4.3 SMALL RUMINANTS

The contribution of the small ruminant sector to GHG emissions is equivalent to 474 million tonnes CO_2-eq. These total emissions from the sheep and goat production comprise emissions from production of edible (meat and milk) and non-edible products (natural fibre) as well as emissions from post farmgate processes. The discussion in subsequent sections presents total emissions and emission intensities related to small ruminant production at global, farming system and regional grouping levels for edible products.

4.3.1 Total production, absolute emissions, and emission intensities

Globally, small ruminant production of meat and milk is responsible for 428.8 million tonnes CO_2-eq, of which 254.4 million tonnes CO_2-eq (59 percent) are associated with sheep production and 174.5 tonnes CO_2-eq (41 percent) are associated with goat production. Total production from the small ruminant sector amounts to 20.0 and 12.6 million tonnes of milk and meat, respectively. Goats contribute almost 60 percent of the milk produced by small ruminants, while sheep contribute 62 percent of the meat (Table 6).

On average, the emission intensity of small ruminant milk is 6.5 kg CO_2-eq/kg FPCM. In terms of emission intensity, goat's milk has lower emission intensity (5.2 kg CO_2-eq/kg FPCM compared with 8.4 kg CO_2-eq/kg FPCM for milk from sheep) due to higher yields compared with milk from sheep. Average emission intensity for small ruminant meat is 23.8 kg CO_2-eq/kg CW, while emission intensity for sheep and goats meat is quite similar – 24.0 and 23.5 kg CO_2-eq/kg CW, respectively (Table 6).

Similar to cattle and buffalo, CH_4 emissions are important, accounting for half of the total emissions associated with small ruminant production (Figure 17). Enteric fermentation is the single most important emission category in both milk and meat production, contributing 57 percent and 55 percent of the total GHG emissions from milk and meat production, respectively.

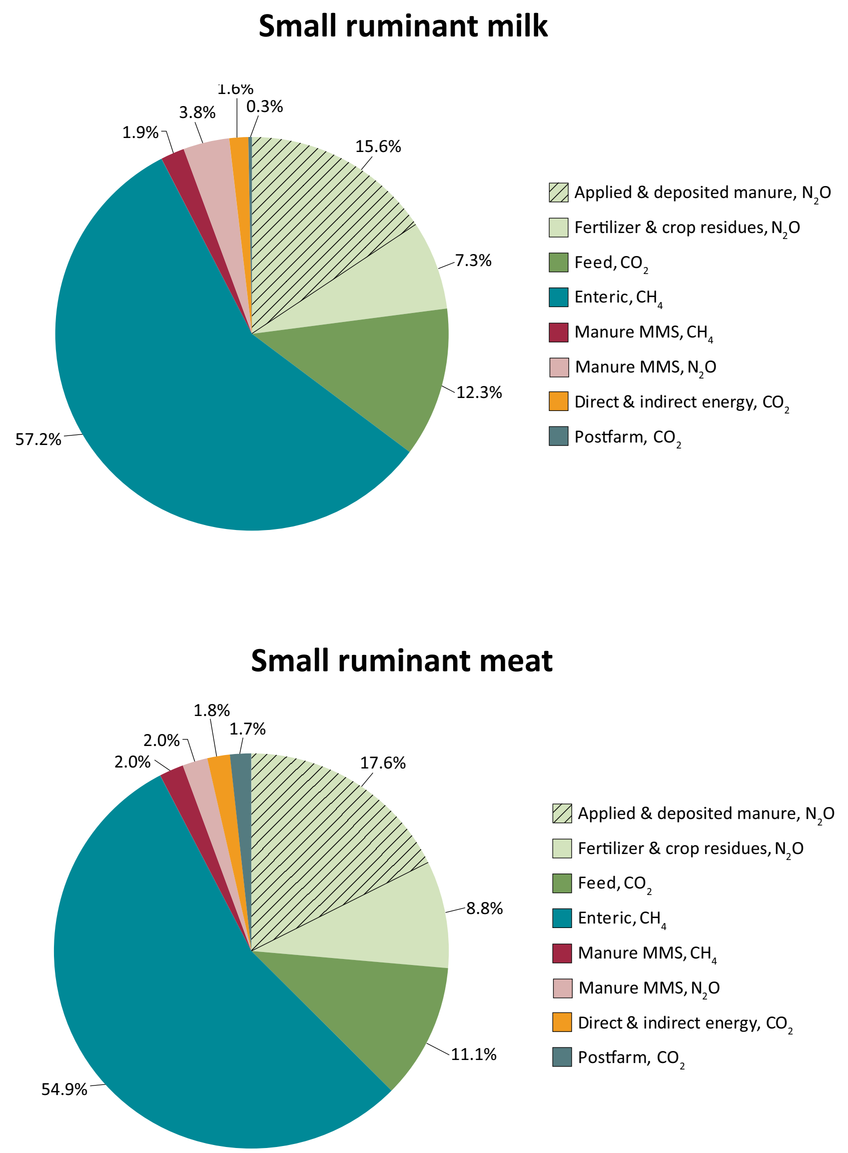
Nitrous oxide emissions amount to relatively similar proportions (27 percent and 28 percent) of the total carbon footprint for both milk and meat. Within this, N_2O emissions from manure storage and management are insignificant (4 percent and 2 percent for milk and meat, respectively), mainly because small ruminants are grazing most of the time and consequently a very small proportion of the manure is managed.

Table 6. Global production, emissions and emission intensity for small ruminants

Species	Production (million tonnes)		Absolute emissions[1] (million tonnes CO_2-eq)		Average emission intensity (kg CO_2-eq/kg product)	
	Milk[2]	Meat[2]	Milk	Meat	Milk[2]	Meat[2]
Sheep	8.0	7.8	67.4	186.9	8.4	24.0
Goats	12.0	4.8	62.4	112.5	5.2	23.5
Totals	**20.0**	**12.6**	**129.4**	**299.4**	**6.5**	**23.8**

[1] Absolute emissions include emissions from production and post farmgate emissions.
[2] Functional unit for milk and meat defined as fat and protein corrected milk and carcass weight.
Source: GLEAM.

