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Appendices

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APPENDIX A

Overview of the Global Livestock Environmental Assessment Model (GLEAM)

1. INTRODUCTION

The Global Livestock Environmental Assessment Model (GLEAM) is a static model that simulates processes within the livestock production systems in order to assess their environmental performance. The current version of the model (V1.0) focuses primarily on the quantification of GHG emissions, but future versions will include other processes and flows for the assessment of other environmental impacts, such as those related to water, nutrients and land use.

The model differentiates the 11 main livestock commodities at global scale, which are: meat and milk from cattle, sheep, goats and buffalo; meat from pigs; and meat and eggs from chickens. It calculates the GHG emissions and commodity production for a given production system within a defined spatial area, thereby enabling the calculation of the emission intensity of combinations of commodities, farming systems and locations at different spatial scales.

The main purpose of this appendix is to explain the way in which GLEAM calculates the emission intensity of livestock products. The input data used in GLEAM (and associated issues of data quality and management) are addressed in Appendix B. The focus of this appendix is on:

- providing an overview of the main stages of the calculations;
- outlining the formulae used;
- explaining some of the key assumptions and methodological choices made.

2. MODEL OVERVIEW

The model is GIS-based and consists of:

- input data layers;
- routines written in Python (http://www.python.org/) that calculate intermediate and output parameters;
- procedures for running the model, checking calculations and extracting output.

The spatial unit used in the GIS for GLEAM is the 0.05 x 0.05 decimal degree cell. The emissions and production are calculated for each cell using input data of varying levels of spatial resolution (see Table B1). The overall structure of GLEAM is shown in Figure A1, and the purpose of each module summarized below.

- The **herd module** starts with the total number of animals of a given species and system within a cell (see Appendix B for a brief description of the way in which the total animal numbers are determined). The module also determines the herd structure (i.e. the number of animals in each cohort, and the rate at which animals move between cohorts) and the characteristics of the average animal in each cohort (e.g. weight and growth rate).

- The **manure module** calculates the rate at which excreted N is applied to crops.
- The **feed module** calculates key feed parameters, i.e. the nutritional content and emissions per kg of the feed ration.
- The **system module** calculates each animal cohort's energy requirement, and the total amount of meat and eggs produced in the cell each year. It also calculates the total annual emissions arising from manure management, enteric fermentation and feed production.
- The **allocation** module combines the emissions from the system module with the emissions calculated outside GLEAM, i.e. emissions arising from (a) direct on-farm energy use; (b) the construction of farm buildings and manufacture of equipment; and (c) post farm transport and processing. The total emissions are then allocated to the meat and eggs and the emission intensity per unit of commodity calculated. Each of the stages in the model is described in more detail below.

3. HERD MODULE

The functions of the herd module are:

- to calculate the herd structure, i.e. the proportion of animals in each cohort, and the rate at which animals move between cohorts;
- to calculate the characteristics of the animals in each cohort, i.e. the average weight and growth rate of adult females and adult males.

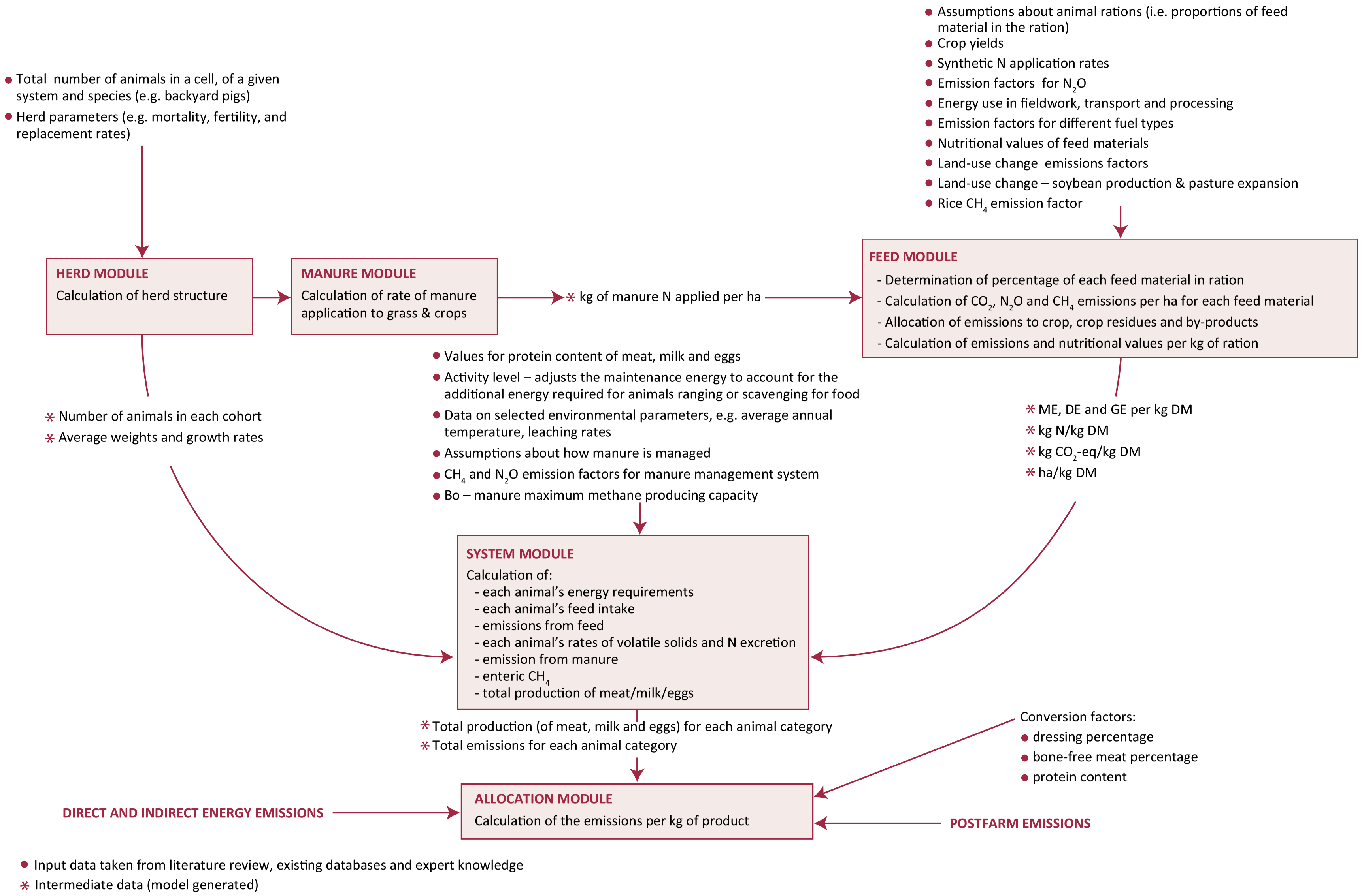
Emissions from livestock vary depending on animal type, weight, phase of production (e.g. whether lactating or pregnant) and feeding situation. Accounting for these variations in a population is important if emissions are to be accurately characterized. The use of the IPCC (2006) Tier 2 methodology requires the animal population to be categorized into distinct cohorts. Data on animal herd structure is generally not available at the national level. Consequently, a specific herd module was developed to decompose the herd into cohorts. The herd module characterizes the livestock population by cohort, defining the herd structure, dynamics and production.

Herd structure. The national herd is disaggregated into six cohorts of distinct animal classes: adult female and adult male, replacement female and replacement male, and male and female surplus or fattening animals which are not required for maintaining the herd and are kept for production only. Figure A2 provides an example of a herd structure (in this case for pigs).

The key production parameters required for herd modelling are data on *mortality, fertility, growth and replacement rates,* also known as rate parameters. In addition, other parameters are used to define the herd structure. They include:

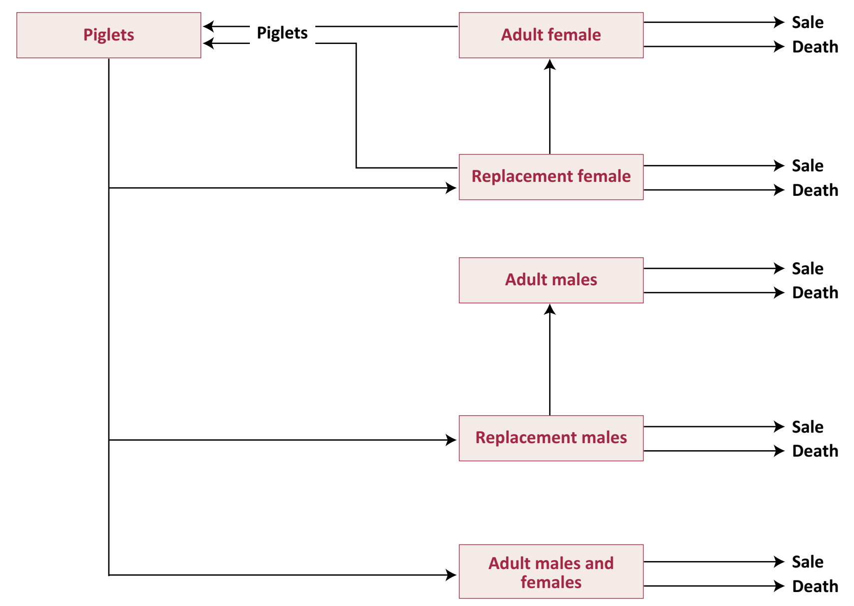
- the age or weight at which animals transfer between categories e.g. the age at first parturition for replacement females or the weight at slaughter for fattening animals;
- duration of key periods i.e. gestation, lactation, time between servicing, periods when housing is empty for cleaning (for all-in all-out broiler systems), moulting periods;
- ratio of breeding females to males.

Figure A1.
Schematic representation of GLEAM



Source: GLEAM.

Figure A2.
Structure of herd dynamics for pigs



Source: GLEAM.

4. MANURE MODULE

The function of the manure module is to calculate the rate at which excreted N is applied to feed crops.

The manure module calculates the amount of manure N collected and applied to grass and cropland in each cell by:

- calculating the amount of N excreted in each cell by multiplying the number of each animal type in the cell by the average N excretion rates;
- calculating the proportion of the excreted N that is lost during manure management and subtracting it from the total N, to arrive at the net N available for application to land;
- dividing the net N by the area of (arable and grass) land in the cell to determine the rate of N application per ha.

