://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/brazilcphaccord_app2.pdf; http://www.brasil.gov.br/cop-english/overview/what-brazil-is-doing/domestic-goals

TABLE 10. Estimates of emission reduction potential based on the analysis of emission intensity gap

	Analysis within unique sets of geographical region, climate and farming system (farming system change excluded)						**Analysis within unique sets of geographical region and climate (farming system change allowed)**					
	Production units align to average emission intensity of the 10th percentile			Production units align to average emission intensity of the 25th percentile			Production units align to average emission intensity of the 10th percentile			Production units align to average emission intensity of the 25th percentile		
	Emission reduction											
	By species *(Million tonnes CO_2-eq)*	By species *(percentage)*	In the scenario *(percentage)*	By species *(Million tonnes CO_2-eq)*	By species *(percentage)*	In the scenario *(percentage)*	By species *(Million tonnes CO_2-eq)*	By species *(percentage)*	In the scenario *(percentage)*	By species *(Million tonnes CO_2-eq)*	By species *(percentage)*	In the scenario *(percentage)*
Beef cattle	-775	-27	44	-482	-17	44	-883	-31	45	-619	-22	51
Dairy cattle	-401	-32	23	-231	-18	21	-440	-35	23	-264	-21	22
Pig	-103	-19	6	-76	-14	7	-108	-19	6	-69	-14	6
Buffalo meat	-96	-41	5	-31	-13	3	-101	-43	5	-32	-14	3
Buffalo milk	-80	-22	4	-51	-14	5	-89	-25	5	-54	-15	4
Chicken eggs	-66	-38	4	-51	-29	5	-73	-42	4	-50	-29	4
Chicken meat	-113	-40	6	-97	-34	9	-94	-33	5	-60	-21	5
Small rum. milk	-45	-36	3	-24	-19	2	-49	-39	3	-17	-14	1
Small rum. meat	-96	-31	5	-50	-16	5	-105	-33	5	-58	-18	5
Total	**-1 775**	**-29**	**100**	**-1 092**	**-18**	**100**	**-1 943**	**-32**	**100**	**-1 224**	**-20**	**100**

BOX 3. ESTIMATING MITIGATION POTENTIAL THROUGH ANALYSIS OF THE EMISSION INTENSITY GAP

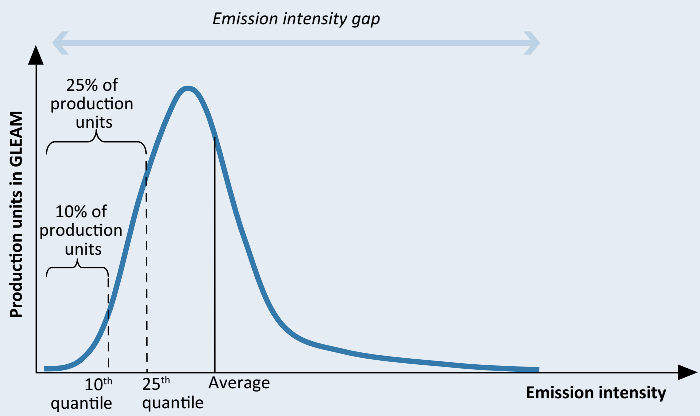
For each commodity, produced in a specific combination of geographical region, climate and farming system, the average emission intensity and the emission intensity of the 10th and 25th percentiles of production units (pixels) showing the lowest emission intensity were computed. The mitigation potential was then estimated by shifting the baseline average emission intensity to either the lowest 10th or 25th percentile (representing production units with lower emission intensity).

The mitigation potential was also computed allowing for changes in farming systems: average and percentile were assessed for each commodity, produced in a discrete combination of geographical region and agro-ecological zone.

This statistical analysis relies on the following assumptions:

- Conducive policies and market signals are in place to overcome barriers to the adoption of most efficient production practices.
- Extending the mix of inputs used by the 25 percent or 10 percent best performing units to all production units in the region/climate/system does not alter the emission intensity of that mix of inputs.
- There is no local resource constraint (e.g. microclimate, water) to the adoption of low emission intensity practices.
- Resources (e.g. commercial feed, energy) are available at regional level to enable the adoption of low emission intensity practices.

