1. Introduction

1.1 BACKGROUND

The global livestock sector is faced with a three-fold challenge: increasing production to meet demand, adapting to a changing and increasingly variable economic and natural environment and, lastly, improving its environmental performance. Major concerns have been raised about the potential consequences of livestock sector growth; in particular, that it will cause increased natural resource use and degradation, contribute to global warming, deplete water resources, impact on biodiversity and cause habitat change. These concerns have raised interest in assessing the environmental performance of livestock production systems (LPS), to improve understanding of how the sector can meet future demand in a sustainable way.

In response to the challenge posed by climate change, the Animal Production and Health Division (AGA) of FAO has, since 2009, engaged in a comprehensive assessment of livestock-related GHG emissions, with the aim of identifying low-emission development pathways for the livestock sector. The assessment has two primary objectives: firstly, to disaggregate and refine the initial estimates of the livestock sector's overall emissions provided in *Livestock's long shadow* (FAO, 2006), and secondly, to identify potential mitigation options along livestock supply chains. This report presents an update of FAO (2006) assessment of GHG emissions from pig and chicken supply chains (meat and eggs). It is one part of continuing efforts by FAO to improve assessment of the sector's GHG emissions.

1.2 SCOPE OF THIS REPORT

Livestock commodities differ in resource use and emission profile. These variations reflect fundamental differences both in their underlying biology and in modes of production. This report quantifies GHG emissions and analyses them in terms of: main pig and chicken products (meat and eggs); predominant pig and chicken production systems; world regions and agro-ecological zones; and major stages in the supply chains.

The assessment takes a supply chain approach. Emissions generated are estimated during: (a) the production of inputs for the production process, (b) crop and animal production and (c) subsequent transport of the outputs and processing into basic commodities. Emissions and food losses that arise after delivery to the retail point are not included in this report. Given the global scope of the assessment and the complexity of livestock supply chains, several hypotheses and generalizations had to be made to keep data requirements of the assessment manageable. They are documented in the report and their impact on results is analysed.

This report is aimed primarily at a technical audience, within private and public organizations, academia, and in the LCA community. General readers will find a comprehensive review of results, methods and the mitigation potential in the livestock sector in an overview report published in parallel to this one (FAO, 2013a).

By providing a consistent global analysis, this assessment should aid efforts to identify priority areas for mitigation, while providing a benchmark against which future trends can be measured.

This report focuses on GHG emissions only. Other environmental dimensions, such as water resources, land, biodiversity and nutrients have not been considered. GHG emissions from the livestock sector need to be placed within this broader context, so that the synergies and trade-offs among competing environmental, social and economic objectives can be fully understood.

The base year selected for this assessment is 2005. This year was chosen because at the start of the assessment the available spatial data and, in particular, the map of predicted livestock densities, were based on 2005 data.

1.3 THE GLOBAL LIVESTOCK ENVIRONMENTAL ASSESSMENT MODEL (GLEAM)

This update is based on a newly developed analytical framework: the Global Livestock Environmental Assessment Model (GLEAM). GLEAM integrates existing knowledge on production practices and emissions pathways and offers a framework for disaggregation and comparisons of emissions on a global scale. GLEAM has been developed for six animal species (cattle, buffalo, sheep, goats, pigs and chickens) and their edible products. It recognizes two farming systems for ruminant species (mixed and grazing), three for pigs (backyard, intermediate and industrial) and three for chickens (backyard, industrial egg and industrial meat). In total, more than 14 000 theoretical supply chains can be identified, each uniquely defined in terms of commodity, farming system, country and climatic zone.

Four publications present the results of this work:

- the present technical report, addressing global pig and chicken (meat and eggs) sectors;
- a report addressing global cattle and small ruminant (sheep and goat) sectors, published in parallel to this report (FAO, 2013b);
- an earlier technical report published in 2010, addressing the world dairy sector (FAO, 2010);
- an overview report, summarizing the above at the sector level and providing additional cross-cutting analysis of emissions and mitigation potential, published in parallel to this report (FAO, 2013a).

1.4 OUTLINE OF THIS REPORT

This report consists of six sections (including this introductory section). Section two starts with a brief introduction to the global monogastric sector describing production systems and their contribution to global meat and eggs production.

Section 3 gives an overview of the approach used in the estimation of GHG emissions in this assessment, providing basic information on the LCA approach. It provides a description of the functional units used, system boundary, allocation to co-products and sources of GHG emissions. The section also gives an overview of the monogastric production system typology applied, the tool (GLEAM) and methods as well as broader information on data sources and management. Detailed description of the approach and methods can be found in the appendices.

