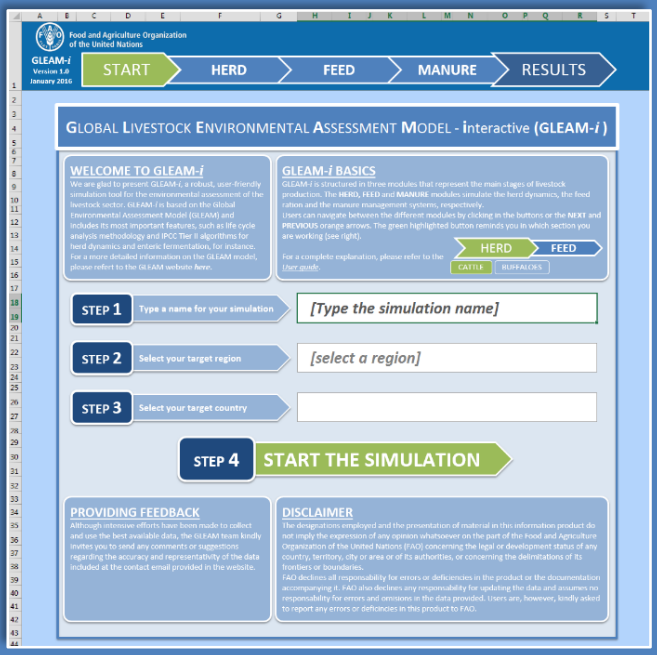
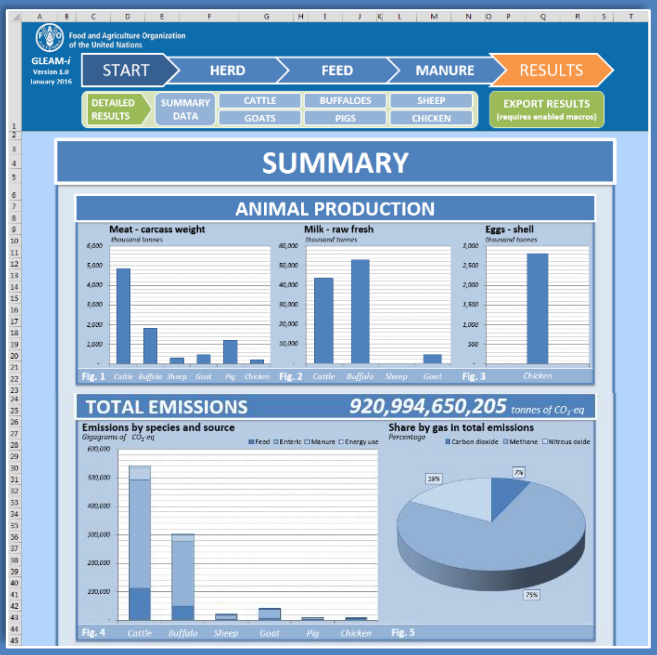
Food and Agriculture Organization of the United Nations

GLOBAL LIVESTOCK ENVIRONMENTAL ASSESSMENT MODEL - *interactive*

A tool for estimating greenhouse gas emissions in livestock production and assessing intervention scenarios





USER GUIDE

Revision 1
February 2016

Table of Contents

1. INTRODUCTION

1.1. GUIDE CONTENT

This user guide describes how to use the Global Environmental Assessment Model-interactive tool (GLEAM-*i*) to estimate greenhouse gas (GHG) emissions and mitigation potential in livestock supply chains. GLEAM-*i* is intended to support policy-makers, private sector, NGOs, scientists and civil society in understanding emissions from livestock production and designing interventions to reduce its contribution to climate change.

This user guide is divided into three chapters and one annex:

- **Introduction.** This chapter provides a brief introduction to key concepts and terminology, describes the general structure of the model and discusses the targeted public of the tool.
- **GLEAM-*i* in detail.** The second chapter describes the livestock production systems covered by GLEAM-*i* and explains the different modules of the tool.
- **Step-by-step example.** This chapter provides a detailed example on how to implement a scenario.
- **Annex.** Users can find detailed lists of all the variables involved in GLEAM-*i* in the Annex.