5. FEED MODULE

The functions of the feed module are:

- to calculate the composition of the ration for each species, system and location;
- to calculate the nutritional values of the ration per kg of feed DM;
- to calculate the GHG emissions and land use per kg of DM of ration.

The feed module determines the diet of the animal, i.e. the percentage of each feed material in the ration and calculates the (N_2O, CO_2 and CH_4) emissions arising from the production and processing of the feed. It allocates the emissions to crop by-products (such as crop residues or meals) and calculates the emission intensity per kg of feed. It also calculates the nutritional value of the ration, in terms of its energy and N content.

5.1 Determination of the ration

The feed materials used for pigs and chickens are divided into three main categories:

- swill and scavenging
- non-local feed materials
- locally-produced feed materials

The proportions of swill, non-local feeds and local feeds in the rations for each system and country are based on reported data and expert judgment (see Appendix B, Tables B8 and B9).

Swill and scavenging. Domestic (and commercial) food waste and feed from scavenging is used in backyard pig and chicken systems and, to a lesser extent, in some intermediate pig systems. As it is a waste product, which generally has no use other than animal feed, it is assumed to have an economic value of 0 and an emission intensity of 0 kg CO_2-eq/kg DM.

Non-local feed materials. These are concentrate feed materials that are blended at a feed mill to produce compound feed. The materials are sourced from various locations, and there is little link between the location where the feed material is produced and where it is utilized by the animal. These materials fall into four categories: (H) whole feed crops, where there is no harvested crop residue; (B) by-products from brewing, grain milling, processing of oilseeds and sugar production; (D) grains, which have harvested crop residues (which may or may not have an economic value); (O) other non-crop derived feed materials (see Table A1).

Locally-produced feed materials. The third category of feed materials consists of feeds that are produced locally and used extensively in intermediate and backyard systems. This is a more varied and, in some ways, complex group of feed materials which, in addition to containing some of the (B) by-products that are in the non-local feeds, also includes: (W) second grade crops deemed unfit for human consumption or use in compound feed; (CR) crop residues; and (F) forage in the form of grass and leaves (see Table A2).

One of the major differences between the local feeds and the non-local feeds is that the proportions of the individual local feed components are not defined, but are based on what is available in the country/agro-ecological zone where the animals are located. The percentage of each feed material is determined by calculating the total yield of each of the parent feed crops within the country/AEZ based on the MAPSPAM yield maps (You *et al.* 2010) then assessing the fraction of that yield that is likely to be available as animal feed. The percentage of each feed material in the ration is then assumed to be equal to the proportion of the total available feed (see Table A3).

Finally, the total amount of local feed available is compared with the estimated local feed requirement within the cell. If the availability is below a defined threshold, small amounts of grass and leaves are added to supplement the ration.

Once the composition of the ration has been determined, the nutritional values, land use and emissions per kg of DM are calculated. The method used to quantify the emissions for each individual feed material is outlined below.

Table A1. List of the non-local feed materials

Name	Type	Description
CMLSOYBEAN	B	By-product from oil production from soybeans
CMLOILSDS	B	By-product from oil production from rape and others
CMLCTTN	B	By-product from oil production from cottonseed
PKEXP	B	By-product from oil production from palm fruit
MOLASSES	B	By-product from sugar production from beet or cane
CGRNBYDRY	B	By-product from grain industries: brans, middlings
GRNBYWET	B	By-product from breweries, distilleries, bio fuels etc.
MLRAPE	B	By-product from rapeseed oil production
SOYBEAN OIL	B	Main product from soybean oil production
CPULSES	D	All types of beans
CWHEAT	D	Grain, straw not used
CMAIZE	D	Grain, stover not used
CBARLEY	D	Grain, straw not used
CMILLET	D	Grain, stover not used
CRICE	D	Grain, straw not used
CSORGHUM	D	Grain, stover not used
CCASSAVA	H	Pellets from cassava roots
CSOYBEAN	H	Leguminous oilseed, sometimes used as feed
RAPESEED	H	Oilseed crop
FISHMEAL	O	By-product from fish industry
SYNTHETIC	O	Synthetic amino acids
LIME	O	Limestone for chickens, mined.

Source: Authors.

5.2 Determination of the ration nutritional values

The nutritional values of the individual feed materials used to calculate the ration energy and N content are given in Appendix B. These nutritional values are multiplied by the percentage of each feed material in the ration, to arrive at the average energy and N content per kg of DM for the ration as a whole. A single set of values is used for swill, although it is recognized that, in practice, the nutritional value of swill could vary considerably, depending on factors such as the human food diet from which the swill is derived.

5.3 Determination of the ration GHG emissions and land use per kg of DM from feed crops

The categories of GHG emission included in the assessment of each crop feed material's emissions are:

- direct and indirect N_2O from crop cultivation;
- CH_4 arising from rice cultivation;
- CO_2 arising from loss of above and below ground carbon brought about by LUC;

- CO_2 from the on-farm energy use associated with field operations (tillage, manure application, etc.) and crop drying and storage;
- CO_2 arising from the manufacture of fertilizer;
- CO_2 arising from crop transport;
- CO_2 arising from off-farm crop processing.

The categories of emissions attributed to each crop are shown in Table A4, and a brief outline of how the emissions were calculated is provided below.

Table A2. List of the local feed materials

Name	Type	Description
MLSOYBEAN	B	By-product from oil production from soybeans
MLOILSDS	B	By-product from oil production from rape and others
MLCTTN	B	By-product from oil production from cottonseed
GRNBYDRY	B	By-product from grain industries: brans, middlings
PSTRAW	CR	Crop residue from pulses
TOPS	CR	Crop residue from sugarcane
BNSTEM	CR	Banana stem, fibrous material
GRASSF	F	Fresh grass
LEAVES	F	Leaves from trees, forest, lanes etc.
SOYBEAN	W	Leguminous oilseed, sometimes used as feed
PULSES	W	All types of beans
CASSAVA	W	Pellets from cassava roots
WHEAT	W	Second grade grain, straw not used
MAIZE	W	Second grade grain, stover not used
BARLEY	W	Second grade grain, straw not used
MILLET	W	Second grade grain, stover not used
RICE	W	Second grade grain, straw not used
SORGHUM	W	Second grade grain, stover not used
BNFRUIT	W	Banana fruit, waste from harvesting
SWILL		Household waste and scavenging

Source: Authors.

Table A3. Example of method used to determine the percentage of local feed material

	Crop 1: Pulses	Crop 2: Banana	...	Total
Total yield in country/AEZ *(Million tonnes/year)*	10 000	20 000	...	200 000
Percentage of yield used as feed	10%	15%	...	NA
Yield used for feed *(Million tonnes/year)*	1 000	3 000	...	30 000
Percentage of total local feed	= 1 000/30 000 = 3.3%	= 3 000/30 000 =10%	...	100%
Percentage of total ration[a]	= 3.3*50% = 1.65%	= 10%*50% = 5%	...	50%

[a] Assuming local feeds comprise 50 percent of the ration.

Source: Authors.

Table A4. Emissions sources included for each crop-derived feed material (x=emissions included; 0=emissions assumed to be minimal; blank=emissions not included). Definitions of each of the feed names are given in Tables A1 and A2; definitions of the emissions categories are given in Table 2.

Category	Name	Type	Crop. N_2O	Rice CH_4	LUC CO_2	Field CO_2	Fert. CO_2	Trans. CO_2	Proc. CO_2	Blend. CO_2
Non-local	CMLSOYBEAN	B	x		x	x	x	x	x	x
Non-local	CMLOILSDS	B	x			x	x	x	x	x
Non-local	CMLCTTN	B	x			x	x	x	x	x
Non-local	PKEXP	B	x			x	x	x	x	x
Non-local	MOLASSES	B	x			x	x	x	x	x
Non-local	CGRNBYDRY	B	x			x	x	x	x	x
Non-local	GRNBYWET	B	x			x	x	x	x	x
Non-local	MLRAPE	B	x			x	x	x	x	x
Non-local	SOYBEAN OIL	B	x		x	x	x	x	x	x
Non-local	CPULSES	D	x			x	x	x	0	x
Non-local	CWHEAT	D	x			x	x	x	0	x
Non-local	CMAIZE	D	x			x	x	x	0	x
Non-local	CBARLEY	D	x			x	x	x	0	x
Non-local	CMILLET	D	x			x	x	x	0	x
Non-local	CRICE	D	x	x		x	x	x	0	x
Non-local	CSORGHUM	D	x			x	x	x	0	x
Non-local	CCASSAVA	H	x			x	x	x	x	x
Non-local	CSOYBEAN	H	x		x	x	x	x	0	x
Non-local	RAPESEED	H	x			x	x	x	0	x
Local	MLSOYBEAN	B	x			x	x	0	x	
Local	MLOILSDS	B	x			x	x	0	x	
Local	MLCTTN	B	x			x	x	0	x	
Local	GRNBYDRY	B	x			x	x	0	x	
Local	PSTRAW	CR	x			x	x	0	0	
Local	TOPS	CR	x			x	x	0	0	
Local	BNSTEM	CR	x			x	x	0	0	
Local	GRASS	F	x			x	x	0	0	
Local	LEAVES	F	x			x	x	0	0	
Local	PULSES	W	x			x	x	0	0	
Local	CASSAVA	W	x			x	x	0	0	
Local	WHEAT	W	x			x	x	0	0	
Local	MAIZE	W	x			x	x	0	0	
Local	BARLEY	W	x			x	x	0	0	
Local	MILLET	W	x			x	x	0	0	
Local	RICE	W	x	x		x	x	0	0	
Local	SORGHUM	W	x			x	x	0	0	
Local	SOYBEAN	W	x			x	x	0	0	
Local	BNFRUIT	W	x			x	x	0	0	

Source: Authors.

Table A5. Source of N_2O emission factors related to feed production

Direct	Indirect - volatilization		Indirect - leaching	
	$N > NH_3$-N	NH_3-N $> N_2O$-N	$N > NO_3$-N	NO_3-N $> N_2O$-N
IPCC (2006) Table 11.1	IPCC (2006) Table 11.3	IPCC (2006) Table 11.3	IPCC (2006) Table 11.3	IPCC (2006) Table 11.3

Determination of feed crop emissions: N_2O from crop cultivation. N_2O from cropping includes direct N_2O, and indirect N_2O from leaching and volatilization of ammonia. It was calculated using the IPCC (2006) Tier 1 methodology, i.e. the formulae and EFs given below and in Table A5.