The results (total emissions and emission intensities) of this assessment are presented in Section 4 for pigs and Section 5 for chickens, with a discussion on the most important sources and drivers of emissions from both species as well as a discussion on uncertainty and assumptions likely to influence the results. These sections also present the results of the Monte Carlo uncertainty analysis performed in this study.

Section 6 presents the conclusions and recommendations that can be drawn from this work, illustrates the gaps within systems and regions and outlines some areas for improvement.

The appendices in this report provide a detailed description of the GLEAM model, methods applied (on quantifying carbon losses from land-use change, on-farm direct and indirect energy use and postfarm emissions) and data. The appendices also explore different computation approaches (e.g. for estimating LUC emissions and allocation of emissions to slaughter by-products) and their impact on emission intensity.

2. Overview of the global monogastric sector

In this report, the monogastric sector comprises pigs and chickens. The global pig population in 2010 was estimated to be 968 million animals (FAOSTAT, 2012), 20 percent more than in 1980. The global poultry population in 2010 was estimated to be almost 22 billion animals, nearly 3 times as much as in 1980, with chickens making up 90 percent (including nearly 6 billion laying hens), ducks 6 percent, geese 2 percent and turkeys 2 percent.

The pig sector is the biggest contributor to global meat production, with 37 percent of the total 296 million tonnes carcass weight (CW) in 2010. Poultry produced 33 percent of the global meat in 2010 and ruminants, 28 percent. Chicken meat accounts for 88 percent of total poultry meat; turkey, 5 percent; duck, 4 percent and goose, 3 percent.

In 2010, total egg production reached 69 million tonnes, hen eggs accounting for 92 percent of it, with 1.2 billion eggs.

Pig production worldwide ranges from traditional subsistence-driven small-scale production to specialized industrial farming. The latter has a distribution pattern similar to the intensive poultry sector in that it is concentrated near towns and sources of inputs. In this study, three different types of pig systems are considered: backyard, intermediate and industrial, with respective contributions to total pig production of 19 percent, 20 percent and 61 percent.

Pig production can be found on all continents, except for some regions with cultural and religious strictures regarding the consumption of pork. But pigs are geographically concentrated, with 95 percent of production taking place in East and Southeast Asia, Europe and the Americas. In addition to cultural preferences, the location of pig production, from large- or medium-scale industrial systems, in particular, is also driven by factors such as proximity of output markets, infrastructures and cost of land (FAO, 2011, p. 44).

Large-scale and market-oriented pig production systems have achieved a high level of uniformity in terms of animal genetics, feed and housing systems. On the other hand, in developing countries, half of the current pig population is still kept in backyard, small-scale and low-input systems in which pigs represent an important source of nutrition and income, as well as fulfilling a role in cultural traditions.

Poultry production also ranges from extensive production systems supporting livelihoods and supplying local or niche markets to industrialized production systems of large- and medium-size feeding into integrated value chains. In this study, three chicken production systems are considered: backyard, broiler and layer.

Backyard chicken systems can be found worldwide and contribute to 4 percent of total poultry meat production and 14 percent of total eggs production, according to the results of this study. Backyard chickens are kept in simple night shelters with limited management and disease prevention measures, and fed a mixture of household food waste and second grade crops, which they supplement by scavenging for opportunistic food sources such as insects and food scraps. Backyard poultry make a significant contribution to food security and livelihoods by providing a relatively low cost source of high quality protein and a source of cash income.

Specialized layer systems contribute to 86 percent of total egg production and to 6 percent of total poultry meat production. Laying hens in commercial medium- or large-scale units are bred to lay eggs and the meat is often used for pet food or animal feed rather than human food. These selected types require a suitable physical environment, optimal nutrition and efficient protection from the effects of disease. To achieve these, the birds are usually confined, so they need to be provided with all or most of their nutritional requirements. East and Southeast Asia dominate egg production, accounting for 42 percent (by mass) of eggs from layers.

Chicken meat production has increased tenfold over the past 50 years, in particular, in specialized broiler systems. According to the results of this study, they now account for 81 percent of total poultry meat production and are particularly concentrated in Latin America and the Caribbean, North America and East and Southeast Asia. Specialized broiler systems in these regions account for around 70 percent of total chicken meat production. As for specialized layer operations, technology developments and advances in breeding have led the poultry industry and the associated feed industry to scale up rapidly, to concentrate themselves close to input sources or final markets, and to integrate vertically (FAO, 2006).

3. Methods

3.1 CHOICE OF LIFE CYCLE ASSESSMENT (LCA)

The LCA approach is now widely accepted in agriculture and other industries as a method by which the environmental impacts of production can be evaluated and hotspots within the life cycle identified. The method is defined by the International organization for standardization (ISO) standards 14040 and 14044 (ISO, 2006a, b). The main strengths of LCA lie in its ability to provide a holistic assessment of production processes, and to identify measures that merely shift environmental problems from one phase of the life cycle to another. However, LCA also presents significant challenges, particularly when applied to agriculture. First, the data-intensive nature of the method often requires simplification of the inherent complexity of food supply chains. A second difficulty lies in the fact that variation in methods and assumptions – such as the choice of system boundary, functional units and allocation techniques – can affect results.