Schematic representation of emission intensity distribution and emission intensity gap, for a given commodity, within a region, climate zone and farming system



Grassland soil carbon sequestration

It is estimated that improved grazing management practices in grasslands could sequester about 409 million tonnes CO_2-eq of carbon per year (or 111.5 million tonnes C per year over a 20-year time period), globally. A further 176 million tonnes CO_2-eq of sequestered emissions (net of increased N_2O emissions) per year over a 20-year time period, was estimated to be possible through the sowing of legumes in some grassland areas. Thus, a combined mitigation potential of 585 million tonnes CO_2-eq was estimated from

Credit: ©FAO/Giulio Napolitano

these practices, representing about 8 percent of livestock supply chain emissions. Chapter 2 presents an introduction to the methodology used.

In grasslands that have experienced the excessive removal of vegetation and soil carbon losses from sustained periods of overgrazing, historical carbon losses can at least be partially reversed by reducing grazing pressure. Conversely, there is also scope to improve grass productivity and sequester soil carbon by increasing grazing pressure in many grasslands that are only lightly grazed (Holland *et al.*, 1992).

There are several other practices which could be used to further increase grassland soil carbon stocks, which were not assessed in this study. They include the sowing of improved, deep-rooted tropical grass species and improved fire management.

According to the 4th Assessment Report to the IPCC (Smith *et al.*, 2007), 1.5 gigatonnes CO_2-eq of carbon could be sequestered annually if a broad range of grazing and pasture improvement practices were applied to all of the world's grasslands. The same study estimates that up to 1.4 gigatonnes CO_2-eq of carbon can be sequestered in croplands annually, and much of these are devoted to feed production. In another global grassland assessment, Lal (2004) estimated a more conservative potential for carbon sequestration of between 0.4 and 1.1 gigatonnes CO_2-eq per year. The sequestration potential estimated in this assessment falls within the range of these global estimates.

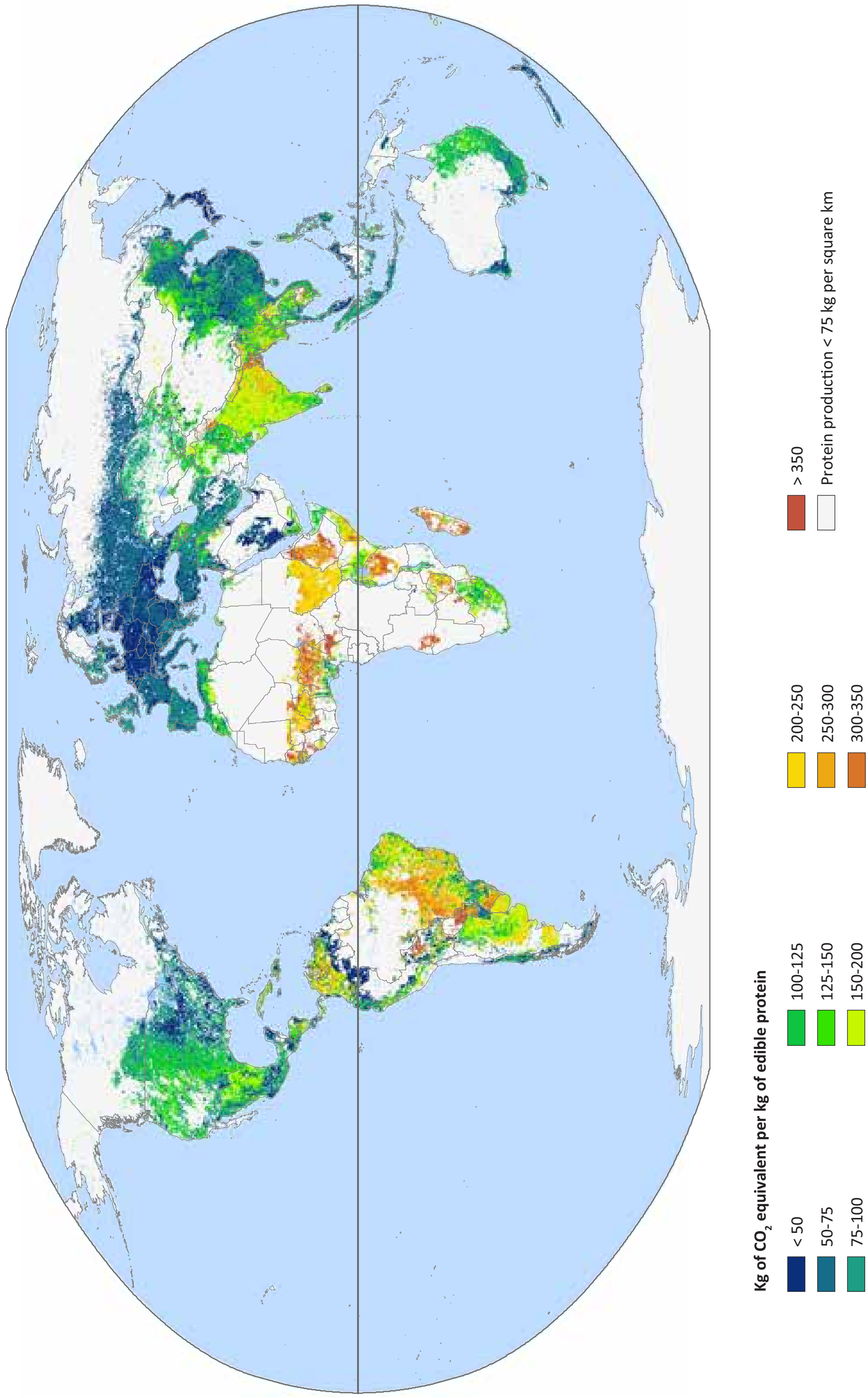
5.3 POTENTIAL BY MAIN GEOGRAPHICAL AREAS