Synthetic N application rates were defined for each crop at a national level, based on existing data sets (primarily FAO's Fertilizer use statistics, http://www.fao.org/ag/agp/fertistat/index_en.htm) and adjusted down where yields were below certain thresholds. Manure N application rates were calculated in the manure module. Crop residue N was calculated using the crop yields and the IPCC (2006, p. 11.17) crop residue formulae.

Determination of feed crop emissions: CH_4 from rice cultivation. Rice differs from all the other feed crops in that it produces significant amounts of CH_4. These CH_4 emissions per ha are highly variable and depend on the water regime during and prior to cultivation, and the nature of the organic amendments. The average CH_4 flux per ha of rice was calculated for each country using the IPCC Tier 1 methodology (IPCC 2006, ch 5.5).

Determination of feed crop emissions: CO_2 from land-use change. This Approach for estimating emissions from land-use change is presented in Appendix C.

Determination of feed crop emissions: CO_2-eq from fertilizer manufacture. The manufacture of synthetic fertilizer is an energy-intensive process, which can produce significant amounts of GHG emissions, primarily via the use of fossil fuels, or through electricity generated using fossil fuels. The emissions per kg of fertilizer N will vary depending on factors such as the type of fertilizer, the efficiency of the production process, the way in which the electricity is generated and the distance the fertilizer is transported. Due to the lack of reliable data on these parameters, and on fertilizer trade flow, the average European fertilizer EF of 6.8 kg CO_2-eq per kg of ammonium nitrate N was used (based on Jenssen & Kongshaug, 2003) – which includes N_2O emissions arising during manufacture.

Determination of feed crop emissions: CO_2 from field operations. Energy is used on-farm for a variety of field operations required for crop cultivation, such as tillage, preparation of the seed bed, sowing, application of synthetic and organic fertilizers, crop protection and harvesting. The type and amount of energy required per ha, or kg of each feed material parent crop was estimated. In some countries field operations are undertaken using non-mechanized power sources, i.e. human or animal labour. To reflect this variation, the energy consumption rates were adjusted to consider the proportion of the field operations undertaken using non-mechanized power sources. The emissions arising from fieldwork per ha of each crop were calculated by multiplying the amount of each energy type consumed per ha by the emissions factor for that energy source.

Determination of feed crop emissions: CO_2 from transport and processing. Swill and local feeds, by definition, are transported minimal distances and are allocated zero emissions for transport. Non-local feeds are assumed to be transported between 100 km and 700 km by road to their place of processing. In countries where more of the feed is consumed than is produced (i.e. net importers), feeds that are known to be transported globally (e.g. soymeal) also receive emissions that reflect typical sea transport distances.

Emissions from processing arise from the energy consumed in activities such as milling, crushing and heating, which are used to process whole crop materials into specific products. Therefore, this category of emissions applies primarily to feeds in the by-product category.

Determination of feed crop emissions: CO_2 from blending and transport of compound feed. In addition, energy is used in feed mills for blending non-local feed materials to produce compound feed and to transport it to its point of sale. It was assumed that 186 MJ of electricity and 188 MJ of gas were required to blend 1 000 kg of DM, and that the average transport distance was 200 km.

Determination of the ration GHG emissions arising from the production of non-crop feed materials. Default values were used for fishmeal, lime and synthetic amino acids (see Table B18).

5.4 Allocation of emissions between the crop and its by-products

In order to calculate the emission intensity of the feed materials, the emissions need to be allocated between the crop and its by-products, i.e. the crop residue or by-products of crop processing. The general expression used is:

$$\text{GHGkgDM} = \text{GHGha}/(\text{DMYGcrop}*\text{FUEcrop}+\text{DMYGco}*\text{FUEco})*\text{EFA}/\text{MFA}*\text{A2}$$

Where:

GHGkgDM = emissions (of CO_2, N_2O or CH_4) per kg of DM
GHGha = emissions per ha
DMYGcrop = gross crop yield (kg DM/ha)
DMYGco = gross crop co-product yield (kg DM/ha)
FUEcrop = feed use efficiency, i.e. fraction of crop gross yield harvested
FUEco = feed use efficiency, i.e. fraction of crop co-product gross yield harvested
EFA = economic fraction, crop or co-product value as a fraction of the total value (of the crop and co-product)
MFA = mass fraction, crop or co-product mass as a fraction of the total mass (of the crop and co-product)
A2 = second grade allocation: ratio of the economic value of second grade crop to the economic value of its first grade equivalent

Yields of DM and estimated harvest fractions were used to determine the mass fractions. Where crop residues were not used, they were assumed to have a value of zero i.e. 100 percent of the emissions were allocated to the crop. In order to reflect the lower value of the second grade crops (i.e. food crops that fail to meet the required standards and are consequently sold as feed) relative to their first grade equivalents, they were allocated a fraction (A2 = 20 percent) of the total emissions arising from their production roughly proportionate to their economic value. Clearly, the relative value could potentially vary for different crops and locations depending on supply and demand, or the extent to which there is a market for second grade crops and the price of alternative feedstuffs. This is an important assumption, which will be investigated and refined in the future.

The allocation of feed emissions is summarized in Table A6 and Figure 3. Note that:

- emissions from post-processing blending and transport are allocated entirely to feed;
- emissions that are not allocated to feed do not cease to exist; rather, they are, or should be, allocated to other commodities. For example, if we assume that swill has zero economic value, then the emissions from swill production should be allocated to household food. Similarly, the 80 percent of emissions not allocated to second grade crops should be allocated to the remaining first grade crops. Failure to follow this approach may lead to incorrect policy conclusions. Overestimating the proportion of crops that fail to meet first grade quality will lead to a reduction in total emissions, rather than an increase in the emission intensity of first grade crops that offsets the decrease in the emission intensity of the second grade crops (see Table A6).

Table A6. Summary of the allocation techniques used in the calculation of plant-based feed emissions

Products	Source of emissions	Allocation technique
Swill	Emissions arising from the production of human food	Assumed to have no economic value, so allocated no emissions
All feed crops and their by-products	N_2O from manure application N_2O from synthetic fertilizer CO_2 from fertilizer manufacture CO_2 from fieldwork	Allocation between the crop and co-product is based on the mass harvested, and the relative economic values (using digestibility as a proxy)
Local second grade crops only	N_2O from manure application N_2O from synthetic fertilizer CO_2 from fertilizer manufacture CO_2 from fieldwork	Allocation between crop and co-product is the same as for other feed crops (see above) PLUS local waste crops receive 20 percent of the emissions allocated to the crop, to reflect their low economic value. The other 80 percent is effectively allocated to the 1st grade crops.
By-products only	CO_2 from processing CO_2 from LUC (for soybean)	Allocated to the processing by-products based on mass and economic value
Non-local feeds only	CO_2 from transportation and blending	100 percent to feed material

Source: Authors.

6. SYSTEM MODULE

The functions of the system module are:

- to calculate the average energy requirement (kJ) of each animal cohort (adult females, adult males etc.) and the feed intake (kg DM) for its needs;
- to calculate the total emissions and land use arising during the production, processing and transport of the feed;
- to calculate the CH_4 and emissions arising during the management of the VSx;
- to calculate enteric CH_4 emissions.

6.1 Calculation of animal energy requirement

The systems module calculates the energy requirement of each animal, in kilojoule (kJ), which is then used to determine the feed intake (in kg of DM). The energy requirement and feed intake are calculated using an IPCC (2006) Tier 2-type approach, i.e. the energy required for each of the metabolic functions is calculated separately then summed. See Tables A7 and A8 for examples of the formulae used, where:

BWavg = average weight of sow or fattening pig (kg/pig)
ACT = adjustment for activity level (dimensionless)
LSIZE = litter size (no. of piglets per litter)
BWGpiglet = weight gain of piglet: birth-weaning (kg)
LACT = length of birth-weaning period (days)
MWGenergy = milk energy derived from fat stored during pregnancy rather than feed intake during lactation (kJ/day)
DWG = daily weight gain (kg/day)
FPROT = fraction of protein in the DWG (dimensionless)
FFAT = fraction of fat in the DWG (dimensionless)
AFkg = average weight of the laying hen (kg/hen)
Pkg = average weight of juvenile chickens (kg/juvenile chicken)
TEMP = ambient temperature (°C)
GROWF = laying hen growth rate (kg/day)
GROWP = juvenile chicken growth rate (kg/day)
EGGKG = weight of eggs laid per day (kg/day)

As the IPCC (2006) does not include equations for calculating the energy requirement of pigs or poultry, equations were derived from NRC (1998) for pigs and Sakomura (2004) for chickens. The NRC (1998) pig equations were adjusted in light of recent farm data supplied by Bikker (personal communication 2011). In order to perform the calculations, data from the herd module (i.e. the number of animals in each cohort, their average weights and growth rates, fertility rates and yields) were combined with input data on parameters (egg weight, protein/fat fraction, temperature, activity levels).

Energy required for maintenance will vary depending on the activity levels of the animals. The maintenance energy requirement is, therefore, adjusted in situations where it is likely to be significantly higher, e.g. where ruminants are ranging rather than grazing, or for backyard pigs and poultry, which are scavenging for food. The maintenance energy requirement of cattle and buffalo is also adjusted to reflect the amount of energy expended in field operations by animals that are used for draft.

Table A7. Formulae for the calculation of the energy requirements of sows and fattening pigs

Metabolic function	Equation for sows[1]	Equation for fattening pigs[1]
Maintenance *(kJ/day)*	443.5*BWavg$^{0.75}$*(1+ACT)[a]	443.5*BWavg$^{0.75}$*(1+ACT)
Growth *(kJ/day)*	[a]	0.23*DWG*1 000*FPROT*54 + 0.90*DWG*1 000*FFAT*52.3
Lactation *(kJ/day)*	LSIZE*(BWGpiglet*1 000*20.59/ LACT)-(MWGenergy)	NA
Pregnancy *(kJ/day)*	148.11*LSIZE	NA

[1] Definition of variables one provided in the text.