3.2 GENERAL PRINCIPLES OF LCA

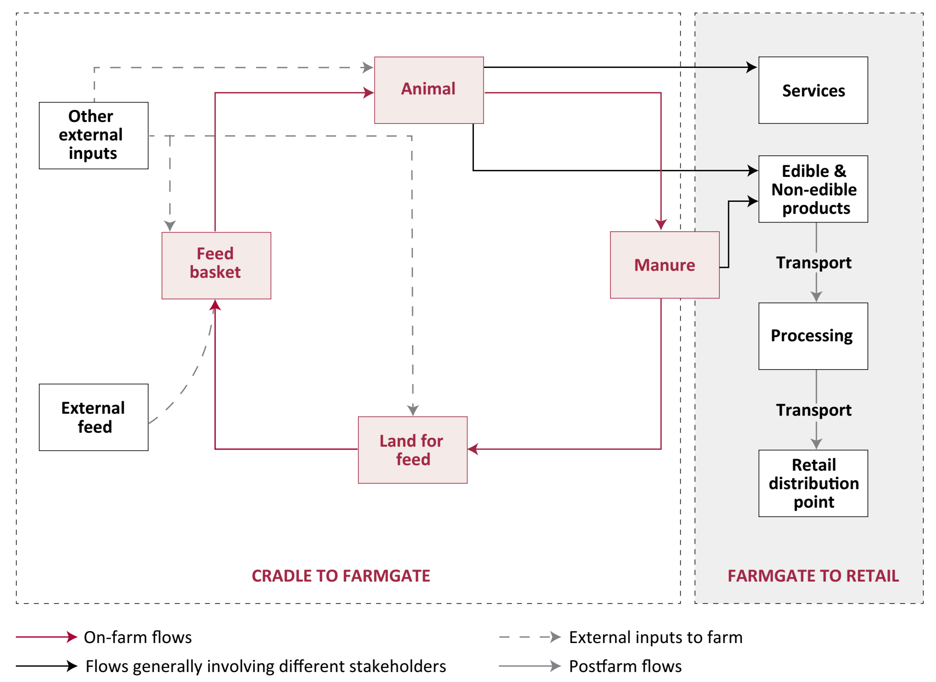
LCA was originally applied to analyse industrial processes, but it has been progressively adapted to assess the environmental impacts of agriculture. LCA involves the systematic analysis of production systems, considering all inputs and outputs for a specific product within a defined system boundary. The system boundary largely depends on the goal of the study. The reference unit that denotes the useful output of the production system is known as the functional unit and it has a defined quantity, such as one kg of CW. The application of LCA to agricultural systems is often complicated by the multiple-output nature of production (e.g. laying chickens produce eggs, meat, manure and some slaughter by-products). This complexity means that the total environmental impact of production needs to be partitioned between the various outputs using system expansion or allocation.

3.3 THE USE OF LCA IN THIS ASSESSMENT

In recent years, a range of LCA studies have been conducted concerning pigs and chickens (see Tables 21 and 30). Although LCA methods are well defined, these studies vary considerably in their level of detail, their definition of system boundaries, the emission factors (EF) they use, and other technical aspects, such as the allocation techniques and functional units they employ. This assessment sets out to perform an LCA for the global pig and chicken sectors, using consistent calculation methods, modelling approaches, and data and parameters for each production system. Unlike previous LCA studies of the livestock sector which have concentrated on emissions in Organisation for Economic Co-operation and Development (OECD) countries, this study is global in scope and includes both developed and developing countries. Onerous data requirements have meant the study has had to employ simplifications resulting in a loss of accuracy, particularly for systems at lower levels of aggregation.

An attributional approach is adopted in this study, i.e. the average environmental performance under current production and market conditions is estimated. The

Figure 1.
System boundary as defined for this assessment



Source: Authors.

consequential LCA approach, by contrast, uses marginal analysis to estimate the environmental performance of producing an additional unit of product.

This assessment is based on the methodology for LCA, as specified in the following documents:

- *Environmental management. Life cycle assessment. Requirements and guidelines.* BS EN ISO14044 (ISO, 2006b).
- British Standards Institute PAS 2050; 2008. *Specification for the assessment of the life cycle greenhouse gas emissions of goods and services* (BSI, 2008).