1.2. KEY CONCEPTS AND TERMINOLOGY

GREENHOUSE GAS EMISSIONS AND GLOBAL WARMING POTENTIAL

GLEAM-*i* covers the emissions of the three main GHG related to agricultural activities: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The Global Warming Potential (GWP) is the measure of the ability of a certain gas to trap heat in the atmosphere for a given period of time relative to a CO_2 molecule. GLEAM-*i* uses the 100 years AR5 IPCC report[1] GWP values: 34 for CH_4 and 298 for N_2O. That is to say that molecules of methane and nitrous oxide trap respectively 34 and 298 times more heat than carbon dioxide over a period of 100 years.

USE OF IPCC TIER 2 METHODOLOGIES

A given IPCC Tier refers to a set of methodological rules used to estimate GHG emissions with an increasing level of complexity[2]. GLEAM-*i* uses Tier 2 methodologies to perform most of its calculations. The enhanced characterisation of animal populations translates into a better and more accurate estimation of feed intake and quality for the calculation of enteric fermentation, emissions from manure managent and the impact of intervention measures.

LIFE CYCLE ASSESSMENT

The general principle of a life cycle assessment (LCA) is to account for all the inputs and outputs associated with a specific product within a defined boundary system. The application of LCA allows the detection of negative environmental burdens along the main stages of livestock production and detects measures that would only shift the negative effects from one stage to another.

BASELINE SCENARIO

The baseline refers to the situation where no program or intervention is carried in the livestock sector. It comprises the circumstances to which any other scenario and its beneficial and detrimental effects is to be compared to.

1.3. GLEAM-*i* STRUCTURE OVERVIEW

GLEAM-*i* is based on the Global Livestock Environmental Assessment Model (GLEAM), a spatially explicit modelling framework that simulates the environmental impacts of the livestock sector using a LCA approach.

GLEAM differentiates key stages along livestock supply chains such as feed production, processing and transport; herd dynamics, animal feeding and manure management. Further details on GLEAM can be found at the dedicated website (http://www.fao.org/gleam/en/).

[1] IPCC, 2014. *Climate change 2014: Synthesis report.* IPCC, Geneva.
[2] IPCC, 2006. *Guidelines for National Greenhouse Gas Inventories*. IPCC, Geneva

GLEAM-*i* retains most of the key characteristics of GLEAM:

- Coverage of six livestock species and their edible products: meat and milk from cattle, buffalo, sheep and goats; meat from pigs and meat and eggs from chicken.
- Estimation of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from each stage of production.
- Use of Tier 2 methodology in animal herd dynamics, enteric fermentation and manure management emissions, providing accurate information on how animal husbandry, feeding and manure management options affect environmental performance.

GLEAM-*i* consists of three modules for data input, representing the main livestock production stages and one calculation module (Figure 1). The purpose of each module is summarized below:

- The herd module determines the proportion of animals in each cohort, the rate at which animals move between cohorts and the average animal characteristics of for each cohort.
- The manure module calculates the rate at which nitrogen from manure is deposited and applied in the fields. This is necessary to calculate emissions associated with feed production.
- The feed module determines the nutritional characteristics of the feed rations and estimates the associated emissions.
- Total herd emissions and production are calculated in the system module using Tier 2 methods.

Users are able to modify any data from the herd, feed and manure modules, effectively impacting both animal production and GHG emissions.