[a] Sows do not have growth energy per se, but their weight and, therefore, maintenance energy varies, depending on their status (i.e. whether they are pregnant, lactating or idle) so the maintenance energy for each of these states is calculated separately, then used to calculate the average maintenance energy, based on the lengths of each period.

NA: Not Applicable.

Source: NRC (1998).

Table A8. Formulae for the calculation of the energy requirements of laying hens and pullets

Metabolic function	Equation for laying hens[1]	Equation for juvenile chickens[1]
Maintenance energy *(kJ/day)*	AFkg$^{0.75}$*(692.8-9.9*TEMP)*(1+ACT)	Pkg$^{0.75}$*386.63*(1+ACT)
Growth energy *(kJ/day)*	27.9*GROWF*1 000	21.17*GROWP*1 000
Egg production *(kJ/day)*	10.03*EGGKG*1 000	NA

[1] Definition of variables one provided in the text.

NA: Not Applicable.

Source: Sakomura N.K. (2004).

It is assumed that layers and broilers are kept in housing with a controlled environment, and the ambient temperature is a constant 20 °C. For backyard chickens, the average annual ambient temperature is used.

6.2 Calculating feed intake, total feed emissions and land use

The feed intake per animal in each cohort (in kg DM/animal/day) is calculated by dividing the animal's energy requirement (in kJ) by the average ME (poultry) or DE (pigs) content of the ration from the feed module, e.g.:

feed intake adult females (kg DM/animal/day) =
energy requirement (kJ/animal/day)/feed energy content (kJ/kg DM)

The feed intake per animal in each cohort is multiplied by the number of animals in each cohort to get the total daily feed intake for the flock/herd.

The feed emissions and land use associated with the feed production are then calculated by multiplying the total feed intake for the flock/herd by the emissions or land use per kg of DM taken from the feed module.

The protein content of the ration is checked at this stage by comparing the average lysine requirement across the flock or herd with the average lysine content of the ration. Assumptions about the proportions of each of the feed materials are adjusted in situations where the protein content appears to be excessively low or high.

6.3 Calculation of CH_4 emissions arising during manure management

Calculating the CH_4 per head from manure using a Tier 2 approach requires (a) estimation of the rate of VSx per animal and (b) estimation of the proportion of the VS that are converted to CH_4. The VSx rates are calculated using Equation 10.24 from IPCC (2006).

Once the VS excretion rate is known, the proportion of the VS converted to CH_4 during manure management per animal per year can be calculated using Equation 10.23 from IPCC (2006).

The CH_4 conversion factor depends on how the manure is managed. In this study, the manure management categories and EFs in IPCC (2006, Table A7) were used. The proportion of manure managed in each system is based on official statistics (such as the Annex I countries' National Inventory Reports to the UNFCCC), other literature sources and expert judgement. Regional average MCFs are given in Tables B19 to B22.

6.4 Calculation of N_2O emissions arising during manure management

Calculating the N_2O per head from manure using a Tier 2 approach requires (a) estimation of the rate of N excretion per animal, and (b) estimation of the proportion of the excreted N that is converted to N_2O. The N excretion rates are calculated using Equation 10.31 from IPCC (2006).

N intake depends on the feed DM intake and the N content per kg of feed. The feed DM intake depends, in turn, on the animal's energy requirement (which is calculated in the system module, and varies depending on mass, growth rate, egg yield, pregnancy weight gain and lactation rate, and level of activity) and the feed energy content (calculated in the feed track). N retention is the amount of N retained in tissue, either as growth, pregnancy LW gain or eggs. The following N contents were used:

Pig LW:	25 g N/kg LW
Chicken LW:	28 g N/kg LW
Eggs:	18.5 g N/kg egg

The rate of conversion of excreted N to N_2O depends on the extent to which the conditions required for nitrification, denitrification, leaching and volatilization are present during manure management. The IPCC (2006) default EFs for direct N_2O (IPCC 2006, Table 10.21) and indirect via volatilization (IPCC 2006, Table 10.22) are used in this study, along with variable N leaching rates, depending on the agro-ecological zone (see Table A9).

6.5 Quantifying enteric CH_4 emissions from pigs

The enteric emissions per pig depend on the amount of feed gross energy (GE) consumed and the proportion of the feed converted to CH_4 (Y_m), and are calculated using IPCC (2006) equation 10.21.

Table A9. N_2O emission factors for manure management

Direct	Indirect - volatilization		Indirect - leaching	
	$N > NH_3\text{-}N$	$NH_3\text{-}N > N_2O\text{-}N$	$N > NO_3\text{-}N$	$NO_3\text{-}N > N_2O\text{-}N$
IPCC (2006) Table 10.21	IPCC (2006) Table 10.23	IPCC (2006) Table 11.3	Leaching rates*	IPCC (2006) Table 11.3

*FAO calculations based on Velthof *et al.* (2009).

The GE consumed is a function of the amount of energy required by the pig (for maintenance, growth, lactation and gestation) and the energy content of the ration. Two values of Y_m were used: 1 percent for adult pigs and 0.39 percent for growing pigs, based on Jørgensen *et al.* (2011, p. 617); see also Jørgensen (2007) and Jia *et al.* (2011).

7. ALLOCATION MODULE

The functions of the allocation module are:

- to sum up the total emissions for each animal cohort;
- to calculate the amount of each commodity (meat and eggs) produced;
- to allocate the emissions to each commodity;
- to calculate the total emissions and emission intensity of each commodity.

The allocation module sums the output (meat and eggs) and emissions and allocates emissions as illustrated by Figure 3.

7.1 Calculation of the total emissions for each animal cohort

The system track calculates the total emissions arising from feed production, manure management and enteric fermentation. Post animal farmgate emissions are calculated separately and incorporated into the allocation module (see Appendix D).

7.2 Calculation of the amount of each commodity produced

LW is converted to CW and to bone-free meat (BFM) by multiplying by the percentages given in Table B24. These percentages vary by species and system (and in some cases, country). The conversion of BFM and eggs to protein is based on the assumption that BFM is 18 percent protein by weight and eggs are 11.9 percent.

7.3 Allocation to by-products and calculation of emission intensity

For the monogastric species, emissions are allocated between the edible commodities, i.e. meat and eggs. In reality, there are usually significant amounts of other commodities produced during processing, such as skin, feathers and offal. However, the values of these can vary markedly between countries, depending on the market conditions which, in turn, depend on factors such as food safety regulations and consumer preferences. Allocating no emissions to these can lead to an over allocation to meat and eggs. The potential effect of this assumption is explored in Appendix D.

Layers and backyard chickens produce both eggs and meat. The emissions were allocated between these two commodities, using the following method:

a. Quantify the total emissions from animals required for egg production (adult female and adult male breeding chickens, replacement juvenile chickens, hens laying eggs for human consumption).
b. Quantify the total emissions from animals not required for egg production, i.e. producing meat only (surplus male juvenile chickens).
c. Allocate emissions to meat and eggs, on the basis of the amount of egg and meat protein produced (see Table A10).

Allocation is undertaken using both physical criteria and economic criteria. While it is recognized that ISO14044 guidance recommends the use of physical criteria before economic criteria (where possible), both approaches have their strengths and weaknesses, and can be useful provided the results are not misinterpreted. Physical criteria reflect the metabolic work required for the production of tissue and the

Table A10. Example of the allocation of emissions to meat and eggs on a protein basis

	Part of flock producing eggs and meat	Part of flock producing meat only
Total emissions *(kg CO_2-eq)*	50 000	39 000
Total protein *(kg)*	Eggs: 800 Meat: 200	Meat: 500
Emission intensity of eggs	= 50 000*(800/1 000)/800 = 50 kg CO_2-eq/kg protein	
Emission intensity of meat	= (50 000*(200/1 000) + 39 000)/(200 + 500) = 70 kg CO_2-eq/kg protein	

Source: Authors.

quantities of biophysical resources (e.g. energy, mass, protein) that remain, while economic criteria (such as price) reflect the balance of supply and demand for the resource and the likelihood of the resource being used. These can lead to quite different results, which need to be used and interpreted accordingly.

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APPENDIX B

Data and data sources

1. DATA RESOLUTION AND DISAGGREGATION

Data availability, quality and resolution vary according to parameters and the country in question. In OECD countries, where farming tends to be more regulated, there are often comprehensive national or regional data sets, and in some cases subnational data (e.g. for manure management in dairy in the United States of America). Conversely, in non-OECD countries, data is often unavailable necessitating the use of regional default values (e.g. for many backyard pig and chicken herd/flock parameters). Examples of the spatial resolution of some key parameters are given in Table B1.

Basic input data can be defined as primary data such as animal numbers, herd/flock parameters, mineral fertilizer application rates, temperature, etc. and are data taken from other sources such as literature, databases and surveys. Intermediate data are an output of the modelling procedure required in further calculation in GLEAM and may include data on growth rates, animal cohort groups, feed rations, animal energy requirements, etc.

2. LIVESTOCK MAPS

Maps of the spatial distribution of each animal species and production systems are one of the key inputs into the GLEAM model. The procedure by which these maps are generated for monogastrics is outlined briefly below.

Total pig and chicken numbers at a national level are reported in FAOSTAT. The spatial distributions used in this study were based on maps developed in the context of FAO's Global Livestock Impact Mapping System (GLIMS) (Franceschini *et al.*, 2009). Regression (based on reported data of the proportions of backyard pigs) was used to estimate the proportion of the pigs in each country in the backyard herd. A simplified version of the procedure described in FAO (2011), was then used to distribute the backyard pigs among the rural population, taken from the Global Rural Urban Mapping Project (GRUMP) dataset (CIESIN, 2005). Reported data, supplemented by expert opinion, was used to determine the proportions of the remaining non-backyard pigs in intermediate and industrial systems. The pig mapping method is currently being revised and the new method and maps will be reported in Robinson *et al.* (forthcoming).

A similar procedure was undertaken to determine the spatial distribution of chickens. FAOSTAT production of meat and eggs was used to determine the proportions of non-backyard chickens in the layer and broiler flocks.

3. HERD/FLOCK PARAMETERS

3.1 Fertility parameters

Data on fertility are usually incorporated in the form of parturition rates (e.g. calving, kidding, lambing rates) and are normally defined as the number of births occurring in a specified female population in a year. For monogastrics, litter/clutch size is taken into account. The model utilizes age-specific fertility rates for adult and young replacement females. The proportion of breeding females that fails to conceive is also included.

