



AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

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10 **The significance of livestock as a contributor to global greenhouse gas emissions**
11 **today and in the near future**

12

13 F.P. O'Mara

14

15 Teagasc,

16 Irish Agriculture and Food Development Authority,

17 Head Office,

18 Oak Park,

19 Carlow,

20 Ireland

21

22 frank.omara@teagasc.ie

23 ph +353599183488

24 fax + 353599182097

25

26 **Abstract**

27 Animal agriculture is responsible for 8% to 10.8% of total global greenhouse gas
28 (GHG) emissions when assessed on the basis of IPCC accounting. When assessed on
29 the basis of a lifecycle analysis, the contribution of livestock is up to 18% of total
30 global emissions. Asia is the source of most enteric methane emissions with Latin
31 America, Africa, Western Europe and North America being significant sources also.
32 These emissions are dominated by emissions from the cattle herd. When emissions
33 are related to food production, the top four most efficient regions are Eastern and
34 Western Europe, North America, and the non-EU former Soviet Union (FSU) which
35 together produced 46.3% of ruminant meat and milk energy and only 25.5% of enteric
36 methane emissions in 2005. In comparison, the three least efficient producers (Asia,
37 Africa and Latin America) produced an equivalent amount (47.1%) of ruminant meat
38 and milk energy and almost three times (69%) as much enteric methane emissions in
39 2005. Livestock related emissions will increase as world population and food demand
40 increases. For instance, enteric methane emissions are projected to grow by over 30%
41 from 2000 to 2020. There are mitigation possibilities, but there is an imperative to
42 develop new technologies, or ways to implement existing technologies in a more cost
43 effective manner.

44

45 **Keywords**

46 Greenhouse gases, livestock, agriculture, food production, greenhouse gas mitigation

47

48 **Introduction**

49 Animal agriculture produces greenhouse gases (GHG) in the form of methane from
50 enteric fermentation, nitrous oxide from the use of nitrogenous fertilisers, and
51 methane and nitrous oxide from manure management and deposition of animal
52 manures at pasture. Some CO₂ is also produced on animal farms from fossil fuel and
53 energy usage.

54

55 This paper reviews several recent estimates of agriculture's contribution to global
56 GHG emissions, and specifically the contribution of animal agriculture. The regional
57 distribution of these emissions is examined, as is their relationship with food
58 production in different regions. Likely trends in future emissions from animal
59 agriculture are discussed and the possibilities for mitigation at a global level are
60 examined.

61

62 **Global emissions of greenhouse gas from agriculture and particularly animal** 63 **agriculture**

64 Several estimates of agriculture's contribution to global GHG emissions⁽¹⁾ have been
65 published recently, including some estimates that specifically relate to animal
66 agriculture. Denman et al. (2007) estimated non CO₂ GHG emissions from
67 agriculture to be 10% of total global emissions, while EPA (2006) estimated them to
68 be 12%. These estimates do not consider CO₂ emissions or removals due to
69 agriculture which are counted in the Intergovernmental Panel on Climate Change
70 (IPCC) GHG inventory sector Land use, land-use change and forestry. FAO (2006a)
71 estimated that animal agriculture contributes 18% of global emissions of GHG, while

¹ All references to greenhouse gas emissions in this paper refer to anthropogenic emissions.

72 FAO (2010) estimated that emissions from the global dairy sector were 4% of total
73 emissions.

74

75 It is worth considering these reports in more detail to help reconcile the various
76 estimates. Obviously the two Food and Agriculture Organisation (FAO) reports have
77 a narrower focus than Denman et al. (2007) or EPA (2006), and in particular the 2010
78 report is only focused on the dairy sector. Yet FAO (2006a) has a much higher
79 estimate for animal agriculture than the Denman et al. (2007) or EPA (2006) reports
80 for the whole agriculture sector. This is because the two FAO reports take a Life
81 Cycle Analysis approach, and include emissions from the production of inputs (such
82 as feed and fertiliser), transport, processing, and land use change including
83 deforestation to bring land into production for animal agriculture, whether as pastures
84 or in the production of animal feed. On the other hand, the other two reports
85 mentioned follow the sectoral approach of the IPCC which outlines five main sectors
86 for GHG emissions reporting: (i) energy, (ii) industry, (iii) waste, (iv) land use, land
87 use change and forestry (LULUCF) and (v) agriculture. This causes a significant
88 difference between FAO (2006a) and the other estimates.

89

90 Table 1 shows the livestock related GHG emission estimates from FAO (2006a), and
91 how these emissions would be counted by IPCC. Of the total livestock related
92 emissions of 7.1 billion tonnes of CO₂ equivalent, 4.26 billion tonnes or 60% would
93 be counted in the agriculture sector by IPCC. Most of the remainder is CO₂ emissions
94 from soils, deforestation, transport, processing, fertilizer production and on-farm
95 fossil fuel usage, with deforestation accounting for 85% of these emissions.