3.3.1 Functional units and system boundary

In this assessment, the results are expressed both in kg of CO_2-eq per kg of product (CW or eggs) and kg of CO_2-eq per kg of protein. The latter allows comparisons between different product types.

The assessment encompasses the entire livestock production chain, from feed production through to the final processing of product, including transport to the retail point (see Figure 1). The cradle to retail system boundary is split into two subsystems:

- *Cradle to farmgate* includes all upstream processes in livestock production up to the farmgate, where the animals or products leave the farm, i.e. production of farm inputs and on-farm production activities.
- *Farmgate to retail* includes transport of animals and product to processing plants or directly to market, processing into primary products, refrigeration during transport and processing, production of packaging material and transport to the retail distributor.

Table 1. Sources of GHG emissions included and excluded in this assessment

<table>
<tr><th>Supply chain</th><th>Activity</th><th>GHG</th><th>Included</th><th>Excluded</th></tr>
<tr><td rowspan="3">Upstream</td><td rowspan="2">Feed production</td><td>N_2O</td><td>Direct and indirect N_2O from:
• Application of synthetic N
• Application of manure
• Direct deposition of manure by scavenging animals
• Crop residue management</td><td>• N_2O losses related to changes in C stocks
• Biomass burning
• Biological fixation
• Emissions from non N fertilizers and lime</td></tr>
<tr><td>CO_2
N_2O
CH_4</td><td>• Energy use in field operations
• Energy use in feed transport and processing
• Fertilizer manufacture
• Feed blending
• Production of non-crop feeds (fishmeal, lime and synthetic amino acids)
• CH_4 from flooded rice cultivation
• Land-use change related to soybean cultivation</td><td>• Changes in carbon stocks from land use under constant management practices</td></tr>
<tr><td>Non-feed production</td><td>CO_2</td><td>• Embedded energy related to the manufacture of on-farm buildings and equipment</td><td>• Production of cleaning agents, antibiotics and pharmaceuticals</td></tr>
<tr><td rowspan="3">Animal production unit</td><td rowspan="3">Livestock production</td><td>CH_4</td><td>• Enteric fermentation
• Manure management</td><td></td></tr>
<tr><td>N_2O</td><td>• Direct and indirect N_2O from manure management</td><td></td></tr>
<tr><td>CO_2</td><td>• Direct on-farm energy use for livestock, e.g. cooling, ventilation and heating</td><td></td></tr>
<tr><td>Downstream</td><td>Post farmgate</td><td>CO_2;
CH_4;
HFCs</td><td>• Transport of live animals and products to slaughter and processing plant
• Transport of processed products to retail point
• Refrigeration during transport and processing
• Primary processing of meat into carcasses or meat cuts and eggs
• Manufacture of packaging</td><td>• On-site waste water treatment
• Emissions from animal waste or avoided emissions from on-site energy generation from waste
• Emissions related to slaughter by-products e.g. rendering material, offal, hides and skin
• Retail and post-retail energy use
• Waste disposal at retail and post-retail stages</td></tr>
</table>

Source: Authors.
Note: The categories used for reporting emissions are outlined in Table 2.

All aspects related to the final consumption of eggs and meat products (i.e. consumer transport to purchase product, food storage and preparation, food waste and waste handling of packaging) lie outside the defined system and so are excluded from this assessment.

3.3.2 Sources of GHG emissions

This study focuses on emissions of the three major GHGs associated with animal food chains, namely, CH_4, N_2O, CO_2 as well as GHGs related to refrigerants. A number of potential GHG emissions and sinks were excluded from the analysis (Table 1). The categories used for reporting emissions are outlined in Table 2.

Table 2. Categories of GHG emissions

Category		Description
Feed N_2O		Direct and indirect N_2O emissions from organic and synthetic N applied to feed crops and crops residues
Feed CO_2	Feed: non-crop	CO_2 arising from the production of fishmeal and synthetic feed additives (and lime for chickens)
	Feed: blending and transport	CO_2 arising from the production and transportation of compound feed
	Feed: fertilizer production	CO_2 from energy use during the manufacture of urea and ammonium nitrate (and small amounts of N_2O)
	Feed: processing and transport	CO_2 from energy use during crop processing (e.g. oil extraction) and transportation by land and (in some cases) sea
	Feed: field operations	CO_2 arising from the use of energy for field operations (tillage, fertilizer application). Includes emissions arising during both fuel production and use.
Feed LUC CO_2		CO_2 from LUC associated with soybean cultivation
Feed rice CH_4		CH_4 arising from the anaerobic decomposition of organic matter during rice cultivation
Indirect energy CO_2		CO_2 arising from energy use during the production of the materials used to construct farm buildings and equipment
Manure N_2O		Direct and indirect N_2O emissions arising during manure storage prior to application to land
Manure CH_4		CH_4 emissions arising during manure storage prior to application to land
Enteric CH_4		CH_4 arising from enteric fermentation
Direct energy CO_2		CO_2 arising from energy use on-farm for heating, ventilation etc.
Post farmgate		Processing and transport energy use

Source: Authors.