Table B1. Spatial resolution of the main input variables

Parameters	Cell[1]	Subnational	National	Regional[2]	Global
Herd					
Animal numbers	X				
Weights		X →		X	
Mortality, fertility and replacement data		X →		X	
Manure					
N losses rates					X
Management system		X →		X	
Leaching rates				X	
Feed					
Crop yields	X				
Harvested area	X				
Synthetic N fertilizer rate			X		
N residues	X[3]			X[4]	
Feed ration			X[5] →	X	
Digestibility and energy content			X →		X
N content				X →	X
Energy use in fieldwork, transport and processing					X
Transport distances					X
Land-use change					
Soybean (area and trade)			X		
Pasture (area and deforestation rate)			X		
Animal productivity					
Yield (milk, eggs, and fibers)			X →	X	
Dressing percentage			X →	X	
Fat and protein content			X →		X
Product farm gate prices[6]			X →	X	
Post farm					
Transport distances of animals or products			X		
Energy (processing, cooling, packaging)			X		
Mean annual temperature	X				
Direct and indirect energy			X →	X	

→ The spatial resolution of the variable varies geographically and depends on the data availability. For each input variable, the spatial resolution of a given area is defined as the finest available.

[1] Animal numbers and mean annual temperature: ~ 5 km x 5 km at the equator; crop yields, harvested area and N residues: ~ 10 km x 10 km at the equator.

[2] Geographical regions or agro-ecological zones.

[3] For monogastrics.

[4] For ruminants.

[5] Ruminants: rations in the industrialized countries; Monogastrics: rations of swill and concentrates.

[6] Only for allocation in small ruminants.

Table B2. Input herd parameters for backyard pigs averaged over region

Parameters	Russian Fed.	E. Europe	E & SE Asia	South Asia	LAC	SSA
Weight of adult females *(kg)*	105	105	104	103	127	64
Weight of adult males *(kg)*	120	120	120	113	140	71
Weight of piglets at birth *(kg)*	1.00	1.00	0.97	0.80	1.00	1.00
Weight of weaned piglets *(kg)*	6.0	6.0	6.0	6.2	6.2	6.0
Weight of slaughter animals *(kg)*	90	90	85	90	88	60
Daily weight gain for fattening animals *(kg/day/animal)*	0.40	0.40	0.30	0.32	0.35	0.18
Weaning age *(days)*	50	50	49	50	50	90
Age at first farrowing *(years)*	1.5	1.5	1.5	1.5	1.5	1.5
Sows replacement rate *(percentage)*	10	10	10	10	10	10
Fertility *(parturition/sow/year)*	1.6	1.6	1.5	1.8	1.6	1.6
Death rate piglets *(percentage)*	17.0	17.0	17.0	17.0	17.0	22.0
Death rate adult animals *(percentage)*	2.0	2.0	2.0	2.0	2.0	2.0
Death rate fattening animals *(percentage)*	3.0	3.0	3.0	3.0	3.0	3.0

Source: Literature, surveys and expert knowledge.

3.2 Mortalities

Data on mortality is incorporated in the form of death rates. In the modelling process, age-specific death rates are used: e. g. mortality rate in piglets and mortality rate in other animal categories. The death rate of piglets reflects the percentage of piglets dying before weaning. This may occur by abortion, still birth or death in the first 30 days after birth.

3.3 Growth rates

Growth rates and slaughter weights are used to calculate age at slaughter, while for chickens the growth rates were calculated based on the weight and age at slaughter.

3.4 Replacement rates

The replacement rate (i.e. the rate at which breeding animals are replaced by younger adult animals) for female animals is taken from the literature. Literature reviews did not reveal any data on the replacement rate of male animals, so the replacement rate was defined as the reciprocal value of the age at first parturition, on the assumption that farmers will prevent in-breeding by applying this rule. For some animals, such as small ruminants, adult males are exchanged by farmers and, therefore, have two or more service periods.

Herd and flock parameters are presented in Tables B2 to B7.

Table B3. Input herd parameters for intermediate pigs averaged over region

Parameters	E. Europe	E & SE Asia	South Asia	LAC	SSA
Weight of adult females *(kg)*	225	175	175	230	225
Weight of adult males *(kg)*	265	195	195	255	250
Weight of piglets at birth *(kg)*	1.2	1.2	1.2	1.2	1.2
Weight of weaned piglets *(kg)*	7	7	7	7	8
Weight of slaughter animals *(kg)*	100	99	100	100	90
Daily weight gain for fattening animals *(kg/day/animal)*	0.500	0.475	0.475	0.500	0.300
Weaning age *(days)*	40	40	40	40	42
Age at first farrowing *(years)*	1.25	1.25	1.25	1.25	1.25
Sows replacement rate *(percentage)*	15	15	15	15	15
Fertility *(parturition/sow/year)*	1.8	1.8	1.8	1.8	1.8
Death rate piglets *(percentage)*	15.0	15.0	15.0	16.0	20.0
Death rate adult animals *(percentage)*	3.0	3.0	3.0	3.0	3.0
Death rate fattening animals *(percentage)*	2.0	2.0	2.0	2.0	1.0

Source: Literature, surveys and expert knowledge.

Table B4. Input herd parameters for industrial pigs averaged over region

Parameters	N. America	Russian Fed.	W. Europe	E. Europe	E & SE Asia	LAC
Weight of adult females *(kg)*	220	225	225	225	175	230
Weight of adult males *(kg)*	250	265	265	265	195	255
Weight of piglets at birth *(kg)*	1.2	1.2	1.2	1.2	1.2	1.2
Weight of weaned piglets *(kg)*	7.0	7.0	7.1	7.0	7.0	7.0
Weight of slaughter animals *(kg)*	115	116	116	116	114	115
Daily weight gain for fattening animals *(kg/day/animal)*	0.66	0.66	0.64	0.66	0.67	0.69
Weaning age *(days)*	30	34	27	34	30	20
Age at first farrowing *(years)*	1.25	1.25	1.25	1.25	1.00	1.25
Sows replacement rate *(percentage)*	48	22	43	22	30	30
Fertility *(parturition/sow/year)*	2.4	2.1	2.3	2.1	2.1	2.2
Death rate piglets *(percentage)*	15.0	15.0	13.5	15.0	11.7	15.0
Death rate adult animals *(percentage)*	6.4	3.4	4.9	3.4	5.6	6.4
Death rate fattening animals *(percentage)*	7.8	4.7	3.9	4.7	5.0	5.6

Source: Literature, surveys and expert knowledge.

Table B5. Input herd parameters for backyard chickens averaged over region

Parameters	Russian Fed.	E. Europe	NENA	E & SE Asia	South Asia	LAC	SSA
Weight of adult females at the end of laying period *(kg)*	1.60	1.61	1.26	1.46	1.24	1.50	1.27
Weight of adult males at the end of reproductive period *(kg)*	2.10	2.10	1.87	1.77	1.55	1.90	1.92
Weight of surplus animals at slaughter *(kg)*	1.300	1.340	1.000	1.300	0.890	1.146	1.146
Weight of chicks at birth *(kg)*	0.045	0.045	0.029	0.035	0.035	0.030	0.025
Egg weight *(g)*	57.50	57.50	42.27	43.80	44.00	52.00	41.26
Age at first egg production *(days)*	150	150	180	195	185	177	168
Age at slaughter, females *(days)*	735	735	926	881	926	926	982
Number of laying cycles	3.3	3.3	2.8	3.3	3.0	3.3	3.6
Number of eggs/hen/year	159	159	106	50	87	100	45
Hatchability of eggs *(fraction)*	0.80	0.80	0.78	0.76	0.75	0.79	0.80
Death rate juvenile chickens *(percentage)*	9.0	9.0	56.0	45.0	49.0	58.0	66.0
Death rate adult animals *(percentage)*	20.0	20.0	21.0	21.0	24.0	20.0	24.0

Source: Literature, surveys and expert knowledge.

Table B6. Input herd parameters for layers averaged over region

Parameters	N. America	Russian Fed.	W. Europe	E. Europe	NENA	E & SE Asia	South Asia	LAC
Weight of adult females at the start of laying period *(kg)*	1.26	1.25	1.56	1.46	1.29	1.48	1.32	1.36
Weight of adult females at the end of first laying period *(kg)*	1.51	1.95	1.87	1.89	1.92	1.92	1.55	1.62
Weight of chicks at birth *(kg)*	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Egg weight *(g)*	54	57	57	57	49	53	53	51
Age at first egg production *(days)*	119	119	119	119	126	119	126	119
Number of eggs/hen/year	279	320	305	298	315	286	302	310
Hatchability of eggs *(fraction)*	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Death rate juvenile chickens *(percentage)*	3.5	2.5	2.9	3.4	4.2	3.8	2.6	4.4
Death rate adult animals in the first laying period *(percentage)*	9.2	5.5	7.0	6.8	6.5	13.4	9.2	7.5

Source: Literature, surveys and expert knowledge.

Table B7. Input herd parameters for broilers averaged over region

Parameters	N. America	W. Europe	E. Europe	NENA	E & SE Asia	South Asia	LAC
Weight of adult females at the start of laying period *(kg)*	1.25	1.56	1.52	1.31	1.48	1.29	1.34
Weight of adult females at the end of laying period *(kg)*	1.51	1.88	1.86	1.91	1.89	1.60	1.80
Weight of slaughter broilers *(kg)*	2.67	2.32	2.19	1.92	2.07	2.00	2.47
Weight of chicks at birth *(kg)*	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Egg weight *(g)*	54	57	57	48	50	50	51
Age at first reproduction *(days)*	119	119	119	119	133	119	119
Age at slaughter, broilers *(days)*	44	44	40	40	44	40	44
Number of eggs/hen/year	278	305	291	305	289	273	313
Hatchability of eggs *(fraction)*	0.80	0.80	0.80	0.80	0.80	0.79	0.80
Death rate juvenile chickens *(percentage)*	3.46	2.80	3.80	4.10	3.70	2.30	4.00
Death rate reproductive animals *(percentage)*	9.2	6.7	7.3	7.3	12.9	10.4	8.4
Death rate broilers *(percentage)*	3.6	4.3	4.8	5.9	4.9	5.0	3.0

Source: Literature, surveys and expert knowledge.