96

97 The livestock related emissions from FAO (2006a) that would be counted in the
98 agriculture sector by IPCC equal 10.8% of global emissions. According to FAO
99 (2006a), livestock constitute nearly 80% of agricultural emissions. Using this figure
100 to calculate livestock's contribution to the other global agriculture emissions estimates
101 gives estimates of 8% and 9.6% for Denman et al. (2007) and EPA (2006)
102 respectively. Thus when these three global estimates are put on an equivalent basis
103 (IPCC inventory system), the estimates of livestock's contribution to total global
104 GHG emissions range from 8 to 10.8%.

105

106 It is worth noting that FAO (2006a) used a figure of 40 billion tonnes for total global
107 GHG emissions, and livestock related emissions were 18% of this total. However, the
108 data source used for total emissions (CAIT, 2010) now estimates global total
109 emissions of 43.6 billion tonnes for 2005 (only CO₂, N₂O and CH₄ considered, and
110 international bunkers included). The livestock emissions calculated in the FAO
111 (2006a) report would be only 16% of this higher global total.

112

113 [Table 1 near here]

114

115 **Regional emissions of livestock related greenhouse gases**

116 Table 2 shows the regional distribution of the main ruminant farm animal species.

117 Cattle are the most numerous, and given their greater size relative to the other two

118 most populous species, sheep and goats, they are by far the greater contributor to

119 global enteric methane emissions. Of the 1.35 billion cattle in the world, 29.1% are in

120 Latin America, and 18.6% are in Africa. Asia has 28.6% of the world's cattle, with

121 India and China having huge cattle populations. North America has 8.2% of the

122 world's cattle population, while Western Europe has 6.8%, and Australia/New
123 Zealand has 2.8%. The vast majority of the world's 175 million buffaloes are in Asia,
124 with India and China having very large populations. Likewise, most of the world's
125 822 million goats are in Asia (52.9%), with Africa also having a very large proportion
126 (33.3%). The world's 1.09 billion sheep are more widely distributed with most
127 regions except North America and Eastern Europe having significant populations.

128

129 [Table 2 near here]

130

131 Greenhouse gas emissions from livestock can be expected to be closely related to
132 ruminant numbers, and particularly cattle numbers. However, factors other than
133 numbers will have an impact. The size and productivity of animals will affect their
134 dietary intake and enteric methane emissions. The system of manure storage and
135 handling (if any) will affect manure related emissions of methane and nitrous oxide.
136 Other species such as pigs and poultry will also contribute significantly to manure
137 related emissions. The extent of grazing, if any, will impact on the emissions of
138 nitrous oxide from manure deposition on pasture.

139

140 Table 3 shows estimates of regional emissions of methane from enteric fermentation
141 and manure management, and nitrous oxide from manure management and
142 agricultural soils. These data are sourced from a US EPA study (EPA, 2006) of
143 global non CO₂ GHG emissions. In that study, global emissions up to the year 2000
144 were based on actual data in national inventory reports where available, thereafter
145 emissions were projected for each country. The individual country data in that study
146 have been aggregated into a larger number of world regions than published in the

147 study. These data estimated total global emissions of enteric methane to be 1,929 Mt
148 CO₂ equivalent (CO₂e), or 91.9 Mt CH₄ in the year 2005 (a global warming potential
149 (GWP) of 21 was used for methane). This is slightly greater than the estimate in FAO
150 (2006a) of 85.63 Mt CH₄ which was for 2004. Asia is the source of most enteric
151 methane emissions, with one third of global emissions coming from this continent,
152 and China and India being the dominant countries (Table 3). FAO (2006a) estimated
153 India to have greater emissions than China, whereas EPA (2006) estimated the
154 reverse. The FAO (2006a) report carried out its own calculations whereas the EPA
155 (2006) report was based on national inventory reports to a large extent. Other world
156 regions with large shares of global enteric methane emissions are Latin America
157 (23.9%), Africa (14.5%), Western Europe (8.3%) and North America (7.1%). The
158 breakdown of global enteric methane emissions by animal species is reported by FAO
159 (2006a), and reproduced in Figure 1. As expected, it is dominated by emissions from
160 the cattle herd.

161

162 [Table 3 near here]

163

164 Global greenhouse gas emissions from manure management total 446 million tonnes
165 of CO₂e, with 53% of this being methane and 47% nitrous oxide (Table 3). Asia,
166 particularly China, Western Europe and North America are the regions with the
167 greatest GHG emissions from manure management. This global estimate of methane
168 emissions from this source is significantly lower than the estimate of FAO (2006a),
169 which is 368 million tonnes of CO₂e using a GWP of 21. FAO (2006a) does not give
170 a separate estimate of nitrous oxide emissions from manure management. The
171 breakdown of methane emissions from manure management by animal species

172 according to FAO (2006a) is shown in Figure 2. In contrast to enteric methane
173 emissions, over half the total emissions from this source come from monogastrics,
174 with pigs by far the dominant species.

175

176 Table 3 also shows emissions of nitrous oxide from agricultural soils. This includes
177 emissions that result from spreading of stored manures, direct deposition of urine on
178 pastures, and emissions resulting from application of nitrogen fertilizer to agricultural
179 soils. Not all this latter category relates to livestock production, as much of the
180 nitrogen fertilizer used in the world is used for crop production. It is not possible
181 from EPA (2006) to distinguish between these sources. According to FAO (2006a),
182 the regions with the greatest emissions of nitrous oxide related to storage, spreading
183 and direct deposition of animal excreta are Asia, Central and South America, Sub-
184 Saharan Africa, Western Europe, North America, and Eastern Europe and
185 Commonwealth of Independent States.