Figure 17.
Relative contribution of different processes to GHG emission profile of small ruminant milk and meat



Source: GLEAM.

Within the emissions profile, CH_4 from manure management is unimportant because virtually all manure is either deposited on pasture or managed in dry systems such as drylots and solid storage systems (see Table B19, Appendix B). Emissions associated with feed production comprising both N_2O (mainly from manure) and CO_2 emissions amount to 35 percent of the total emissions. Carbon dioxide emissions from on-farm energy use and embedded energy as well as post farmgate activities make a relatively small contribution towards the overall carbon footprint.

4.3.2 Emissions by production system and agro-ecological zone

Emission intensity for milk is higher in grazing systems with an average of 7.6 kg CO_2-eq/kg FPCM compared with 6.6 kg CO_2-eq/kg FPCM in mixed farming systems (Figure 18). A similar trend is found for small ruminant meat; average emission intensity per kg CW is 24.0 and 23.2 kg CO_2-eq/kg CW in grazing and mixed systems, respectively (Figure 19).

In small ruminant milk production in grazing systems, emissions intensity is highest in temperate zones, a trend which contrasts with the emission intensity trends for dairy cattle (see Figure 7). The higher emission intensity for small ruminant milk in grazing temperate zones is explained by a combination of factors: (i) total emissions are dominated by emissions from the temperate areas in regions such as Asia and Africa, where production conditions are poor for the most part; (ii) sheep milk production dominates small ruminant milk in the temperate zones, however milk yields from sheep are much lower compared with goats; and (iii) goats milk, which is characterized by higher yields per animal, mainly occurs in the arid areas.

On the other hand, for small ruminant meat there is no systematic trend across production systems; in grazing systems, highest emission intensity is found in temperate zones, while in mixed systems, meat produced in the arid zones has the highest emission intensity.

The difference in emission intensity of small ruminant meat is explained by a combination of factors: (i) high emission intensity in grazing temperate areas is related to the fact that in temperate zones small ruminants, particularly sheep, are reared for mainly for meat and therefore the carcass bears the whole burden of emissions; (ii) temperate grazing areas are also characterized by low yields, which are closely related to poor production conditions and low feed digestibility, hence the high emission intensity.

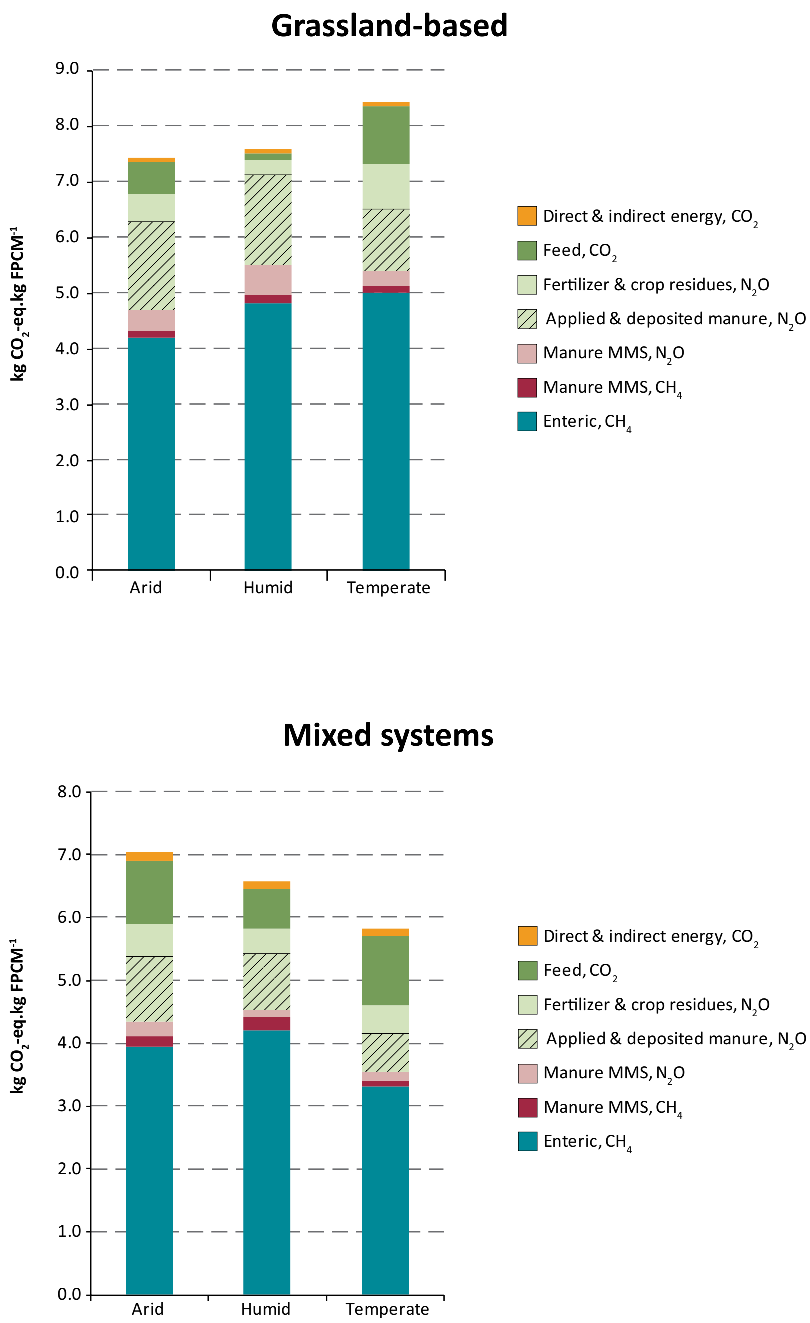
Figure 19, however, masks much of the variation that can be found within similar production systems and climatic conditions. Disaggregated emission intensity at production system level show temperate zones in grassland-based systems with highest emission intensity, about 27.5 kg CO_2-eq/kg CW. However, regions such as Oceania and W. Europe show a contrasting trend, with lowest emission intensities within this production system and AEZ typology (13.7 and 19.8 kg CO_2-eq/kg CW, respectively) as a result of their efficient production systems. Within temperate grassland-based systems, the predominance of other regions such as East & Southeast Asia, NENA and Latin America & Caribbean drive the emission intensities of the system. These high emissions are largely related to poor quality feed, poor performance of animals, and slower growth rates.