4. FEED

The feed materials used for pigs and chickens are divided into three main categories:

- swill and scavenging
- non-local feed materials
- locally-produced feed materials

The proportions of the three main feed groups making up the ration were defined for each of the production systems, based on literature and expert knowledge. Default regional values were used for minor producing countries. Tables B8 to B15 summarize the average feed baskets (weighted by total production) for each region and system.

The proportion of the non-local feeds was defined for each country, where possible, using existing literature. For pigs, literature consulted included: FAO (2001); Ndindana *et al.* (2002); Tra (2003); van der Werf *et al.* (2005); Grant Clark *et al.* (2005); FAO (2006); Hu (2007) and Rabobank (2008). For chickens, literature consulted included: FAO (2003); Petri and Lemme (2007); Thiele and Pottgüter (2008); Pelletier (2008); FAO (2010); Wiedemann and McGahan (2011); Nielsen *et al.* (2011); CEREOPA (2011); Jeroch (2011); Leinonen *et al.* (2012a, 2012b) and Wiedemann *et al.* (2012).

Gaps in the literature were filled through discussions with experts (both within FAO and the industry) and also through primary data gathering (a questionnaire survey of commercial egg producers was undertaken with the assistance of the International Egg Commission). See Tables B8 to B17 for regional averages of ration composition for pigs and chickens per systems and characteristics of feed materials.

In this assessment, all feed materials are identified by three key parameters: dry-matter yield per ha; net energy content (or digestibility) and N content. The DM yield per ha is important because it determines the type of feed ingredients that make up the local feed ration, as well as the potentially available feed (quantity of feed). The digestibility and N content of feed define the nutritional properties of feed. They also determine the efficiency with which feed is digested and influences the rate at which GHG emissions are produced. The feed module, additionally, brings together information related to the production of feed, such as fertilization rates, manure application and energy coefficients for feed production, processing and transport.

The nutritional values of the individual feed materials used to calculate the ration digestibility and N content are given in Tables B16 to B17. These are based on the values in the Dutch Feed Board Feed Database, adjusted from "as fed" to DM basis and augmented with data from other sources, such as FEEDIPEDIA (http://www.trc.zootechnie.fr/node/527) and also the NRC guidelines for pigs and poultry (NRC 1994, 1998).

Table B8. Regional average ration composition by feed category: pigs

	Industrial *(percentage)*			**Intermediate** *(percentage)*			**Backyard** *(percentage)*		
	non-local	**local**	**SS**	**non-local**	**local**	**SS**	**non-local**	**local**	**SS**
LAC	100	0	0	49	50	1	10	70	20
E & SE Asia	100	0	0	49	46	4	10	70	20
E. Europe	100	0	0	69	30	1	17	64	19
N. America	100	0	0	NA	NA	NA	NA	NA	NA
Oceania	100	0	0	NA	NA	NA	10	70	20
Russian Fed.	100	0	0	70	30	0	20	60	20
South Asia	100	0	0	50	50	0	10	70	20
SSA	75	25	0	47	50	3	4	78	18
NENA	100	0	0	50	50	0	5	75	20
W. Europe	100	0	0	69	30	0	20	69	10
Global average	100	0	0	52	45	3	10	70	20

NA: Not Applicable – areas with no pig populations.
SS: Swill/Scavenging.
Source: Literature, surveys and expert knowledge.

Table B9. Regional average ration composition by feed category: chickens

	Industrial layers *(percentage)*	**Industrial broilers** *(percentage)*	**Backyard** *(percentage)*	
	non-local	**non-local**	**local**	**SS**
LAC	100	100	60[a]	40[a]
E & SE Asia	100	100	60[b]	40[b]
E. Europe	100	100	80	20
N. America	100	100	80	20
Oceania	100	100	60[c]	40[c]
Russian Fed.	100	100	80	20
South Asia	100	100	60	40
SSA	100	100	60	40
NENA	100	100	60[d]	40[d]
W. Europe	100	100	80	20

[a] Chile and Mexico have 80 percent local feed and 20 percent swill.
[b] Japan has 80 percent local feed and 20 percent swill.
[c] Australia and New Zealand have 80 percent local feed and 20 percent swill.
[d] Turkey has 80 percent local feed and 20 percent swill.
SS: Swill/Scavenging.
Source: Literature, surveys and expert knowledge.

Table B10. Regional average ration composition and nutritional value: backyard pigs

LOCAL feeds*	LAC	E & SE Asia	E. Europe	Russian Fed.	South Asia	SSA	NENA	Global average
	Percentage of feed material in the ration (by mass on a dry matter basis)							
GRASSF	0	0	0	0	0	0	1	0
SWILL	19	20	19	20	20	19	20	20
PULSES	0	0	1	1	1	2	0	0
PSTRAW	1	2	7	5	10	14	2	3
CASSAVA	1	0	0	0	0	7	0	0
WHEAT	1	6	12	18	6	0	21	5
MAIZE	5	7	7	1	1	8	5	7
BARLEY	0	0	5	7	0	0	7	1
MILLET	0	0	0	0	1	2	0	0
RICE	2	17	0	0	9	3	0	13
SORGHUM	1	0	0	0	1	3	0	0
SOY	2	1	0	0	0	0	0	1
TOPS	27	5	1	0	16	6	0	7
LEAVES	0	0	0	0	0	0	1	0
BNFRUIT	1	0	0	0	0	2	0	0
BNSTEM	4	0	0	0	2	8	1	1
MLSOY	15	8	1	1	3	1	0	8
MLOILSDS	5	8	17	13	10	9	7	8
MLCTTN	1	1	0	0	2	3	7	1
GRNBYDRY	5	15	12	13	9	8	17	13
NON-LOCAL feeds*	**LAC**	**E & SE Asia**	**E. Europe**	**Russian Fed.**	**South Asia**	**SSA**	**NENA**	**Global average**
	Percentage of feed material in the ration (by mass on a dry matter basis)							
CMLOILSDS	5	5	8	10	5	2	5	5
CMLCTTN	5	5	8	10	5	2	5	5
Nutritional values	**LAC**	**E & SE Asia**	**E. Europe**	**Russian Fed.**	**South Asia**	**SSA**	**NENA**	**Global average**
GE *(kJ/kg DM)*	18 886	18 747	18 835	18 814	18 657	18 501	18 740	18 753
DE *(kJ/kg DM)*	12 143	12 739	12 512	12 481	11 666	11 852	12 552	12 585
N *(g/kg DM)*	35.2	34.7	37.5	38.1	30.9	26.7	34.2	34.6
DE/GE *(percentage)*	64	68	66	66	63	64	67	67

* Definitions of each of the feed names are given in Tables A1 and A2.

Source: GLEAM based on input data from literature, national inventory reports, expert knowledge and databases (SPAM, FAOSTAT).

Table B11. Regional average ration composition and nutritional value: intermediate pigs

LOCAL feeds*	LAC	E & SE Asia	E. Europe	Russian Fed.	South Asia	SSA	NENA	W. Europe	Global average
	Percentage of feed material in the ration (by mass on a dry matter basis)								
GRASSF	0	0	0	0	0	0	1	0	0
SWILL	1	4	0	0	0	3	0	0	3
PULSES	0	0	0	0	1	1	0	0	0
PSTRAW	1	1	2	2	7	9	1	2	1
CASSAVA	0	0	0	0	0	7	0	0	0
WHEAT	1	3	9	9	3	0	15	11	3
MAIZE	5	4	2	0	2	4	3	10	4
BARLEY	0	0	3	4	0	0	5	6	1
MILLET	0	0	0	0	1	1	0	0	0
RICE	1	12	0	0	8	2	0	0	9
SORGHUM	1	0	0	0	0	2	0	0	0
SOY	1	1	0	0	0	0	0	0	1
TOPS	18	4	0	0	10	2	0	0	5
LEAVES	0	0	0	0	0	0	1	0	0
BNFRUIT	1	0	0	0	1	1	0	0	0
BNSTEM	3	0	0	0	2	4	1	0	1
MLSOY	9	4	0	1	1	1	0	2	4
MLOILSDS	4	6	7	6	6	8	5	5	6
MLCTTN	1	1	0	0	1	2	5	0	1
GRNBYDRY	4	10	7	7	7	5	12	13	9
NON-LOCAL feeds*	**LAC**	**E & SE Asia**	**E. Europe**	**Russian Fed.**	**South Asia**	**SSA**	**NENA**	**W. Europe**	**Global average**
	Percentage of feed material in the ration (by mass on a dry matter basis)								
CPULSES	0	0	0	0	0	0	0	2	0
CCASSAVA	1	1	0	0	1	7	7	0	1
CWHEAT	8	2	21	24	0	0	0	8	5
CMAIZE	18	25	17	14	6	12	12	12	23
CBARLEY	0	2	6	7	0	0	0	7	2
CMILLET	0	0	0	0	0	7	0	0	0
CRICE	1	3	0	0	12	3	10	0	2
CSORGHUM	4	0	0	0	11	10	0	0	1
CSOY	3	2	0	0	0	0	2	0	2
CMLSOY	10	8	10	10	10	3	12	10	9
CMLOILSDS	0	0	7	7	0	0	0	5	1
CMLCTTN	0	0	0	0	4	0	0	0	0
FISHMEAL	1	1	2	3	2	2	2	0	1
MOLASSES	0	0	0	0	0	1	0	2	0
CGRNBYDRY	1	4	4	4	2	0	2	3	4
SYNTHETIC	1	1	1	1	1	1	1	1	1
Nutritional values	**LAC**	**E & SE Asia**	**E. Europe**	**Russian Fed.**	**South Asia**	**SSA**	**NENA**	**W. Europe**	**Global average**
DE *(kJ/kg DM)*	14 309	14 310	14 616	14 587	13 325	13 710	14 200	14 384	14 310
N *(g/kg DM)*	33.5	31.8	35.8	36.2	31.4	25.7	34.6	32.5	32.3
DE *(percentage)*	75	76	77	77	71	74	76	76	76

* Definitions of each of the feed names are given in Tables A1 and A2.

Sources: GLEAM based on input data from literature, national inventory reports, expert knowledge and databases (SPAM, FAOSTAT).