186

187 Methane and nitrous oxide are direct emissions related to animal agriculture. As FAO
188 (2006a) outlined, there are also other emissions associated with livestock production.
189 These include emissions associated with fertiliser manufacture, fossil fuel usage,
190 transport and processing of agricultural products, but the main source of additional
191 emissions is deforestation. Overall, UNFCCC (2008) reported that emissions from
192 deforestation are greater than total agricultural emissions. Not all deforestation relates
193 to bringing land into agriculture for livestock production, but FAO (2006a) estimated
194 deforestation was responsible for 34% of global emissions from the livestock sector,
195 calculated using a lifecycle analysis approach. This includes cleared land sown to

196 pasture for grazing, and croplands where the crops (or their by-products) are used for
197 animal feeding.

198

199 **Livestock related greenhouse gas emissions in relation to food production**

200 The main livestock derived products are food: meat, milk and eggs. Global
201 production of these commodities from the main livestock species are shown in Tables
202 4 and 5. In addition, livestock provide other goods and services such as hides and
203 wool, draught power, fuel and social goods. These are not quantified here, but
204 represent a very significant contribution from livestock, particularly in some regions
205 of the world.

206

207 Global production of meat was 244.7 million tonnes in 2005, of which 30.8% is
208 ruminant meat, mainly beef. Ruminant meat production was greatest in Asia, Latin
209 America, North America and Western Europe. Pig meat is the meat produced in the
210 highest quantity in the world, and is concentrated in China, Western Europe and North
211 America. Chicken meat production is higher than global beef production, and is
212 distributed across all regions of the world.

213

214 [Table 4 near here]

215

216 World milk production is dominated by cow's milk, which makes up 84% of total
217 milk production. Cow's milk production is concentrated in Western Europe, the
218 Americas, and the non EU former Soviet Union. Egg production is distributed
219 throughout the world, and is greatest in Asia (particularly China), the Americas, and
220 Western Europe.

221

222 [Table 5 near here]

223

224 The quantities of animal products cannot be compared simply by weight. Dry matter
225 content will vary, especially between milk, eggs and meat. Comparisons could be
226 made on the basis of economic value, or protein content (as recently used in FAO,
227 2010), but in this analysis, the energy content of the commodities are used to put them
228 all in a common currency. Milk, meat and egg production were converted to energy
229 values using energy values for whole milk, eggs and whole dressed carcasses from
230 McCance and Widdowson (1978), as outlined in Table 6. The resulting energy
231 corrected output of meat and milk and eggs are shown in Tables 7 and 9. The
232 regional distribution of these follows the same trend as outlined above for the
233 commodities.

234

235 [Table 6 near here]

236

237 [Table 7 near here]

238

239 [Table 8 near here]

240

241 Total energy from ruminant milk and meat production was compared with total
242 greenhouse gas emissions from enteric fermentation in Figure 3. This is not a
243 completely satisfactory index of ruminant emissions, as manure related emissions and
244 emissions of nitrous oxide from soils are not included. Neither are upstream or
245 downstream emissions of related emissions from deforestation. Nevertheless, it does

246 provide a reasonable assessment of regional emissions from ruminants. Where the bar
247 for milk and ruminant meat energy production is higher than the bar for enteric
248 methane emissions (both as a percentage of global totals), this indicates that a region
249 is efficient at producing milk and meat, i.e. the higher the ratio between the
250 percentage of global totals, the more efficient production is. The top four most
251 efficient regions are Eastern and Western Europe, North America, and the non-EU
252 FSU. Together, these produced 46.3% of ruminant meat and milk energy and only
253 25.5% of enteric methane emissions in 2005. In comparison, the three least efficient
254 producers (Asia including China and India, Africa and Latin America) produced an
255 equivalent amount (47.1%) of ruminant meat and milk energy and almost three times
256 (69%) as much enteric methane emissions in 2005. In both India and Australia/New
257 Zealand, the share of global energy from ruminant milk and meat production was
258 similar to methane emissions from enteric fermentation: 11.4 and 11.1% respectively
259 for India and 4.4 and 4.2% respectively for Australia/New Zealand. There are of
260 course very significant inter-regional differences between individual countries which
261 are not discussed here.

262

263 In Figure 4, total energy from meat and milk production was compared with total
264 greenhouse gas emissions from enteric fermentation, manure management and
265 agricultural soils. The trends are much the same as in Figure 3, although the
266 differences between regions have narrowed somewhat. The improvement in the
267 position of China when total energy from milk and meat production is considered
268 (Figure 4) compared to when only ruminant meat and milk was considered (Figure 3)
269 is noteworthy. This is due to the very large pigmeat production in China which
270 increased total food energy production significantly but which did not contribute

271 much GHG to the categories considered in Figure 4. It should be noted that the
272 emissions considered in both Figures 3 and 4 do not include emissions associated with
273 land-use change which are particularly relevant for grain-fed meat and milk
274 production.