Methane emissions from enteric fermentation dominate the emission profile in both systems and across all three AEZs. Nitrous oxide emissions associated with feed production are relatively higher for grassland-based systems and this arises from the deposition of manure on pasture.

The high CH_4 emissions from manure management in the mixed farming systems relative to grazing systems indicate the management of manure in systems other than pasture-based systems.

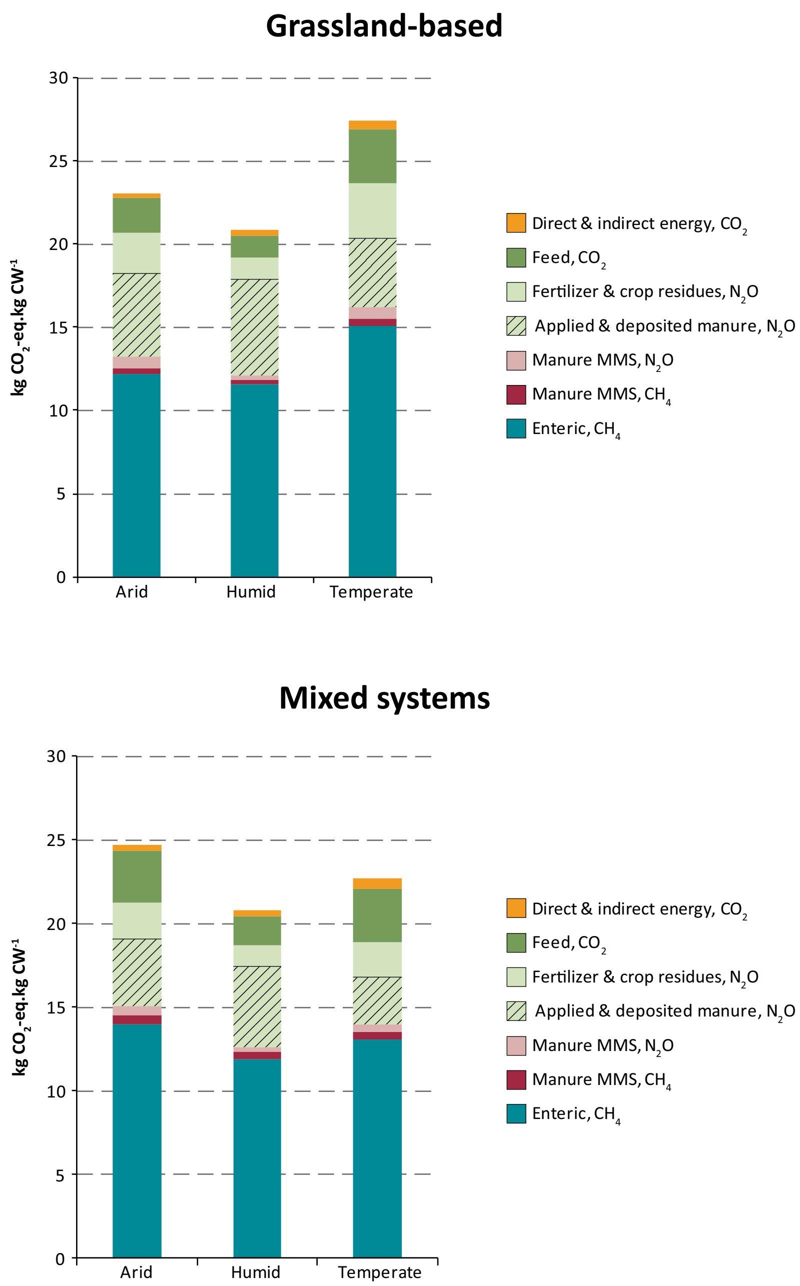
CO_2 emissions related to feed production, transport and processing are important in the temperate areas in both systems, accounting for 12 percent and 19 percent, respectively, and 12 percent and 14 percent, respectively, of the average carbon footprint of small ruminant milk and meat produced in grazing and mixed temperate zones.

Figure 18.
Emission intensities for small ruminant milk by production system and agro-ecological zone[1]



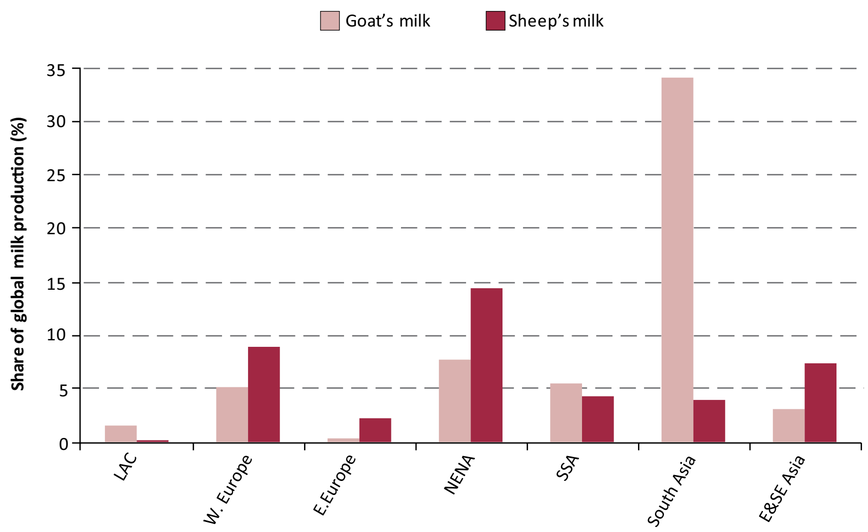
[1] Excluding post farmgate.
Source: GLEAM.