Table B12a. Regional average ration composition and nutritional value (excluding sub-Saharan Africa): industrial pigs

NON-LOCAL feeds*	LAC	E & SE Asia	E. Europe	N. America	Oceania	Russian Fed.	South Asia	NENA	W. Europe	Global average
	Percentage of feed material in the ration (by mass on a dry matter basis)									
CPULSES	0	0	0	0	0	0	0	0	3	1
CCASSAVA	1	1	0	0	0	0	2	15	0	0
CWHEAT	12	4	27	10	20	34	0	0	26	15
CMAIZE	50	55	28	54	0	20	12	24	13	37
CBARLEY	0	3	9	17	16	10	0	0	22	12
CMILLET	0	0	0	0	0	0	0	0	0	0
CRICE	1	3	0	0	0	0	23	20	0	1
CSORGHUM	11	1	0	0	43	0	22	0	0	1
CSOY	2	4	0	0	0	0	1	4	0	1
CMLSOY	19	17	15	11	19	15	21	25	16	15
CMLOILSDS	0	0	10	1	0	10	0	0	11	5
CMLCTTN	0	0	0	0	0	0	9	0	0	0
FISHMEAL	1	1	3	1	0	4	4	5	0	1
MOLASSES	1	0	0	0	0	0	0	0	2	1
CGRNBYDRY	1	9	6	4	0	5	5	5	5	6
SYNTHETIC	2	2	2	2	2	2	2	2	2	2
Nutritional values	**LAC**	**E & SE Asia**	**E. Europe**	**N. America**	**Oceania**	**Russian Fed.**	**South Asia**	**NENA**	**W. Europe**	**Global average**
DE *(kJ/kg DM)*	16 263	15 822	15 227	15 723	15 531	15 188	14 817	15 269	14 762	15 421
N *(g/kg DM)*	32.5	32.6	37.0	27.6	32.1	38.4	39.5	38.8	36.5	33.3
DE *(percentage)*	85	83	80	83	82	80	79	81	78	81

* Definitions of each of the feed names are given in Table A1.

Sources: GLEAM based on input data from literature, national inventory reports, expert knowledge and databases (SPAM, FAOSTAT).

Table B12b. Regional average ration composition and nutritional value in Sub-Saharan Africa: industrial pigs

SSA average ration	**LOCAL feed** *(percentage)*	**NON-LOCAL feed** *(percentage)*
PULSE STRAW	4	NA
CASSAVA	4	11
MAIZE	2	18
MILLET	1	10
RICE	1	5
SORGHUM	1	19
SUGARCANE TOPS	1	NA
BANANA STEM	1	NA
SOYMEAL	1	6
OIL SEED MEAL	5	0
COTTON SEED MEAL	1	0
GRNBYDRY*	3	0
FISH MEAL	NA	3
MOLASSES	NA	1
SYNTHETIC	NA	2

Nutritional values	**SSA average ration**
DE *(kJ/kg DM)*	14 692
N *(g/kg DM)*	26.4
DE *(percentage)*	79

* Grain by-products.

NA: Not Applicable.

Sources: GLEAM based on input data from literature, national inventory reports, expert knowledge and databases (SPAM, FAOSTAT).

Table B13. Regional average ration composition and nutritional value: backyard chickens

LOCAL Feeds*	LAC	E & SE Asia	E. Europe	Russian Fed.	South Asia	SSA	NENA	W. Europe	Global average
	Percentage of feed material in the ration (by mass on a dry matter basis)								
SWILL	40	40	20	20	40	40	40	20	39
PULSES	0	0	1	1	1	2	1	0	0
CASSAVA	2	1	0	0	0	8	0	0	1
WHEAT	1	3	16	27	12	1	15	17	6
MAIZE	7	5	11	1	2	11	2	23	5
BARLEY	0	0	6	10	2	0	4	4	1
MILLET	0	0	0	1	0	3	0	0	0
RICE	6	14	0	0	14	3	1	0	10
SORGHUM	1	0	0	0	0	3	3	0	1
SOY	3	1	0	0	0	0	0	1	1
MLSOY	20	5	1	2	2	2	0	4	6
MLOILSDS	12	18	26	19	6	11	18	8	16
MLCTTN	2	1	0	0	5	6	3	0	2
GRNBYDRY	7	11	17	19	15	11	13	22	12
Nutritional values	**LAC**	**E & SE Asia**	**E. Europe**	**Russian Fed.**	**South Asia**	**SSA**	**NENA**	**W. Europe**	**Global average**
ME *(kJ/kg DM)*	11 582	11 608	11 565	11 550	11 750	12 023	11 787	12 189	11 668
GE *(kJ/kg DM)*	18 928	18 681	18 825	18 749	18 574	18 601	18 693	18 824	18 699
ME/GE *(percentage)*	61	62	61	62	63	65	63	65	62
N *(g/kg DM)*	43.9	37.0	35.7	33.6	32.7	33.3	35.7	30.0	36.8

* Definitions of each of the feed names are given in Table A2.

Sources: GLEAM based on input data from literature, national inventory reports, expert knowledge and databases (SPAM, FAOSTAT).

Table B14. Regional average ration composition and nutritional value: broilers

NON-LOCAL Feeds*	LAC	E & SE Asia	E. Europe	N. America	Oceania	Russian Fed.	South Asia	SSA	NENA	W. Europe	Global Average
	Percentage of feed material in the ration (by mass on a dry matter basis)										
CWHEAT	0	13	39	0	33	38	18	6	16	40	10
CMAIZE	70	47	28	62	5	30	38	64	44	24	53
CBARLEY	0	4	0	0	7	0	5	0	4	0	1
CSORGHUM	0	7	0	0	21	0	9	0	7	5	3
CSOY	0	0	25	2	3	25	0	0	0	15	3
CMLSOY	28	25	0	24	16	0	24	28	25	10	23
CMLOILSDS	0	1	6	5	2	5	2	0	2	2	2
FISHMEAL	0	1	0	5	5	0	2	0	2	0	2
SYNTHETIC	1	1	1	1	1	1	1	1	1	1	1
RAPESEED	0	0	0	0	1	0	0	0	0	1	0
MLRAPE	0	0	0	0	4	0	0	0	0	1	0
LIME	1	1	1	1	2	1	1	1	1	1	1

Nutritional values	LAC	E & SE Asia	E. Europe	N. America	Oceania	Russian Fed.	South Asia	SSA	NENA	W. Europe	Global Average
ME *(kJ/kg DM)*	13 940	13 689	14 484	13 804	13 278	14 583	13 596	13 860	13 656	14 154	13 845
GE *(kJ/kg DM)*	18 989	18 892	19 831	19 064	18 771	19 831	18 856	18 967	18 878	19 568	19 060
ME/GE *(percentage)*	73	72	73	72	71	74	72	73	72	72	73
N *(g/kg DM)*	33.7	34.8	32.8	39.2	37.3	32.2	35.3	34.0	34.9	33.3	35.7

* Definitions of each of the feed names are given in Table A1.

Sources: GLEAM based on input data from literature, national inventory reports, expert knowledge and databases (SPAM, FAOSTAT).

Table B15. Regional average ration composition and nutritional value: layers

NON-LOCAL Feeds*	LAC	E & SE Asia	E. Europe	N. America	Oceania	Russian Fed.	South Asia	SSA	NENA	W. Europe	Global Average
	Percentage of feed material in the ration (by mass on a dry matter basis)										
CWHEAT	4	3	48	2	32	52	30	7	22	44	14
CMAIZE	29	57	9	65	10	0	27	59	42	22	44
CBARLEY	0	0	16	0	0	30	0	0	0	0	2
CSORGHUM	37	0	0	0	21	0	0	0	0	0	4
CSOY	3	18	2	2	4	0	0	3	15	19	12
CMLSOY	14	3	3	22	2	0	8	14	4	1	7
CMLOILSDS	5	3	5	0	9	8	9	9	2	0	4
FISHMEAL	0	0	2	0	5	2	10	0	0	0	1
CGRNBYDRY	0	5	0	0	0	0	8	0	0	1	3
SYNTHETIC	1	1	1	1	1	1	1	1	1	1	1
RAPESEED	0	1	7	0	8	0	0	0	7	4	1
LIME	7	8	7	8	7	7	6	7	7	8	8
Nutritional values	**LAC**	**E & SE Asia**	**E. Europe**	**N. America**	**Oceania**	**Russian Fed.**	**South Asia**	**SSA**	**NENA**	**W. Europe**	**Global Average**
ME *(kJ/kg DM)*	13 177	13 602	13 168	13 152	13 356	12 637	12 503	13 114	13 868	13 791	13 398
GE *(kJ/kg DM)*	17 855	18 511	18 161	17 735	18 485	17 258	17 683	17 850	18 940	18 641	18 260
ME/GE *(percentage)*	74	73	73	74	72	73	71	73	73	74	73
N *(g/kg DM)*	28.7	28.0	27.2	30.1	31.4	24.6	37.1	30.0	28.5	27.6	28.9

* Definitions of each of the feed names are given in Table A1.

Sources: GLEAM based on input data from literature, national inventory reports, expert knowledge and databases (SPAM, FAOSTAT).

Table B16. Characteristics of non-local feed materials

Name*	GE (kJ/kg of DM)	N content (g/kg of DM)	ME (kJ/kg of DM)	ME (kJ/kg of DM)	DE (kJ/kg of DM)
	All Species	**All Species**	**Chickens**	**Pigs**	**Pigs**
CMLSOY	19 960	76.9	9 758	14 621	16 047
CMLOILSDS	19 240	61.8	9 252	11 967	12 893
CMLCTTN	19 240	61.4	8 246	10 053	10 837
PKEXP	19 240	27.0	NA	11 489	11 874
MOLASSES	15 230	9.4	10 463	12 561	12 638
CGRNBYDRY	18 910	28.1	7 292	10 112	10 423
GRNBYWET	20 050	47.2	NA	9 215	9 721
MLRAPE	19 240	56.1	9 252	NA	NA
SOYBEAN OIL	39 800	0.0	39 055	NA	NA
CPULSES	18 850	39.6	11 319	14 759	15 443
CWHEAT	18 500	20.0	14 506	15 044	15 357
CMAIZE	18 880	15.1	15 839	16 447	16 684
CBARLEY	18 460	18.7	13 112	13 680	13 942
CMILLET	18 680	19.7	13 533	13 714	13 999
CRICE	17 700	13.8	12 551	13 398	13 576
CSORGHUM	18 800	16.9	15 101	15 702	15 969
CCASSAVA	16 900	4.5	13 148	13 580	13 610
CSOY	23 960	61.5	14 945	18 314	19 703
RAPESEED	28 800	34.3	16 490	NA	NA
FISHMEAL	18 840	110.3	15 215	15 215	17 522
SYNTHETIC	18 450	160.0	12 000	12 500	15 763
LIME	0	0.0	0	0	0

NA: Not Applicable.