275

276 **Future trends in livestock related emissions**

277 In a business as usual scenario, emissions from livestock and agriculture in general
278 are expected to grow, as food productions expands to keep pace with a growing world
279 population. World population is expected to reach 8.3 billion by 2030 and 9.1 billion
280 by 2050 (UN, 2008), with most of this growth projected to occur in Asia and Africa.
281 Greenhouse gas emissions projections are subject to uncertainty in the amount and
282 composition of the diet of this expanding population. In particular, the amount of
283 meat consumption is dependent on living standards, particularly in countries of Asia
284 where the population is expanding rapidly and living standards are rising. FAO
285 (2006b) projected demand for all food commodities (crop and livestock based) will
286 rise by 1.5% per annum to 2030, and by 0.9% per annum thereafter to 2050. By 2030,
287 food demand would have risen by 56% compared to 2000, and by 2050, the increase
288 would be 86%, according to these growth rates. Bovine meat production is expected
289 to have a higher growth rate in the period 2000 – 2030 (1.3% p.a.) than it had in the
290 nineties (0.7% p.a.). Production of milk and dairy produce is expected to expand by
291 1.4% p.a. in the period 2000 - 2030, up from 1.1% p.a. in the nineties. Figure 5 shows
292 projections for growth in production of bovine and ovine meat, and milk to 2050,
293 using production growth projections from FAO (2006b). These projections are for
294 increases of 72%, 110% and 82% in bovine meat, ovine meat and milk production,
295 respectively, by 2050 compared with 2000. The increase in ovine meat is large but is

296 from a small base (Table 4) and is projected to be higher in developing countries. In
297 the absence of mitigation, these increases in milk and meat production are likely to
298 lead to large increases in related greenhouse gas emissions.

299

300 In the absence of mitigation, agricultural emissions were projected to rise from 5.6 (in
301 2005) to 8.2 billion tonnes of CO_{2e} in 2030 by the IPCC Fourth Assessment Report
302 (Smith et al., 2007). This was based on emissions in 2020 forecast by EPA (2006)
303 and projecting these forward to 2030. Figure 6 uses data from EPA (2006) to show
304 emission projections to 2020. These projections were built up country by country
305 from National Inventory Reports. The greatest growth is in enteric methane emissions,
306 which are projected to grow by over 30% from 2000 to 2020. The smaller manure
307 sources are also projected to grow over this period: nitrous oxide by 29% and methane
308 by 20%. FAO (2003) projected that global emissions of methane from enteric
309 fermentation and manure management would rise by 60% by 2030 compared with the
310 base period (1997-99), and nitrous oxide emissions from agriculture would rise by
311 50% over this period. The higher emissions projections compared with EPA (2006)
312 can be at least partly attributed to the longer period.

313

314 Emissions may not rise on a pro rata basis in line with the projected increases in food
315 production outlined above. It is anticipated that most of the increased food production
316 will be met from farms with greater intensity of production than current farms (FAO,
317 2003), which will permit a reduction in the emissions per kg of product (Lovett et al.,
318 2006; FAO, 2010). On the other hand, the extra emissions associated with
319 deforestation to bring extra land into production either for pastures, for production of
320 animal feed, or where livestock are fed by-products from crop production could

321 greatly increase emissions associated with livestock production from these regions
322 (FAO, 2006a). It has been estimated that deforestation accounted for over 30% of
323 total emissions associated with livestock production in 2005 (FAO, 2006a).

324

325 **Mitigation possibility on a global scale**

326 The mitigation potential for agricultural emissions to 2030 has recently been
327 comprehensively assessed in the IPCC Fourth Assessment Report (Smith et al., 2007).

328 This report showed a significant technical mitigation potential for agricultural
329 emissions of 5,500 – 6,000 Mt CO₂e/yr by 2030 (in comparison to total projected
330 emissions in 2030 of 8,200 Mt CO₂e/yr). Most of this is related to soil carbon
331 sequestration, which was estimated to contribute 89% of the technical mitigation
332 potential. The technical mitigation potential for methane (both enteric fermentation,
333 manure management, and rice management) was only 9% of the total, or
334 approximately 500 Mt CO₂e/yr. Less than half of this was related to enteric
335 fermentation.

336

337 The mitigation potential for enteric methane emissions was considered under three
338 broad headings: improved feeding practices (includes replacing roughage with
339 concentrate, improving forages/inclusion of legumes and feeding extra dietary oil),
340 specific agents and dietary additives (includes bovine somatotrophin, growth
341 hormones, ionophores and propionate precursors), and longer term structural and
342 management changes and animal breeding. The highest proportional reductions were
343 from improved feeding practices, particularly with dairy cows, where the technical
344 mitigation potential was 22% from improved feeding practices in the Oceania region.
345 The regions which had the highest mitigation potential were developed regions of

346 Europe, North America, Japan and Oceania. However, many of the technical
347 mitigation options have cost implications for producers, and thus the actual potential
348 is lower than the technical potential, and will depend on the price that would be paid
349 per tonne of CO₂e mitigated. At a price of \$20 per tonne of CO₂e, the mitigation
350 potential for enteric methane was reduced to less than 150 Mt CO₂e/yr. Manure
351 management mitigation potential was very low, and while there was significant
352 technical potential to reduce emissions due to improved grazing land management (c.
353 800 Mt CO₂e/yr), this is mostly related to increased soil carbon, and has significant
354 costs. At a price of \$20 per tonne of CO₂e, the mitigation potential for improved
355 grazing land management was reduced to less than 200 Mt CO₂e/yr.