Figure 19.
Emission intensities for small ruminant meat by production system and agro-ecological zone[1]



[1] Excluding post farmgate.
Source: GLEAM.

Figure 20a.
Regional contribution to global small ruminant milk production[1]



[1] Excludes regions where contribution to global production is less than 2 percent.
Source: GLEAM.

4.3.3 Regional production, emissions and emission intensities

The production of small ruminant milk and meat is largely concentrated in developing regions. Figures 20a and 20b illustrate this trend; with the exception of small ruminant milk production in Western Europe and lamb and mutton production in Oceania and Western Europe, small ruminant production is generally more important in developing world regions.

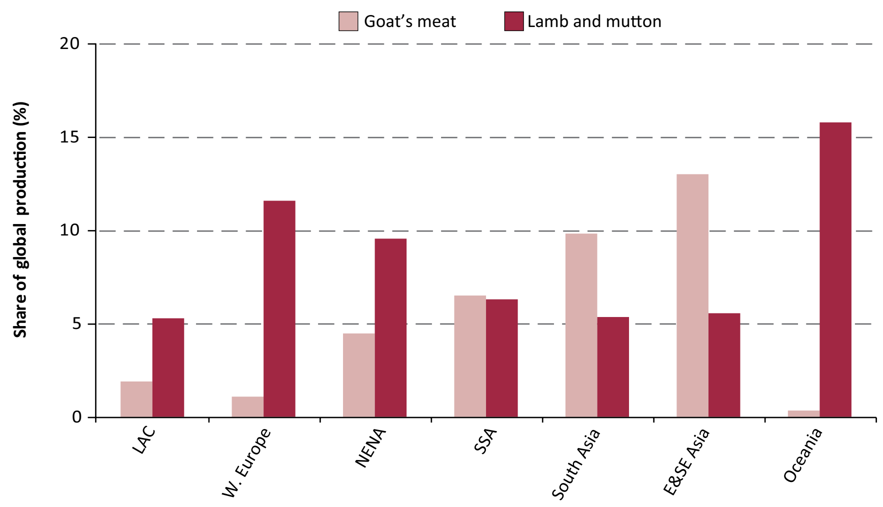
Small ruminants produce not only edible products; other important co-products include natural fibre such as wool, cashmere and mohair. As mentioned in Section 3.6 of this report, we have applied an economic value allocation to partition total GHG emissions between the edible products (meat and milk) and non-edible products (natural fibre). Figure 21 illustrates the impact of allocation to co-products.

Figure 21 illustrates those regions where the natural fibre production is important and has a high economic value compared with edible products, such as North America, Latin America & Caribbean, Oceania, and East & Southeast Asia. In the other regions, natural fibre production is generally not profitable and of low economic value.

At a regional level, emission intensity for small ruminant milk ranges from 4.7 kg CO_2-eq/kg FPCM in Western and Eastern Europe to almost 8.9 kg CO_2-eq/kg FPCM in East & Southeast Asia. Emissions in NENA, sub-Saharan Africa and South Asia are 8.7, 6.9, and 4.9 kg CO_2-eq/kg FPCM, respectively (Figure 22a). Within the developing regions, South Asia has the lowest emissions explained by high milk productivity. Overall, across the regions, goats milk tends to have lower emission intensity mainly because of the higher productivity compared with sheep.

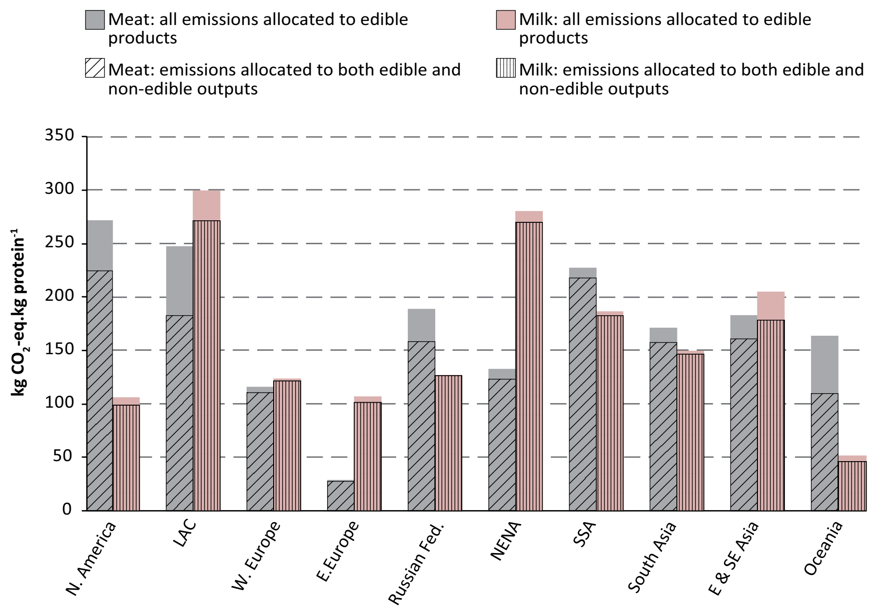
Methane from enteric fermentation is the dominant source of emissions in developing regions, ranging from 60 percent of the GHG emissions profile in South Asia to 69 percent in sub-Saharan Africa. For developing regions, N_2O emission related

Figure 20b.
Regional contribution to global small ruminant meat production[1]