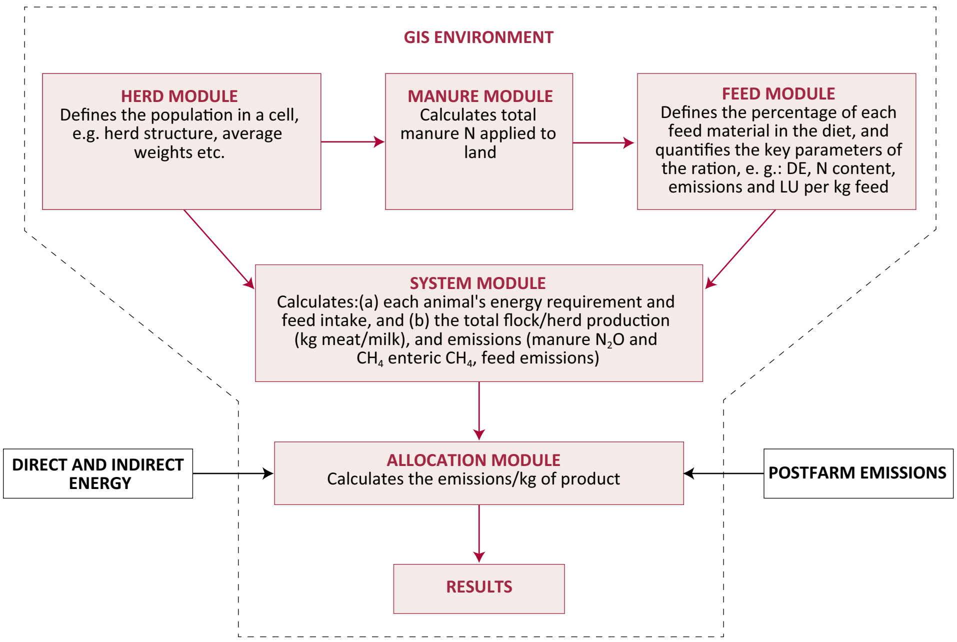
3.4 OVERVIEW OF CALCULATION METHOD

A specific model and related databases were developed to carry out this assessment. GLEAM was designed to represent processes and activities from the production of inputs to the farmgate: the point at which products and animals leave the farm. It consists of five modules: *herd module, manure module, feed module, system module and allocation module* (see Figure 2 and Figure A1 in Appendix A). Two additional modules calculate emissions from (i) post farmgate activities and (ii) indirect energy associated with production of capital goods and on-farm energy use not related to feed production.

3.4.1 Spatial variation and the use of Geographic Information System (GIS)

A challenge faced when using conventional LCA modeling is the complexity and variation in biophysical characteristics (such as soil and climate) as well as production processes. Data on farming activities and farming system parameters were collected at different levels of aggregation: production system, country level, agro-ecological zones or a combination thereof. Thus, for example, information on manure storage in developing countries was found for a combination of production systems and agro-ecological zones, while additional data, such as livestock numbers, pasture and availability of feedstuff were obtained in the form of GIS grids (raster layers) with a spatial resolution not coarser than 5 arc minutes (ca. 10 km x 10 km at the equator).

Figure 2.
Overview of the GLEAM modules and computation flows



Source: Authors.

For the outputs of GLEAM, a spatial resolution of 3 arc minutes (ca. 5 km x 5 km at the equator) has been used. GIS can store data for specific locations (e.g. soil types, climate factors) and perform calculations with them. It can also calculate regional summaries, such as total area and emissions. GIS was used to analyse spatially varied data (such as crop yields, livestock species distribution). It was used to generate location-specific input data required for LCA modeling (e.g. to define the typology of LPS, to calculate location-specific feed crop availability and to classify dominant soil types in forested areas and location-specific temperature to estimate emission factors such as methane conversion factors (MCFs) for manure management systems. GIS was also used to store numerical GLEAM input and output data. The use of GIS has allowed the incorporation of spatial heterogeneity into the modeling process, enhancing the validity of the analysis.

In this way, emissions can be estimated at any location on the globe, using the most accurate information available, and then aggregated for the desired category, such as farming systems, country groups, commodities or animal species. This assessment demonstrates the potential of coupling GIS technology with LCA for assessing GHG emissions from the livestock food chain.