356

357 In summary, while there is significant technical mitigation potential for livestock
358 related emissions, the cost of implementing the measures will reduce this potential
359 significantly. This is with currently available technologies, which outlines the need to
360 develop new technologies, or ways to implement existing technologies in a more cost
361 effective manner.

362

363 **Conclusions**

364 Livestock production is a significant source of greenhouse gases, which will increase
365 over the next 40 years as a consequence of increased food production unless there is
366 major progress in mitigation technologies. There is significant regional variation in
367 the efficiency of food production from a greenhouse gas perspective, but it must also
368 be considered that livestock contribute significant non-food goods in many less
369 developed regions. There are mitigation possibilities with currently available
370 technologies, but they are limited, and there are cost implications which will limit

371 their implementation. This highlights the need to develop new technologies, or ways
372 to implement existing technologies in a more cost effective manner.

373

374

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378 **References**

- 379 CAIT, 2010. Climate Analysis Indicator Tool. World Research Institute. Available
380 at <http://cait.wri.org/>, accessed on 23 June 2010.
- 381 Denman, K.L., Brasseur, G., Chidthaisong, A., Ciais, P., Cox, P.M., Dickinson, R.E.,
382 Hauglustaine, D., Heinze, C., Holland, E., Jacob, D., Lohmann, U.,
383 Ramachandran, S., da Silva Dias, P.L., Wofsy, S.C. and Zhang, X., 2007.
384 Couplings Between Changes in the Climate System and Biogeochemistry. In:
385 Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B.,
386 Tignor, M. and Miller, H.L. (Eds.), *Climate Change 2007: The Physical Science*
387 *Basis. Contribution of Working Group I to the Fourth Assessment Report of the*
388 *Intergovernmental Panel on Climate Change*, Cambridge University Press,
389 Cambridge, United Kingdom and New York, NY, USA, pp 499-587.
- 390 EPA, 2006. *Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990-2020*.
391 United States Environmental Protection Agency, EPA 430-R-06-003, June 2006.
392 Washington, D.C., < <http://www.epa.gov/nonco2/econ-inv/dow>.
- 393 FAO, 2003. *World Agriculture: Towards 2015/2030. An FAO Perspective*. FAO,
394 Rome.
- 395 FAO, 2006a. *Livestock's Long Shadow: Environmental Issues and Options*. Rome: Food
396 and Agricultural Organization.
- 397 FAO, 2006b. *World agriculture: towards 2030/2050*. Food and Agriculture Organization,
398 Rome.
- 399 FAO, 2010. *Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle*
400 *Assessment*. Food and Agriculture Organization, Rome.
- 401 FAOSTAT, 2010. FAO Statistical Database. From Food and Agricultural
402 Organization: <http://faostat.fao.org/site/339/default.aspx>, accessed 27 June 2010.

403 Lovett, D.K., Shalloo, L., Dillon, P. and O'Mara, F.P., 2006. A systems approach to
404 quantify greenhouse gas fluxes from pastoral dairy production as affected by
405 management regime. *Agric. Sys.*, 88, 156-179.

406 Sen, A.R., Santra, A., and Karim, S.A., 2004. Carcass yield, composition and meat
407 quality attributes of sheep and goat under semiarid conditions. *Meat Sci.*, 66, 757-
408 763.

409

410 Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle,
411 S., O'Mara, F., Rice, C., Scholes, B., and Sirotenko, O., 2007. Agriculture, in B.
412 Metz, Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A. (Eds), *Climate*
413 *Change 2007: Mitigation. Contribution of Working Group III to the Fourth*
414 *Assessment Report of the Intergovernmental Panel on Climate Change,*
415 *Cambridge University Press, Cambridge, United Kingdom and New York, NY,*
416 *USA, pp 497-540.*

417 UN, 2008. *World Population Prospects: The 2008 Revision.* <http://esa.un.org/unpp>,
418 accessed 10 July 2010.

419 UNFCCC, 2008. Challenges and opportunities for mitigation in the agricultural
420 sector. Technical paper. United National Framework Convention on Climate
421 Change.