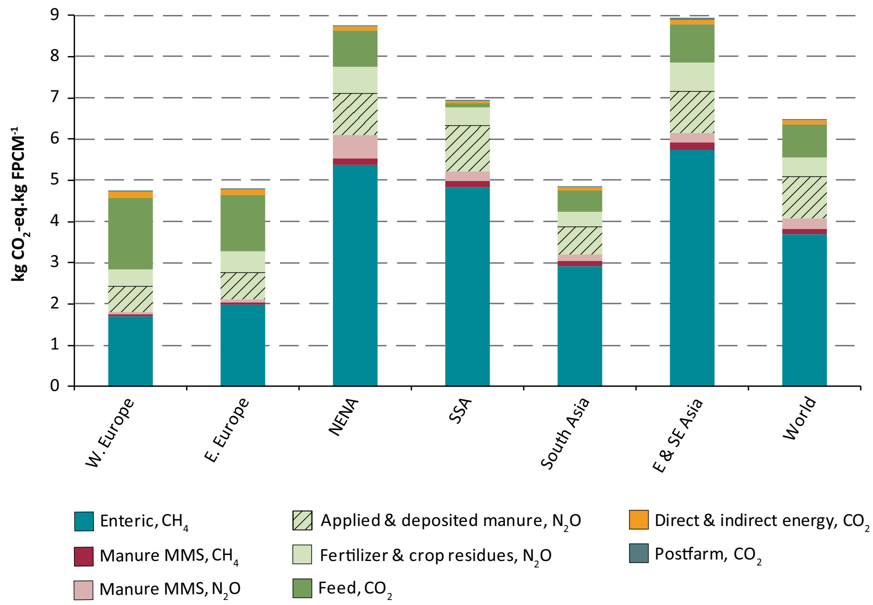
[1] Excludes regions where contribution to global production is less than 2 percent.
Source: GLEAM.

Figure 21.
Emissions per kg meat and milk protein, comparing allocation of emissions to different outputs



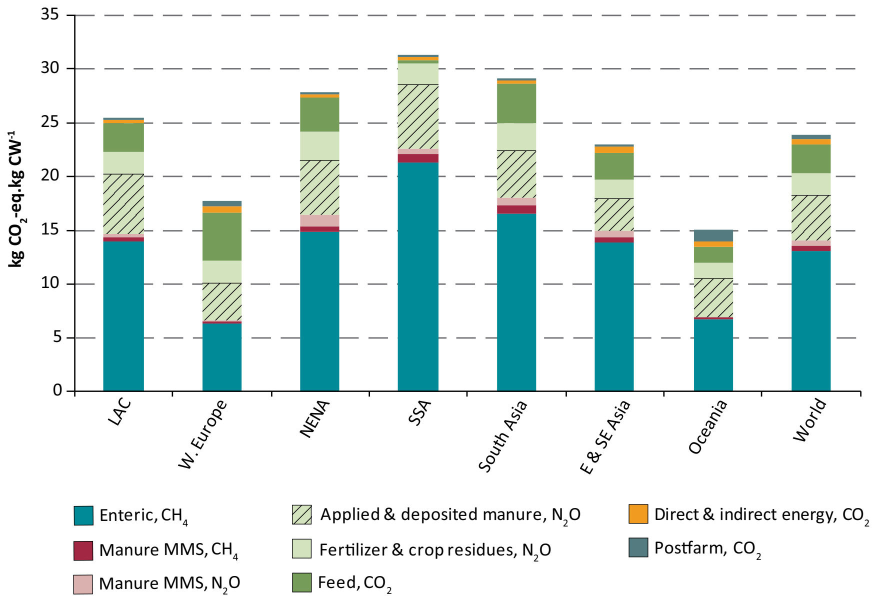
Source: GLEAM.

Figure 22a.
Regional variation in GHG emission intensities for small ruminant milk[1]



[1] Excludes regions where contribution to global production is less than 2 percent.
Source: GLEAM.

Figure 22b.
Regional variation in GHG emission intensities for small ruminant meat[1]



[1] Excludes regions where contribution to global production is less than 2 percent.
Source: GLEAM.

to feed production is a significant source of emissions as a result of the deposition of manure during grazing (see Section 5.3 in Chapter 5). While CH_4 emissions from manure are negligible in most regions because manure is mainly managed in dry systems, in South Asia and East & Southeast Asia, CH_4 emissions from manure are slightly higher as a result of the higher temperatures in warmer climatic zones.

In most regions, N_2O from manure management is also negligible because a large proportion of the manure produced is deposited on pasture and these emissions are captured in feed production (in this analysis, manure deposited on pasture is considered as a fertilizer). However, NENA, sub-Saharan Africa, South Asia and East & Southeast Asia have relatively high N_2O emissions from manure because manure is not only deposited on pasture but also managed in other MMS such as drylot or solid systems which tend to have higher rates of conversion of N excreted to N_2O emissions.

Emissions of meat from small ruminants range from as low as 15 kg CO_2-eq/kg CW in Oceania to 31 kg CO_2-eq/kg CW in sub-Saharan Africa. Very little variation exists within the developing regions; emissions for East & Southeast Asia, Latin America, NENA and South Asia are 23.0, 25.5, 27.9 and 29 kg CO_2-eq/kg CW, respectively (Figure 22b). Contributions of different sources to emission intensity, differences among regions and the underlying reasons are very much the same as described above for milk.

Post farmgate emissions per kg carcass weight in Oceania are significant because of the importance of mutton and lamb exports from Australia and New Zealand. The two countries supply a major portion of global lamb and mutton exports, equivalent to 50 percent and 67 percent of their total production in 2005, respectively.