3.4.2 Emission factors

GHG EFs applied for the various emission sources in this assessment are specified in Appendix B of this report. A combination of IPCC (2006) Tier 1 and 2 approaches and EFs are used in the estimation of emissions. Despite the existence of country-specific EFs, the study applies the same approach to all countries. The use of a unified approach was preferred for the assessment, to ensure consistency and comparability of results across regions and farming systems. IPCC Tier 2 approaches were used to model livestock cohorts, to calculate emissions related to enteric fermentation as well as manure management. IPCC Tier 1 method was used where data was generally lacking, such as in the estimation of carbon stocks from LUC, and N_2O from feed production.

The global warming potential (GWP) with a time horizon of 100 years based on the *IPCC Fourth Assessment Report (AR4)* (2007) is used to convert N_2O and CH_4 to CO_2-eq terms. Consequently, GWP of 25 and 298 were used for CH_4 and N_2O, respectively.

3.4.3 Land-use change

Land-use change (LUC) is a highly complex process. It results from the interaction of drivers which may be direct or indirect[9] and which can involve numerous transitions, such as clearing, grazing, cultivation, abandonment and secondary forest re-growth. The debate surrounding the key drivers of deforestation is a continuing one and the causal links (direct and indirect) are both complex and unclear.

The methodology to estimate emissions from LUC associated with feed production considers the effects of converting forested land to cropland. Appendix C provides an elaboration of the approach. It applies the Intergovernmental Panel on Climate Change (IPCC) stock-based approach, termed the *Stock-Difference Method*, which can be applied where carbon stocks, in relevant pools, are measured at two points in time to assess carbon stock changes (IPCC, 2006). Carbon is released to the atmosphere through removal of vegetation at the time of deforestation and decay of plant material and soil organic matter in the years following conversion. C pool is defined as the sum of all organically derived carbon present in soils, roots and above ground material. The following emissions from deforestation are considered:

- CO_2 emissions from changes in biomass stocks (above and below ground biomass);
- CO_2 emissions from changes in dead organic matter (litter and deadwood);
- CO_2 emissions from changes in soil carbon stocks.

In this assessment, LUC considered is deforestation associated with soybean production in Brazil and Argentina. This choice results from the use of 2005 as year of reference and from the following observations of trends in land-use transitions and crop expansions:

- In the period 1990-2006[10], which is used as the reference time period in this study, the main global cropland expansions were for maize and soybean production;
- Maize and soybean expansion occurred in different regions of the world but only in Latin America can it be linked to a decrease in forest area during the same period;
- Within Latin America, Brazil and Argentina account for 91 percent of the total soybean area. Over the period 1990–2006, 90 percent of the soybean area expansion in Latin America took place in these two countries.

[9] Direct drivers include conversion of forest areas for plantation crops or cattle ranching, rural settlements, mining and logging. Indirect drivers include subsidies for agribusiness, investment in infrastructure, land tenure issues, absence of adequate surveillance by the government and demand for forest products, such as timber.

[10] 1990 is chosen as the initial year because it is the most recent available year with a consistent forest dataset from the FAOSTAT database. This practically discounts 4 years of LUC related emissions, compared to the 20-year timeframe recommended by IPCC (IPCC, 2006).

LUC emissions were then attributed to only those countries supplied by Brazil and Argentina for soybean and soybean cake, proportionally to the share on imports from these two countries in their soybean supply. This study also provides an analysis of sensitivity to these assumptions, in particular on the reference time period, the expansion of soybean at the expense of other land types including forestland (arable and perennial cropland and grassland) and the assumption that all traded soybean and soybean cake is associated with LUC (see Appendix C).

3.5 DATA SOURCES AND MANAGEMENT

The availability of data varies considerably within and between key parameters. In general, the OECD countries possess detailed statistics, supported by scientific and technical publications. In contrast, there is a paucity of data in non-OECD countries. Where detailed and accurate data are available, they are often outdated and/or lack supporting metadata. During the process of data collection, gaps were addressed, as far as possible, by extensive research of databases, literature sources and expert opinion. Assumptions were made when data could not be obtained. Data collection involved a combination of research, direct communication with experts, and access to public and commercially available Life Cycle Inventories (LCI) packages such as Ecoinvent. The study's main data sources include:

- Gridded Livestock of the World (FAO, 2007);
- datasets from FAOSTAT;
- national inventory reports (NIRs) of the Annex I countries (United Nations Framework Convention for Climate Change (UNFCCC, 2009a);
- national communications of the non-Annex I countries (UNFCCC, 2009b);
- geo-referenced databases on crop production from the International Food Policy Research Institute (You *et al.*, 2010);
- data on above ground net primary production (NGPP) from Habert *et al.*, (2007);
- peer-reviewed journal articles;
- technical reports and other grey literature;
- expert opinion, from individuals and via surveys;
- LCI such as Ecoinvent and the inventories held by the Swedish Institute for Food and Biotechnology (Flysjö *et al.*, 2008), and Wageningen University, the Netherlands (I. de Boer, *Personal communication*).