422

Table 1. Livestock related GHG emission estimates from FAO (2006a) allocated to IPCC emission source category

	IPCC Agriculture sector	IPCC Other sectors
CO₂		
N fertiliser production		0.04
On farm fossil fuel, feed		0.06
On farm fossil fuel, livestock related		0.03
Deforestation		2.4
Cultivated soils, tillage		0.02
Cultivated soils, liming		0.01
Desertification of pasture		0.1
Processing		0.075
Transport		0.001
CH₄		
Enteric fermentation	1.8	
Manure management	0.37	
N₂O		
N fertilizer application	0.1	
Indirect fertilizer emission		0.1
Leguminous feed cropping	0.2	
Manure management	0.33	
Manure application/deposition	0.84	
Indirect manure emission	0.62	
Total	4.26	2.836

424 All figures in billion tonnes of CO₂e

425

426

427 Table 2. Regional distribution of the global populations (000 head) of cattle,
428 buffaloes, sheep and goats for the year 2005

	Cattle	Buffaloes	Goats	sheep
Africa	251,513	3,898	273,478	274,925
Latin America	392,769	1,180	34,899	82,892
North America	110,364	0	2,745	7,113
Non EU former				
Soviet Union	54,153	383	10,464	65,472
Eastern Europe	14,653	38	2,996	17,832
Western Europe	92,304	315	19,042	128,322
India	180,837	98,875	124,906	62,854
China	90,134	22,365	152,134	152,035
Asia (excl. China and India)	113,206	46,675	158,025	60,084
Australia/New Zealand	37,293	0	616	141,005
Middle East	13,346	798	42,590	97,878
World	1,350,571	174,526	821,895	1,090,410

429 Source: FAOSTAT (2010)

430

431

432 Table 3. Regional emissions of major agricultural greenhouse gases (million tonnes
433 of CO₂e)

	Enteric fermentation (methane)	Manure (methane)	Manure (nitrous oxide)	Soils (nitrous oxide)
Africa	280	14	6	361
Latin America	460	17	11	394
North America	136	43	22	300
Non EU former Soviet Union	97	12	28	76
Eastern Europe	28	7	12	43
Western Europe	160	69	26	257
India	218	23	0	58
China	259	22	69	536
Asia (excl. China and India)	175	24	35	192
Australia/New Zealand	88	3	1	32
Middle East	27.3	1.6	0.7	50.7
World	1,929	235	211	2,299

434 Source: EPA (2006) data reworked by author

435
436

Table 4. Global production of meat (000 tonnes) by world region in 2005

	Cattle meat	Buffalo meat	Sheep meat	Goat meat	Chicken meat	Pig meat	Total ruminant meat	Total meat
Africa	4,601	270	1,205	1,073	3,276	820	7,149	11,245
Latin America North America	16,527	0	305	126	15,737	5,695	16,958	38,390
Non EU former Soviet Union	12,707	0	103	0.001	16,869	11,303	12,810	40,982
Eastern Europe	3,866	0	535	46	2,128	2,650	4,447	9,225
Western Europe	930	0.2	117	20	1,868	4,089	1,067	7,024
India	7,935	8	1,299	132	7,827	18,717	9,374	35,918
China	1,334	1,501	234	527	1,900	497	3,596	5,993
Asia (excl. China and India)	5,357	345	1,800	1,704	9,964	46,622	9,207	65,793
Australia/New Zealand	2,786	1,025	387	806	7,052	8,074	5,004	20,130
Middle East	2,814	0	1,138	23	917	441	3,974	5,332
World	720	22	766	233	2,912	20	1,740	4,672
	59,576	3,172	7,888	4,691	70,451	98,927	75,327	244,705

437 Source: FAOSTAT (2010)

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Table 5. Global production of whole fresh milk (000 tonnes) and eggs (million) by region in 2005

	Cow milk	Buffalo milk	Sheep milk	Goat milk	Total whole milk	Hen eggs, in shell (Number)
Africa	23,861	2,300	1,632	3,181	30,974	46,340
Latin America	68,060	0	36	539	68,635	112,163
North America	88,062	0	0	0	88,062	96,945
Non EU former Soviet Union	65,786	0	202	745	66,733	61,046
Eastern Europe	28,467	7	829	267	29,571	27,954
Western Europe	140,852	253	2,890	2,063	146,058	103,328
India	39,759	52,070		3,790	95,619	46,231
China	27,837	2,800	1,115	256	32,008	420,951
Asia (excl. China and India)	25,111	21,045	363	2,889	49,408	122,134
Australia/New Zealand	24,765	0	0	0	24,765	3,341
Middle East	10,787	414	1,686	828	13,715	26,024
World	543,347	78,889	8,753	14,559	645,548	1,066,457

443 Source: FAOSTAT (2010)
444

445 Table 6. Energy value of foods

	kJ per 100g
Beef, dressed carcass raw	1,168
Lamb, dressed carcass raw	1,377
Goat carcass	Assume 0.8 that of lamb carcass ¹
Buffalo	Assume same as beef
Pork, dressed carcass raw	1,397
Chicken, raw meat	508
Cow's milk, whole	272
Buffalo milk, whole	Assume same as cow's milk
Goat milk, whole	296
Sheep milk, whole	388
Eggs, whole raw	612

446 Source: McCance and Widdowson (1978)

447 ¹ based on carcass composition of sheep and goats in Sen et al. (2004)

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Table 7. Global meat energy production (million MJ) by world region in 2005