4.4 SUMMARY OF RESULTS

4.4.1 Comparison between ruminant species

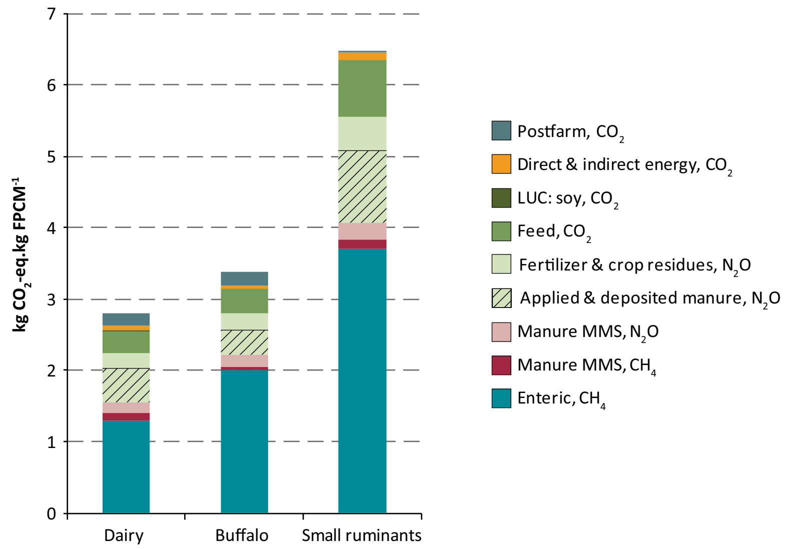
Despite the similarities in emission profiles, there are differences among cattle, buffalo and small ruminant species. The carbon footprint for milk from small ruminants is more than double that of milk from dairy cattle and buffalo: 6.5 kg CO_2-eq/kg FPCM vs. 2.8 and 3.4 kg CO_2-eq/kg FPCM, respectively (Figure 23a). With regard to meat from ruminants, small ruminant meat has a smaller carbon footprint compared with that of beef; 23.8 kg CO_2-eq/kg CW vs. 46.2 and 53.4 kg CO_2-eq/kg CW for beef and buffalo meat, respectively (Figure 23b).

Among the edible commodities produced by ruminant systems, milk generally has the lowest emission intensity compared to meat suggesting that dairy systems are more efficient than pure meat systems. This is because dairy herds produce both milk and meat while beef systems are maintained mainly for calf production.

The difference in emission intensity among ruminant species can be attributed to a number of factors such as:

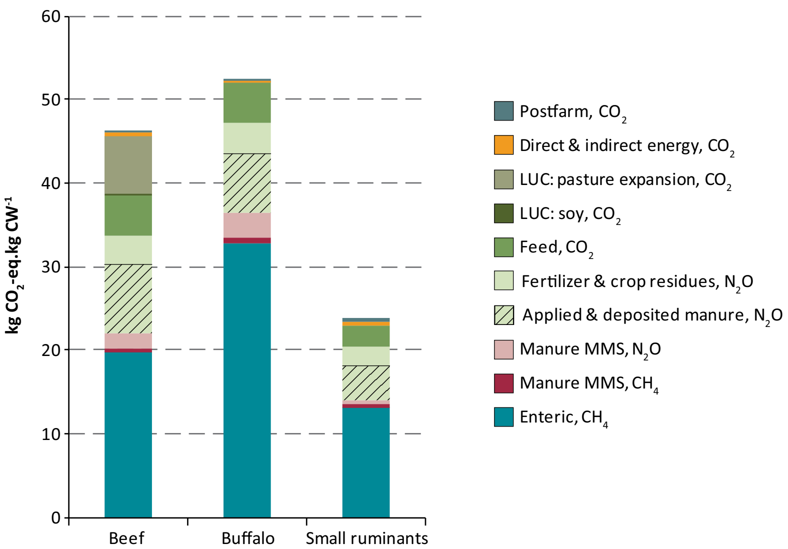
- Higher milk yields from dairy cattle and buffalo as opposed to small ruminants;
- Greater fecundity, and faster reproductive cycles and growth rates in small ruminants;
- Larger supporting breeding herds are required to sustain the production of beef; non-productive animals produce CH_4 and urinary-N without contributing to milk and meat production; and
- Whether LUC is associated with the production process.

Figure 23a.
Average emission intensity for milk from cattle, buffalo and small ruminants



Source: GLEAM.

Figure 23b.
Average emission intensity for meat from cattle, buffalo and small ruminants



Source: GLEAM.

This assessment also found a wide diversity in emission intensity at regional and production system level. These variations are largely driven by differences in production goals (specialized versus non-specialized production) and management practices, including animal husbandry methods, animal health and genetics which influence levels of productivity.

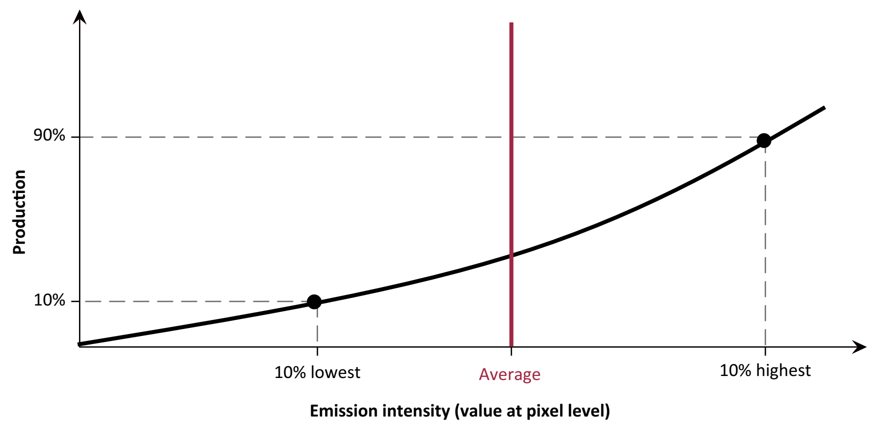
4.4.2 Emission intensity gap within systems, climatic zones and regions

The comparison of emission intensity for ruminant commodities produced within the same region and comparable production conditions (production systems and agro-ecological zones) shows the existence of a considerable emission intensity gap. Average emission intesities within each region for each combination of production system and climatic zone as well as the lowest and highest emission intesity of pixels accounting for 10 percent of the production in the same system-region-AEZ were assessed. Figure 24 is a schematic representation of the analytical approach used to assess the emission intensity gap within regions, production systems and climatic zones.