The year of reference used in this report is 2005, the most recent year for which all input data and parameters are available. Further detail is given in Appendix B.

3.6 ALLOCATION OF EMISSIONS BETWEEN PRODUCTS, BY-PRODUCTS AND SERVICES

Livestock produce a mix of goods and services that cannot easily be disaggregated into individual processes. For example, a laying hen produces eggs, manure, meat and other by-products when it is slaughtered. In LCA, specific techniques are required to attribute relative shares of GHG emissions to each of these goods and services. The ISO recommends avoiding allocation by dividing the main process into subprocesses, or by expanding the product system to include additional functions related to the co-products (ISO, 2006). In situations where allocation cannot be avoided (as is often the case in biological processes, such as livestock production) GHG emissions can be allocated on the basis of causal and physical relationships.

Where physical relationships alone cannot be established or used as a basis for allocation, emissions should be allocated in a way that reflects other fundamental relationships. The most commonly used approach is economic allocation which, in the context of jointly produced products, allocates emissions to each product according to its share of the product's combined economic value. Other indexes, such as weight or protein content can also be used (Cederberg and Stadig, 2003). The allocation techniques used in this assessment to apportion emissions to products and services produced by monogatric systems are summarized below:

- Edible products (meat and eggs): allocation based on protein content
- Slaughter by-products: no allocation is performed in this assessment. Appendix F explores the impact of allocating emissions to slaughter by-products
- Manure: allocation based on sub-division of production process
  - manure storage: emissions from MMS allocated to livestock sector
  - manure applied to feed: emissions allocated to livestock sector based on mass harvested and relative economic value
  - manure applied to non-feed: no allocation to livestock sector
- Capital function: no allocation is performed in this assessment

A detailed account of the application of the allocation technique is provided in Appendix A. Figure 3 illustrates the outputs from the monogastric sector.

3.7 PRODUCTION SYSTEM TYPOLOGY

Three different production systems are defined for pigs (backyard, intermediate and industrial) and chickens (backyard, layers and broilers). Analysing the intermediate and backyard systems is complicated by the fact that, in reality, these are two broad categories covering a wide range of systems. In addition, the boundaries between intermediate and backyard are somewhat blurred. Key features of the systems (as defined in this LCA) are outlined in Table 3 and Table 4.

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

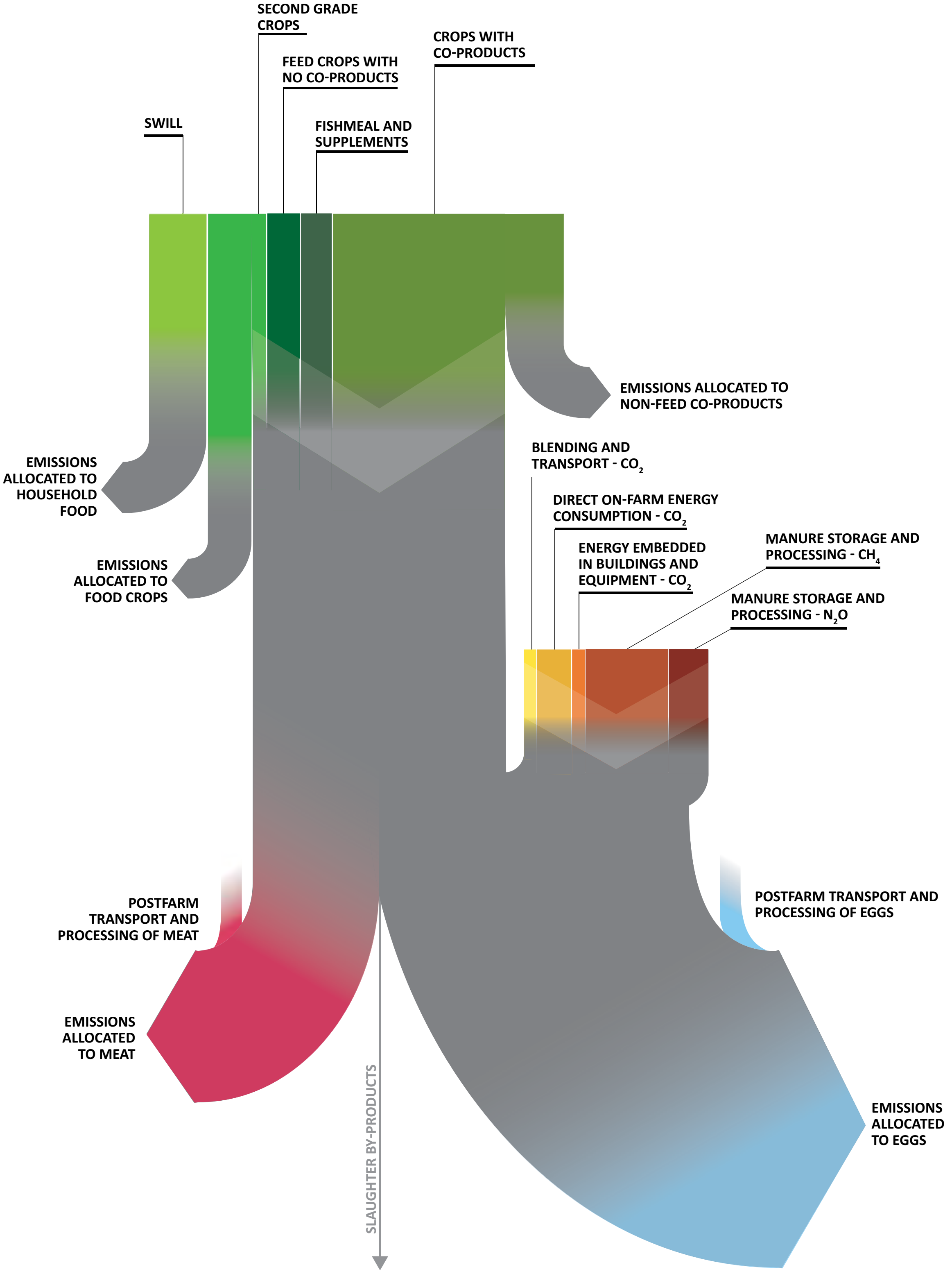
- swill and scavenging
- non-local feed materials
- locally-produced feed materials