* Definitions of each of the feed names are given in Table A1.

Source: based on CVB tables (Dutch feed board database), FEEDIPEDIA and NRC (1994, 1998).

Table B17. Characteristics of local feed materials

Name*	**GE** *(kJ/kg of DM)*	**N content** *(g/kg of DM)*	**ME** *(kJ/kg of DM)*	**ME** *(kJ/kg of DM)*	**DE** *(kJ/kg of DM)*
	All Species	**All Species**	**Chickens**	**Pigs**	**Pigs**
MLSOY	19 960	76.9	9 758	14 621	16 047
MLOILSDS	19 240	61.8	9 252	11 967	12 893
MLCTTN	19 240	61.4	8 246	10 053	10 837
GRNBYDRY	18 910	28.1	7 292	10 696	11 024
PSTRAW	18 450	8.9	NA	8 889	8 956
TOPS	18 450	9.0	NA	9 500	9 584
BNSTEM	17 900	12.0	NA	9 000	9 116
GRASSF	17 800	27.8	NA	10 556	10 880
LEAVES	19 000	50.0	NA	8 500	9 068
SOY	23 960	61.5	14 945	18 314	19 703
PULSES	18 850	39.6	11 319	14 759	15 443
CASSAVA	16 900	4.5	13 148	13 580	13 610
WHEAT	18 500	20.0	14 506	15 044	15 356
MAIZE	18 880	15.1	15 839	16 447	16 684
BARLEY	18 460	18.7	13 112	13 680	13 942
MILLET	18 680	19.7	13 533	13 714	13 999
RICE	17 700	13.8	12 551	13 398	13 576
SORGHUM	18 800	16.9	15 101	15 702	15 969
BNFRUIT	17 200	8.5	NA	16 092	16 224
SWILL	18 450	35.0	13 000	10 500	10 971

NA: Not Applicable.

* Definitions of each of the feed names are given in Table A2.

Source: based on CVB tables (Dutch feed board database), FEEDIPEDIA and NRC (1994, 1998).

5. EMISSION FACTORS FOR KEY INPUTS INTO FEED PRODUCTION

Emissions of fossil CO_2 from feed production, transport and processing are dependent on the amount and type of fuel used. Table B18 presents EF used in the calculation of the feed emission intensity.

6. MANURE MANAGEMENT

There are considerable differences in emission between manure management systems (MMSs). Data requirements for the estimation of GHG emissions from MMSs include: information on how manure is managed, the types of MMS, and the proportion of manure managed in these systems. Additionally, climatic information (e.g. temperature) is important as emission factors are climate dependent. It was, thus, necessary to consider the climate under which livestock is managed in each country.

On a global scale, there are very limited data available on how manure is managed and the proportion of the manure managed in each system. Consequently, this study relied on various data sources such as national inventory reports, literature, expert knowledge to define the MMS and the proportions of manure managed in these systems. This study uses the IPCC (2006) classification of MMSs (definition in Table 10.18). Regional variations of MMS are presented in Tables B19 to B22.

Quantifying enteric emissions from pigs. The national average Y_m in this study varies depending on the herd structure, between 0.42 percent and 0.48 percent. This value is lower than the default value used by most Annex I countries using the Tier 2 approach (EEA 2007, Table 6.22), which is based on the IPCC (1997 p4.35 Table A6) values of 0.6 percent for developed countries and 1.3 percent for developing countries (see Table B23).

Table B18. Emission factors used in crop production, non-crop feeds and fuel consumption

	EF	Source
Ammonium nitrate	6.8 $kg\ CO_2\text{-}eq/kg\ N$	Jenssen and Kongshaug (2003)
Feed		
Fishmeal	1.4 $kg\ CO_2\text{-}eq/kg\ DM$	Berglund *et al.* (2009)
Synthetic	3.6 $kg\ CO_2\text{-}eq/kg\ DM$	Berglund *et al.* (2009)
Lime	0.079 $kg\ CO_2\text{-}eq/kg\ DM$	FEEDPRINT*
Fuel		
Diesel	3.2 $kg\ CO_2\text{-}eq/l\ diesel$	Berglund *et al.* (2009)
Oil	5.7 $kg\ CO_2\text{-}eq/kg\ oil$	de Boer (2009)
Coal	17.8 $kg\ CO_2\text{-}eq/kg\ coal$	de Boer (2009)
Gas	7.6 $kg\ CO_2\text{-}eq/m^3\ gas$	de Boer (2009)

*http://webapplicaties.wur.nl/software/feedprint/

Table B19. Regional average manure management and CH_4 and N_2O emissions factors for industrial and intermediate pigs

	Regional weighted average percentage of manure managed in each system												Weighted average conversion factors	
	Uncovered anaerobic lagoon	Liquid/ slurry - no crust	Liquid/ slurry - crust	Solid storage	Drylot	Pasture, range, paddock	Daily spread	Burned for fuel	Pit < 1 month (Pit1)	Pit > 1 month (Pit2)	Litter	Anaerobic digester	Methane conversion factor *(percentage)*	kg N_2O-N/ kg Nx
LAC	13	15	15	14	41	0	2	0	0	0	0	0	23.6	0.014
E & SE Asia	32	10	10	0	6	0	0	0	34	0	0	7	30.6	0.007
E. Europe	7	15	15	54	2	0	0	0	3	3	0	0	10.3	0.009
N. America	27	17	17	4	3	0	0	0	0	33	0	0	29.8	0.006
Oceania	93	0	0	0	7	0	0	0	0	0	0	0	68.9	0.006
Russian Fed.	0	12	12	76	0	0	0	0	0	0	0	0	5.0	0.009
South Asia	12	11	11	14	33	0	8	0	3	0	0	8	23.9	0.012
SSA	0	4	4	6	85	0	0	0	1	0	0	0	7.1	0.021
NENA	10	15	15	0	53	0	0	0	0	0	0	7	11.9	0.016
W. Europe	6	27	27	14	0	0	1	0	1	25	0	0	16.8	0.007
Global average	21	16	16	10	8	0	1	0	16	10	0	3	25.0	0.008

Source: Literature, surveys and expert knowledge.

Table B20. Regional average manure management and CH_4 and N_2O emissions factors for backyard pigs

	Percentage of manure managed in each system												Global average conversion factors	
	Uncovered anaerobic lagoon	Liquid/ slurry - no crust	Liquid/ slurry - crust	Solid storage	Drylot	Pasture, range, paddock	Daily spread	Burned for fuel	Pit < 1 month (Pit1)	Pit > 1 month (Pit2)	Litter	Anaerobic digester	Methane conversion factor *(percentage)*	kg N_2O-N/ kg Nx
Global	5	30	0	15	15	5	5	0	15	5	0	5	16.4	0.010

Source: Literature, surveys and expert knowledge.

Table B21. Regional average manure management and CH_4 and N_2O emissions factors for layers

	Regional weighted average percentage of manure managed in each system												Weighted average conversion factors	
	Uncovered anaerobic lagoon	Liquid/ slurry - no crust	Liquid/ slurry - crust	Solid storage	Drylot	Pasture, range, paddock	Daily spread	Burned for fuel	Pit < 1 month (Pit1)	Pit > 1 month (Pit2)	Litter	Anaerobic digester	Methane conversion factor *(percentage)*	kg N_2O-N/ kg Nx
LAC	0	33	33	35	0	0	0	0	0	0	0	0	27.5	0.009
E & SE Asia	0	6	6	0	1	2	3	0	0	83	0	0	26.0	0.009
E. Europe	0	0	0	0	49	0	0	0	0	33	17	0	6.7	0.014
N. America	1	15	15	70	0	0	0	0	0	0	0	0	8.3	0.009
Oceania	0	0	0	0	0	23	0	0	0	77	0	0	24.4	0.012
Russian Fed.	0	0	0	0	0	0	0	0	0	100	0	0	17.7	0.008
South Asia	0	0	0	100	0	0	0	0	0	0	0	0	4.1	0.010
SSA	0	0	0	0	0	0	0	0	0	90	10	0	54.2	0.008
NENA	18	3	3	18	0	0	0	0	0	55	2	0	33.9	0.008
W. Europe	0	0	0	21	18	0	1	0	0	46	14	0	9.8	0.011
Global average	1	8	8	22	4	1	1	0	0	53	2	0	21.3	0.009

Source: Literature, surveys and expert knowledge.

Table B22. Regional average manure management and CH_4 and N_2O emissions factors for broilers and backyard chickens

	Percentage of manure managed in each system			Weighted average conversion factors	
	Litter	**Pasture, range, paddock**	**Daily spread**	**Methane conversion factor** (*percentage*)	**kg N_2O-N/ kg Nx**
Broilers	100			1.5	0.005
Backyard		50	50	1.0	0.010

Source: Literature, surveys and expert knowledge.

Table B23. Comparison of enteric CH_4 emission factors in EU15 and Annex I countries with more than 10 million pigs in 2005

	NIR implied enteric EF (*kg CH_4/head/year*)	FAO LCA enteric CH_4 (*kg CH_4/head/year*)
EU-15	1.00	1.03
Canada	1.50	1.02
Russian Federation	1.50	1.02
United States of America	1.50	0.97

Source: GLEAM.

Table B24. Percentages for the conversion of live weight to carcass weight and carcass weight to bone-free meat

Species	System	CW/LW (*percentage*)	BFM/CW (*percentage*)
Pigs	Backyard	65	65
	Intermediate	75	65
	Industrial	Country-specific values	65
Chickens	Layers	55	75
	Broilers	Country-specific values	75
	Backyard	Laying hens: 55, other chickens: same as broilers	75

Source: Literature, surveys and expert knowledge.

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