Tables 7-9 provide an illustration of this variation in emission intensity for cattle (dairy and beef), buffalo milk and small ruminants (milk and meat). The emission intensity gap is particularly substantial in dairy and beef production. For example, in mixed temperate dairy systems in sub-Saharan Africa, the average emission intesity is 7.6 kg CO_2-eq/kg FPCM, compared to 1.6 and 13.3 kg CO_2-eq/kg FPCM in lowest and higher 10 percent, respectively (Table 7).

Within the dairy mixed and grassland-based systems in sub-Saharan Africa, Latin America and the Caribbean, and East and Southeast Asia, the emission intensity of the lowest 10 percent is comparable to other regions with similar production conditions. This is explained by the dominance of high productive countries within these systems and climatic zones. For example, in sub-Saharan Africa, within the dairy mixed and grassland-arid zones, South Africa alone accounts for almost 25 percent

Figure 24.
Schematic representation of emission intensity gap, for a given commodity, within a region, climate zone and farming system



Source: Authors.

Table 7. Variation of cattle emission intensities within regions, systems and agro-ecological zone[1]

	Arid			Temperate			Humid		
	10% lowest	Average	10% highest	10% lowest	Average	10% highest	10% lowest	Average	10% highest
Mixed dairy									
N. America	1.7	1.9	2.0	1.3	1.5	1.7	1.5	1.7	1.9
Russian Fed	1.7	1.8	1.9	1.8	1.9	2.0	1.7	1.8	2.0
W. Europe	1.5	1.6	1.8	1.5	1.6	1.7	1.5	1.7	1.8
E. Europe	1.8	1.8	2.0	1.4	1.6	1.8	1.8	1.9	1.9
NENA	1.9	4.3	9.7	2.6	3.7	5.3	2.3	3.5	9.4
E & SE Asia	2.1	2.7	3.7	1.4	2.3	2.9	1.5	2.6	3.4
Oceania	1.7	1.8	1.9	1.0	1.0	1.8	NA	NA	NA
South Asia	4.0	5.2	6.8	3.4	4.5	6.5	4.1	6.8	8.0
LAC	1.4	3.1	4.9	1.4	3.0	5.0	1.7	4.0	5.4
SSA	1.7	10.0	17.2	1.7	7.6	13.3	5.5	9.7	17.3
Grassland dairy									
N. America	1.7	1.9	1.9	1.3	1.7	1.8	1.7	1.9	2.0
Russian Fed	1.7	1.8	1.8	1.8	1.9	2.0	NA	NA	NA
W. Europe	1.5	1.6	1.8	1.5	1.7	1.8	1.7	1.7	1.9
E. Europe	1.7	1.9	2.0	1.5	1.6	1.7	NA	NA	NA
NENA	1.4	5.9	10.6	2.7	3.2	4.1	10.0	10.1	10.2
E & SE Asia	1.6	1.8	2.0	1.6	2.5	7.3	2.4	7.7	10.1
Oceania	1.7	1.8	1.9	1.5	1.5	1.5	1.5	1.6	1.8
South Asia	2.9	3.8	5.2	2.7	4.1	5.5	3.8	4.1	4.2
LAC	1.7	3.1	6.0	1.8	3.6	5.5	2.2	4.8	6.3
SSA	1.8	9.6	16.6	1.7	3.1	5.6	6.3	10.8	18.9
Mixed beef									
N. America	28.4	32.0	36.1	26.0	28.5	30.3	26.9	28.6	30.5
W. Europe	13.6	19.9	23.0	12.9	17.3	21.9	20.2	24.1	25.7
E. Europe	11.1	12.0	12.7	12.3	13.9	16.3	11.2	11.9	12.6
NENA	17.5	28.4	35.7	16.7	20.4	25.5	18.1	24.4	34.0
E & SE Asia	36.9	46.9	61.3	33.1	43.0	54.0	40.1	54.5	81.0
Oceania	29.1	31.1	33.8	11.7	20.5	31.6	11.0	18.9	31.9
South Asia	25.3	73.0	110.5	20.4	46.8	77.6	58.8	103.0	168.1
LAC	36.5	42.9	48.5	37.4	46.6	59.0	38.2	46.8	53.9
SSA	44.2	75.0	106.6	27.4	56.0	73.0	32.9	59.7	95.3
Grassland beef									
N. America	24.2	31.2	36.6	27.4	29.9	32.9	27.7	28.7	30.1
W. Europe	14.1	20.4	23.0	18.7	21.7	24.7	23.9	23.9	25.6
E. Europe	11.6	12.4	13.2	12.0	12.9	14.6	NA	NA	NA
NENA	19.5	36.6	38.5	15.9	18.6	21.5	35.0	35.3	35.6
E & SE Asia	47.3	55.0	66.7	26.4	47.5	57.5	53.3	62.4	70.1
Oceania	28.9	30.5	33.2	10.3	17.4	29.4	11.2	25.2	31.9
South Asia	22.6	31.6	33.6	21.3	26.9	26.5	71.4	76.9	80.6
LAC	42.8	48.9	57.2	40.8	52.4	72.7	43.8	53.9	64.9
SSA	41.1	76.9	102.6	38.3	43.2	58.8	49.9	93.4	118.8

[1] Regions representing less than 2% of global production within systems are not included.
Note: The 'average' is calculated at regional-climatic zone level. "10% lowest" is the upper bound of lowest emission intensities up to 10% of production.
"10% highest" is the lower bound of highest emission intensities down to 90% of production.
NA: Not Applicable. Some regions may not have data for a combination of system and AEZ or production is insignificant within the system and AEZ.
Source: GLEAM.