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. Definitions of the feed categories (swill, local feeds, non-local feeds) are provided in Appendix B.

This assessment seeks to estimate emissions at global, regional and farming system levels. This typology is based on the classification principles set out by FAO (1996); namely, the feed-base and the agro-ecological conditions of production systems. The following three agro-ecological zones (AEZ) were used:

- *"temperate": temperate regions*, where for at least one or two months a year the temperature falls below 5 °C, and *tropical highlands*, where the daily mean temperature in the growing season ranges from 5 °C to 20 °C ;
- *"arid": arid and semi-arid tropics* and *subtropics*, with a growing period of less than 75 days and 75 to 180 days, respectively;
- *"humid": subhumid tropics and subtropics* and *humid* where the length of the growing period ranges from 181 to 270 days or exceeds 271 days, respectively.

Figure 3.
Illustration of partitioning emissions between chicken outputs



Source: Authors.

Table 3. Summary of the pig systems

System	Housing	Characteristics
Industrial	Fully enclosed: slatted concrete floor, steel roof and support, brick, concrete, steel or wood walls	100 percent market oriented; highest level of capital input requirements (including infrastructure, buildings and equipment); highest level of overall herd performance; purchased non-local feed in diet or on-farm intensively produced feed
Intermediate	Partially enclosed: no walls (or made of a local material if present), solid concrete floor, steel roof and support	100 percent market oriented; medium level of capital input requirements; reduced level of overall herd performance (compared to industrial); locally-sourced feed materials constitute 30 to 50 percent of the ration
Backyard	Partially enclosed: no concrete floor, or if any pavement is present, this is done with local material. Roof and support made of local materials (e.g. mud bricks, thatch, timber; see Ajala *et al.,* 2007)	Mainly subsistence driven or for local markets; level of capital inputs reduced to the minimal; herd performance lower than in commercial systems; feed contains max. 20 percent of purchased non-local feed; high shares of swill, scavenging and locally-sourced feeds

Source: Authors.

Table 4. Summary of the chicken systems

System	Housing	Characteristics
Broilers	Broilers assumed to be primarily loose housed on litter, automatic feed and water provision	100 percent market oriented; high level of capital input requirements (including infrastructure, buildings and equipment); high level of overall flock performance; 100 percent purchased non-local feed in diet or on-farm intensively produced feed
Layers	Layers housed in a variety of cage, barn and free range systems, with automatic feed and water provision	100 percent market oriented; high level of capital input requirements (including infrastructure, buildings and equipment); high level of overall flock performance; 100 percent purchased non-local feed in diet
Backyard	Simple housing using local wood, bamboo, clay, leaf material and handmade construction resources for supports (columns, rafters, roof frame) plus scrap wire netting walls and scrap iron for roof. When cages are used, these are made of local material or scrap wire	Animals producing meat and eggs for the owner and local market, living freely. Diet consist of swill and scavenging (20 to 40 percent) and locally-produced feeds (60 to 80 percent)

Source: Authors.