The mitigation potential varies amongst regions depending on production volume and related emission intensities. Emissions per unit of animal protein and emissions per unit of land are displayed on maps in Figure 27A, B, and C.

Areas for which both emissions per unit of animal protein and per unit of land are low (e.g. parts of Central Europe, Middle East and Andean regions) are generally areas where little production takes place, mostly relying on monogastric species, and it can be assumed that these areas offer relatively low potential for mitigation.

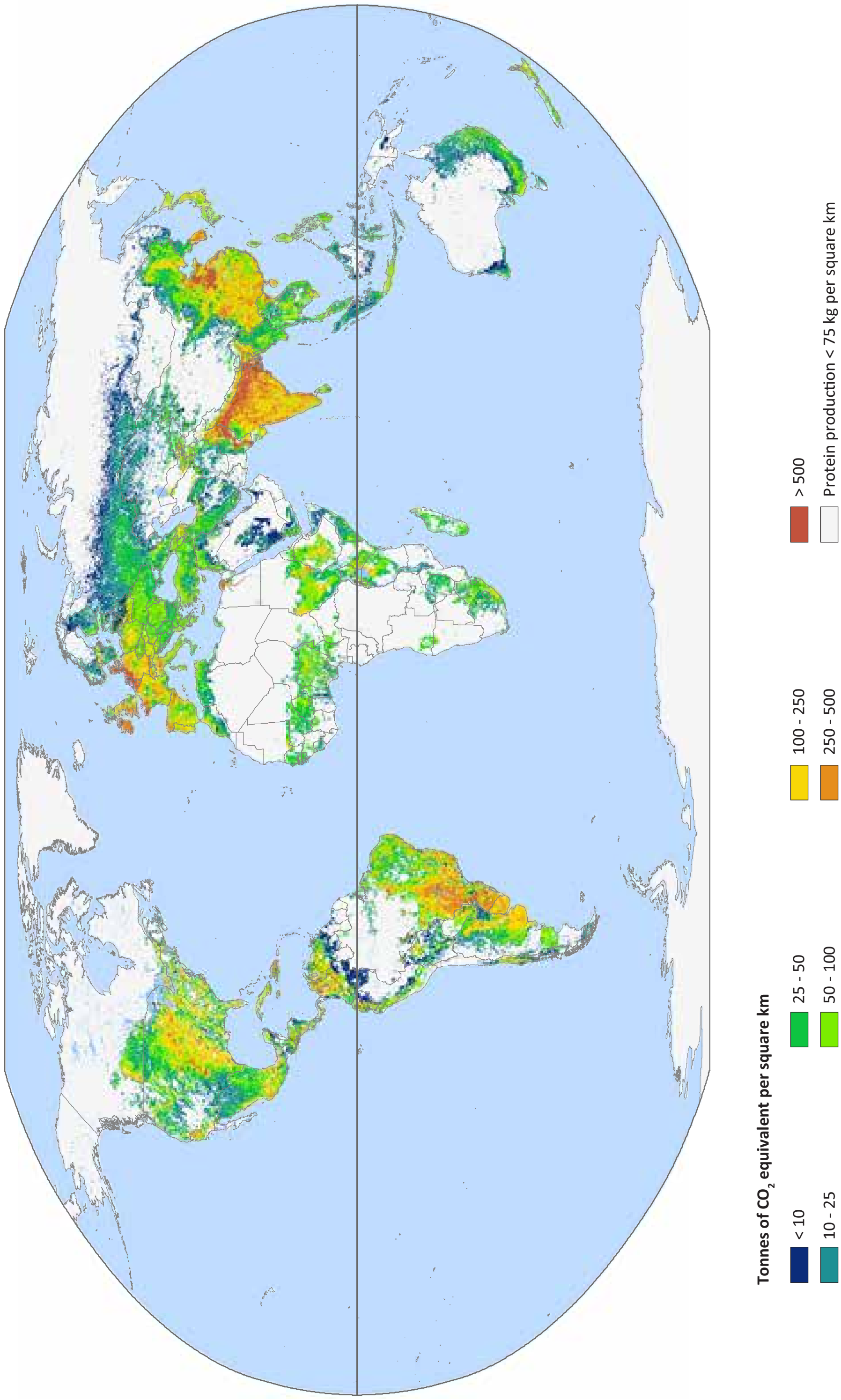
The most affluent areas of the globe usually combine low emission intensity per unit of product with high emission intensity per area of land. Here, relatively marginal emission intensity gains can result in a significant mitigation effect, given the sheer volume of emissions.