Table 8. Variation of buffalo milk emission intensities within regions, systems and agro-ecological zone[1]

	Arid			Temperate			Humid		
	10% lowest	Average	10% highest	10% lowest	Average	10% highest	10% lowest	Average	10% highest
Mixed dairy									
NENA	2.8	3.4	4.8	2.8	3.6	4.3	3.3	3.3	4.0
E & SE Asia	2.6	4.0	5.8	3.7	5.2	6.6	4.2	5.2	6.2
South Asia	2.7	3.3	4.1	2.4	3.0	4.2	2.6	3.5	4.5
Grassland dairy									
NENA	2.7	4.3	5.0	3.5	3.6	3.8	NA	NA	NA
E & SE Asia	2.6	2.7	2.8	2.5	3.0	4.0	3.0	3.3	3.5
South Asia	2.7	3.0	3.3	2.4	2.7	2.9	2.5	2.7	2.8

[1] Regions representing less than 2% of global production within systems are not included.
Note: The 'average' is calculated at regional-climatic zone level. "10% lowest" is the upper bound of lowest emission intensities up to 10% of production. "10% highest" is the lower bound of highest emission intensities down to 90% of production.
NA: Not Applicable. Some regions may not have data for a combination of system and AEZ or production is insignificant within the system and AEZ.
Source: GLEAM.

of production in this regional-system-climatic zone with emission intensity ranging between 1.4 and 1.8 kg CO_2-eq/kg FPCM. Similarly, in mixed and grassland-based systems in temperate zones, South Africa contributes 20 and 70 percent of the regional production, respectively, with emission intensity ranging between 1.5 and 1.9 kg CO_2-eq/kg FPCM.

In Latin America and the Caribbean, milk production in Mexico in both grassland and mixed arid and temperate areas represents 30 percent of the production within these regional climatic zones and emission intensity ranges between 1.4 and 1.9 kg CO_2-eq/kg FPCM.

High milk productivity systems in countries such as Israel and Saudi Arabia within the arid zones result in low emission intensity (range between 1.2-1.5 kg CO_2-eq/kg FPCM for Israel and 1.1-2.0 kg CO_2-eq/kg FPCM for Saudi Arabia). About 23 percent of production within the mixed temperate dairy system in East and Southeast Asia occurs in Japan with a range of emission intensity 1.2 to 1.4 kg CO_2-eq/kg FPCM.

This variation highlights the heterogeneity within each production system and emphasizes the opportunities for reducing emission intensity particularly in low productive regions by bridging the gap in emission intensities between efficient producers and producers with a potential for improvement. This mitigation potential doesn't require changes in farming systems and can be based on already existing technologies and practices. It is estimated to 30% of the sector's total emissions and further explored in the overview report published in parallel to the current one (FAO, 2013a). This situation is completed by case study analysis to explore regional dimensions of mitigation in the sector.

Table 9. Variation of small ruminants emissions intensities within regions, system and agro-ecological zone[1]

	Arid			Temperate			Humid		
	10% lowest	Average	10% highest	10% lowest	Average	10% highest	10% lowest	Average	10% highest
Grassland dairy									
W. Europe	2.8	4.9	6.4	2.5	5.1	6.5	1.6	2.9	4.4
E. Europe	4.2	4.7	5.1	2.6	3.6	5.0	NA	NA	NA
NENA	5.7	11.2	14.2	4.1	5.4	6.6	8.0	9.5	10.7
E & SE Asia	6.3	6.9	7.9	9.0	11.3	13.5	3.4	5.7	11.8
South Asia	3.3	6.0	8.1	3.8	6.5	8.8	2.5	2.6	2.7
LAC	3.0	8.0	11.7	3.2	8.1	11.6	3.2	9.6	11.4
SSA	5.1	6.6	9.4	6.1	7.0	8.3	7.2	8.7	10.6
Mixed dairy									
W. Europe	3.1	4.7	6.4	2.3	4.7	7.6	3.5	5.3	8.4
E. Europe	4.5	4.8	5.2	2.9	4.4	5.2	4.3	4.9	5.2
NENA	4.6	9.3	13.1	3.6	5.9	7.9	3.7	7.8	9.8
E & SE Asia	3.0	5.6	7.5	5.4	9.3	11.4	6.0	7.5	9.8
South Asia	2.9	4.2	6.3	3.0	5.1	7.7	3.0	5.9	7.9
LAC	2.7	5.9	10.2	2.9	4.8	10.4	1.9	5.5	11.1
SSA	5.3	7.4	10.2	6.5	7.5	8.6	5.7	7.3	8.9
Grassland meat									
W. Europe	7.8	12.7	20.2	9.6	20.4	23.8	19.2	19.9	21.5
NENA	11.4	24.7	42.2	18.2	42.9	57.5	15.3	16.1	16.8
E & SE Asia	19.1	24.6	32.0	18.3	25.8	32.4	9.4	13.2	19.0
Oceania	13.4	14.9	16.7	13.2	14.1	14.5	14.0	14.7	15.3
South Asia	9.3	26.7	35.4	8.5	16.6	24.5	20.8	22.1	23.7
LAC	18.6	24.6	29.9	17.4	29.0	38.5	18.3	24.9	33.8
SSA	16.8	26.2	37.4	20.3	22.4	30.0	21.7	33.8	46.3
Mixed meat									
W. Europe	7.4	15.2	21.6	9.7	18.8	22.6	18.0	25.4	26.7
NENA	12.9	23.4	41.1	14.8	32.6	51.7	14.3	16.1	17.9
E & SE Asia	13.9	20.4	29.9	18.0	22.2	26.5	9.3	15.5	23.7
Oceania	13.4	14.3	15.6	13.6	13.9	15.0	13.9	14.6	15.2
South Asia	17.2	32.8	44.5	9.9	29.5	45.8	14.7	20.0	35.5
LAC	17.2	22.7	27.5	22.1	30.4	38.5	16.4	23.5	30.4
SSA	18.0	34.0	49.7	19.3	28.2	34.7	25.4	35.6	43.3

[1] Regions representing less than 2% of global production within systems are not included.
Note: The 'average' is calculated at regional-climatic zone level. "10% lowest" is the upper bound of lowest emission intensities up to 10% of production. "10% highest" is the lower bound of highest emission intensities down to 90% of production.
NA: Not Applicable. Some regions may not have data for a combination of system and AEZ or production is insignificant within the system and AEZ.
Source: GLEAM.