	Cattle meat	Buffalo meat	Sheep meat	Goat meat	Chicken meat	Pig meat	Total ruminant meat	Total meat
Africa	53,744	3,154	16,599	11,815	16,640	11,450	85,313	113,402
Latin America	193,031	0	4,197	1,393	79,945	79,559	198,621	358,126
North America	148,422	0	1,414	0	85,695	157,900	149,837	393,432
Non EU former Soviet Union	45,153	0	7,366	510	10,812	37,022	53,029	100,862
Eastern Europe	10,864	3	1,607	221	9,487	57,125	12,695	79,307
Western Europe	92,678	91	17,889	1,459	39,763	261,470	112,117	413,350
India	15,579	17,530	3,222	5,805	9,652	6,943	42,137	58,732
China	62,571	4,035	24,786	18,775	50,620	651,308	110,167	812,095
Asia (excl. China and India)	32,536	11,978	5,326	8,878	35,826	112,798	58,717	207,341
Australia/New Zealand	32,864	0	15,670	250	4,658	6,161	48,785	59,604
Middle East	8,406	255	10,546	2,564	14,792	276	21,771	36,839
World	695,849	37,046	108,623	51,671	357,890	1,382,012	893,189	2,633,091

451 Source: FAOSTAT (2010) and author calculations

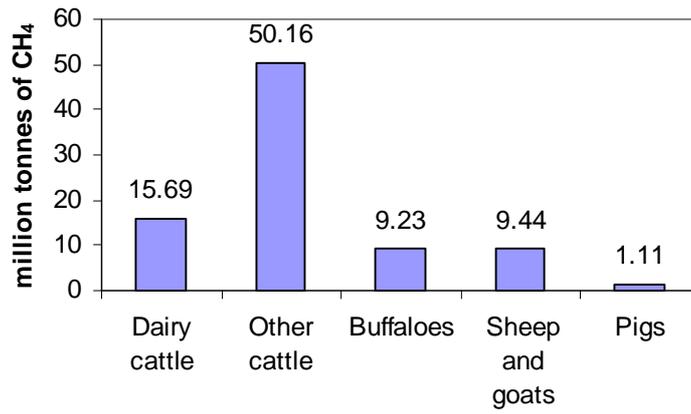
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454 Table 8. Global milk and egg¹ energy production (million MJ) by region in 2005

	Cow milk	Buffalo milk	Sheep milk	Goat milk	Total whole milk	Hen eggs, in shell
Africa	64,901	6,256	6,332	9,417	86,906	14,180
Latin America	185,122	0	138	1,597	186,857	34,322
North America	239,528	0	0	0	239,528	29,665
Non EU former Soviet Union	178,939	0	782	2,206	181,927	18,680
Eastern Europe	77,431	19	3,217	791	81,458	8,554
Western Europe	383,116	689	11,213	6,106	401,125	31,618
India	108,144	141,630	0	11,218	260,993	14,147
China	75,718	7,616	4,326	758	88,418	128,811
Asia (excl. China and India)	68,302	57,241	1,410	8,553	135,506	37,373
Australia/New Zealand	67,361	0	0	0	67,361	1,022
Middle East	29,341	1,126	6,542	2,450	39,459	7,963
World	1,477,903	214,578	33,961	43,095	1,769,538	326,336

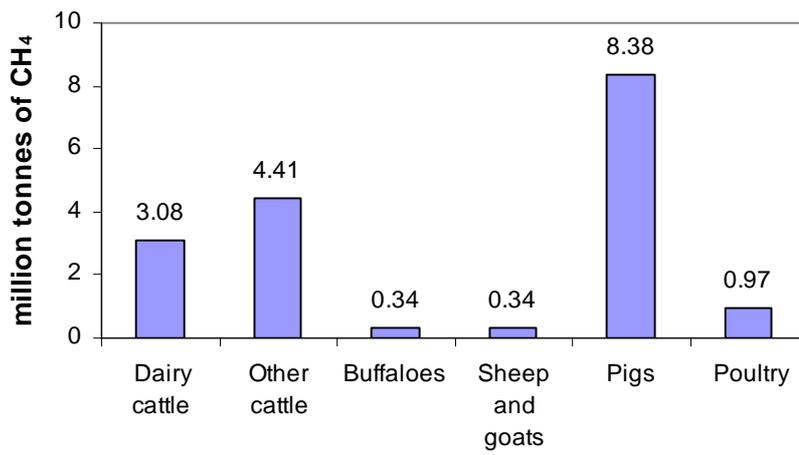
455 Source: FAOSTAT (2010) and author calculations