FIGURE 27A. Emission intensity per unit of edible protein



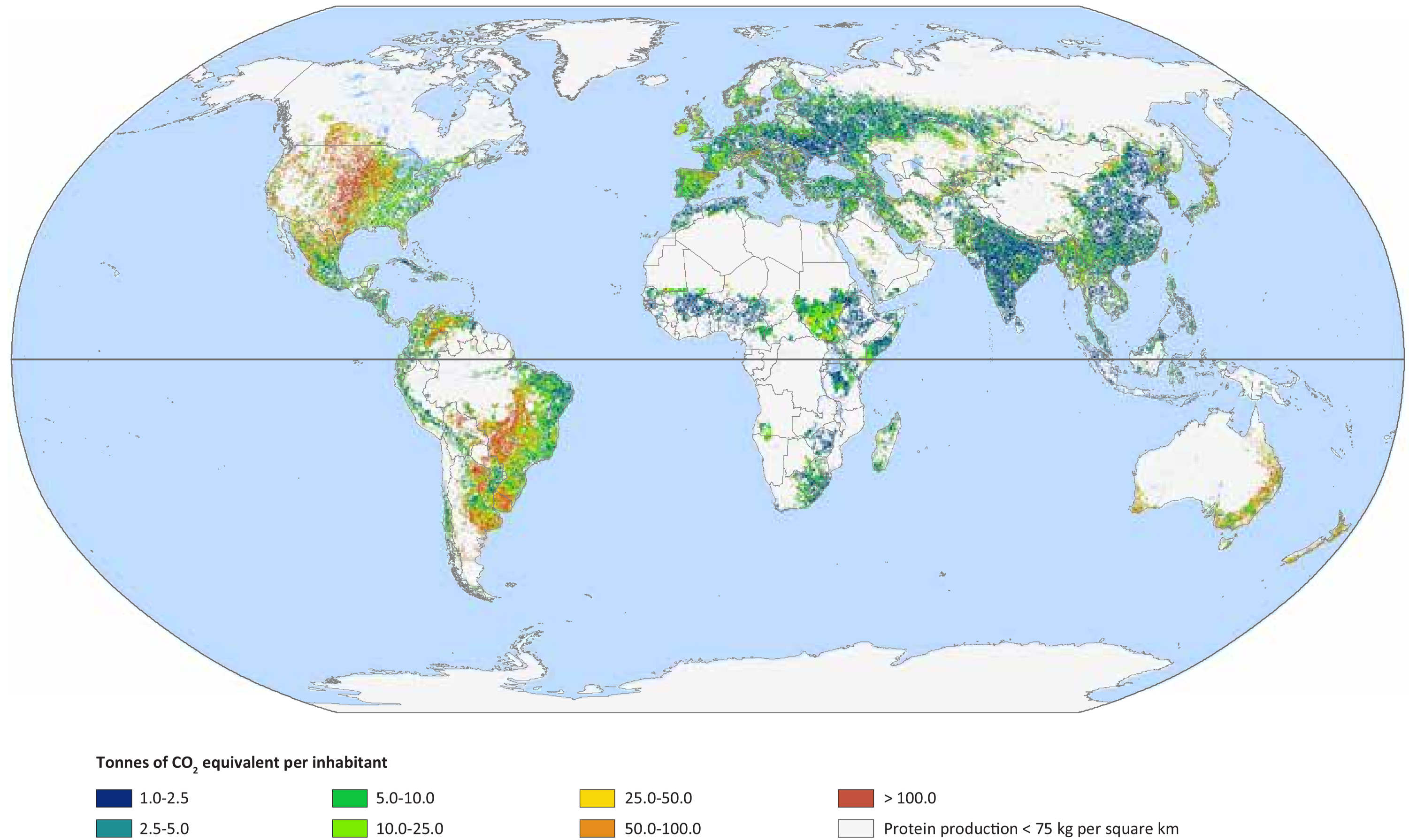
Source: GLEAM.

FIGURE 27B. Emission intensity per unit of land area



Source: GLEAM.

FIGURE 27C. Emission intensity per unit of human population



Source: GLEAM; GIS data for human population: Dobson *et al.*, 2000.

Large areas in the subhumid and semi-arid zones of Africa and Latin America display high emission intensity per unit of protein but low emission intensity when expressed per unit of land. Mitigation is achievable in these areas but should be considered in view of food security and climate change adaptation concerns. Even modest productivity improvements in ruminant systems and improved grazing practices could yield substantial gains in both emission intensities and food security. However, many of these areas suffer from remoteness and climate variability that limit the opportunities to adopt new practices. Specific policies are required to overcome these constraints, as outlined in Chapter 7.

The major technical mitigation potential is probably to be found in areas where both measures of emission intensity are high. They are mainly found in Latin America and South Asia, and in parts of Eastern Africa. Here, a large potential for emission reduction per unit of protein coincides with substantial volumes of production. These areas are generally characterized by high cattle densities and low animal productivity. The range of mitigation options discussed above apply here, including animal performance improvement (e.g. genetics, health), feeding practices (e.g. digestibility of ration, protein content), herd structure management (e.g. reducing breeding overhead), manure management (storage, application, bio-digestion) and land management (improved pasture management).

Another way to express emission intensity is to relate total emissions from the livestock sector to human population (Figure 27C). Emission intensity values are relatively high where animals are produced in sparsely populated areas, typically for commercial grazing beef systems, such as parts of North America, Latin America and Oceania. Here, the economic and social implication of any mitigation intervention will need particular attention because livestock is among the major economic activities. Effects on local communities through income, risk and competitiveness issues will be of particular relevance.