456 ¹Average weight of egg without shell assumed to equal 50g



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458 Figure 1. Global emissions of methane from enteric fermentation by animal type in
459 2004 (drawn from data in FAO, 2006a)
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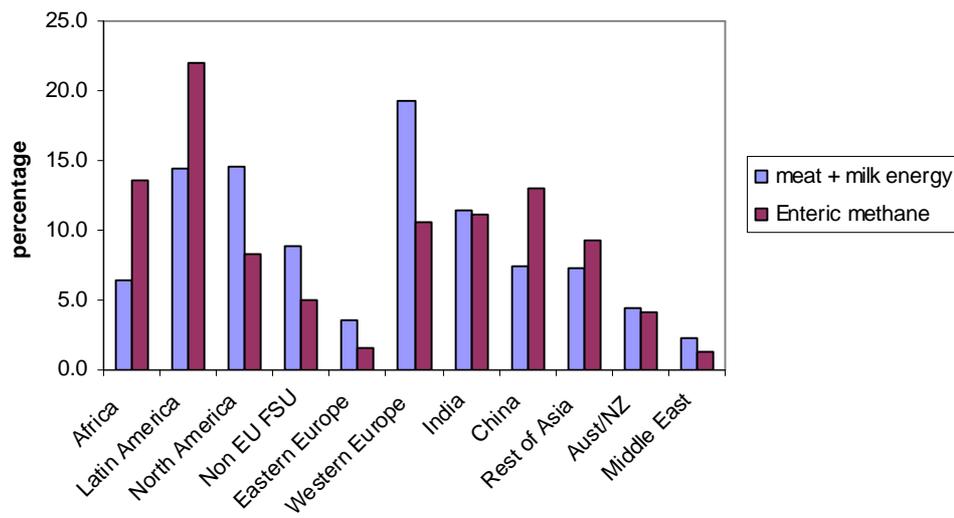
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Figure 2. Global emissions of methane from manure management by animal type in 2004 (drawn from data in FAO, 2006a)

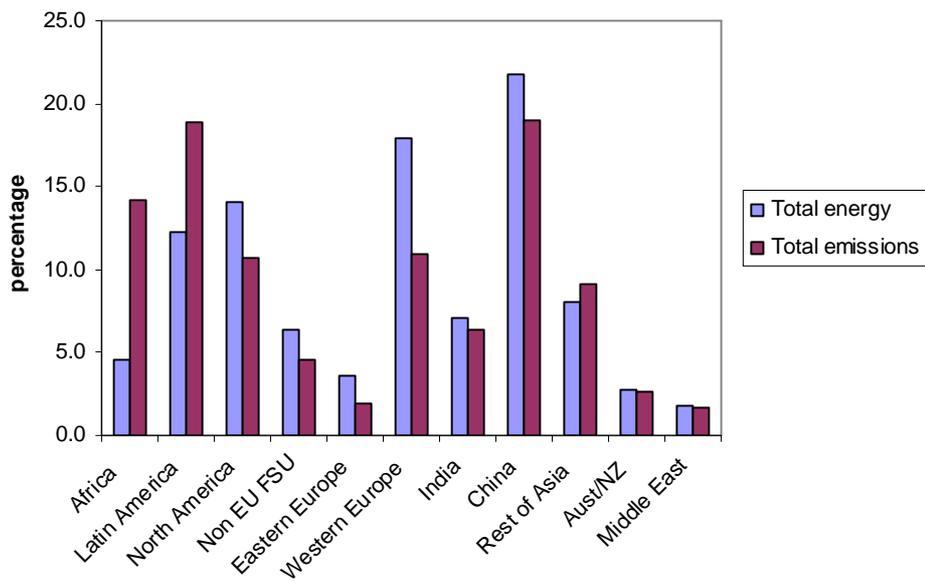
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Figure 3. Relative contribution of world regions to milk and ruminant meat energy production and methane emissions from enteric fermentation

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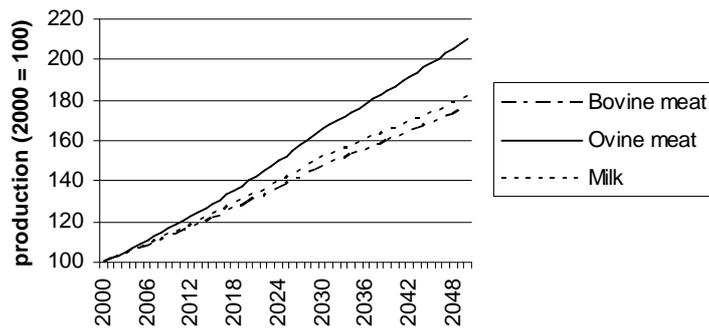
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Figure 4. Relative contribution of world regions to milk and meat energy production and greenhouse emissions from enteric fermentation, manure management and agricultural soils

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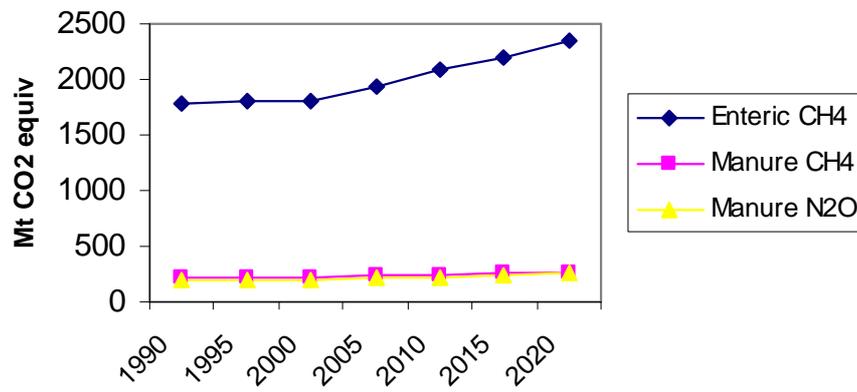
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479 Figure 5. Projected growth of global milk and meat production to 2050 using
480 production growth projections from FAO (2006b)

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Figure 6. Global growth in GHG emissions from livestock sources to 2000 and projections to 2020 (drawn from data in EPA, 2006)