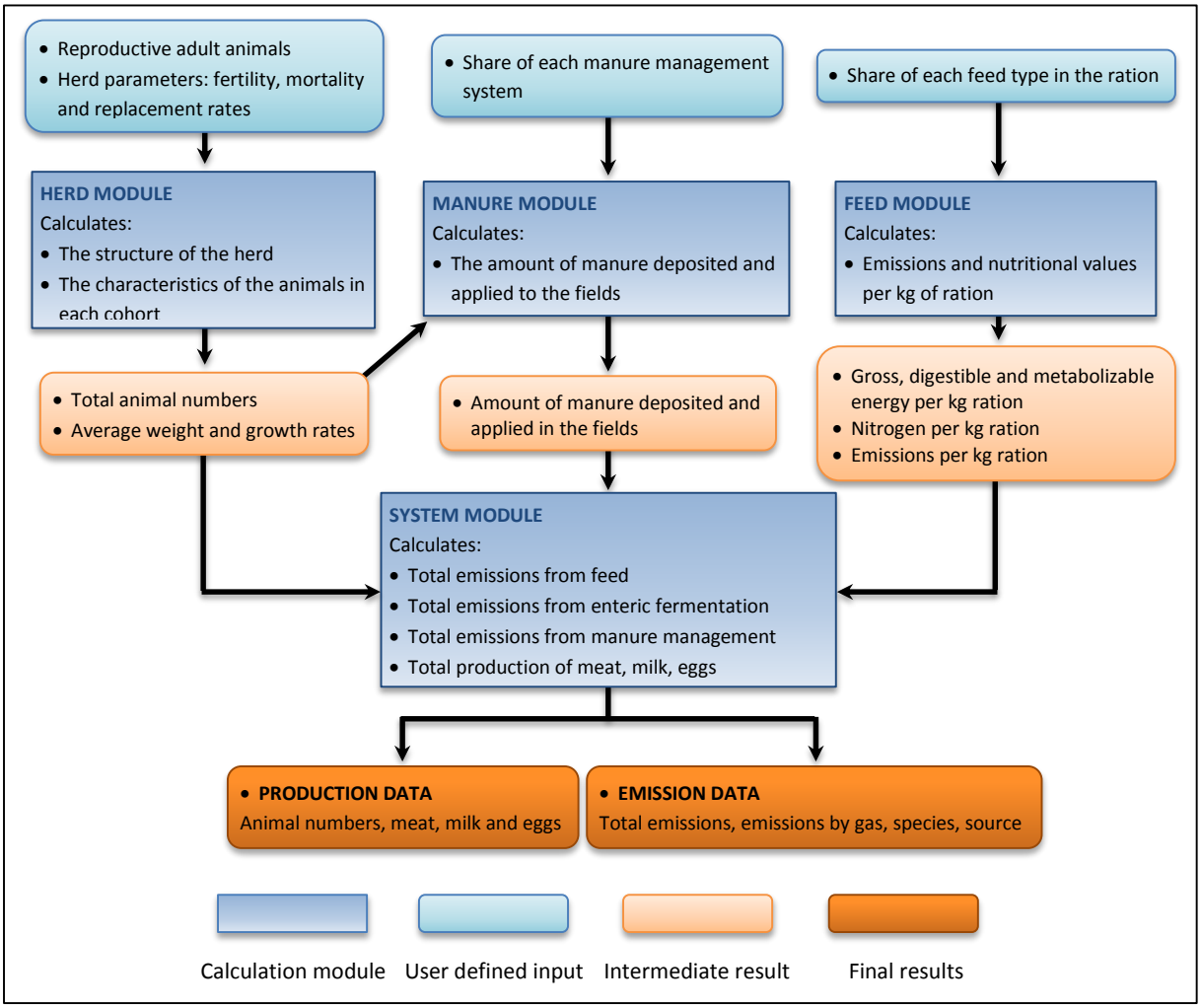


Figure 1. *Schematic representation of GLEAM-i, showing the main modules, input data and calculation flows.*

1.4. TARGETED USERS

GLEAM-*i* users are national and international project planners in governments, producers and civil society organizations with the aim of understanding GHG emissions from the sector and reducing its contribution to climate change. Users of GLEAM-*i* should be those involved in GHG inventories and in the design, discussion or implementation of mitigation projects at national or subnational scale.

2. GLEAM-*i* IN DETAIL

2.1. GENERAL ASPECTS

2.1.1 Navigating through GLEAM-i

The navigation bar (Figure 2) located at the top of each page allows the users to move between the different pages within modules and between modules either using the *Previous* and *Next* arrows or by clicking directly on the desired module.

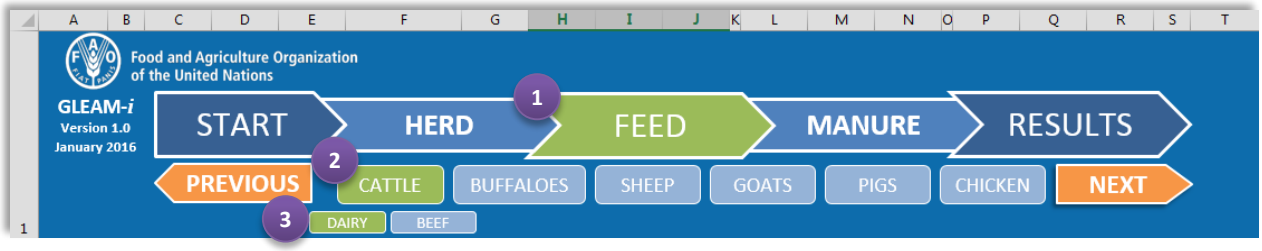


Figure 2. *GLEAM-i navigation bar. Current module (1), species (2) and herd (3) are highlighted in green.*

2.1.2 GLEAM-i pages structure and color code

Every page in GLEAM-*i* follows a clear structure and color code. A short explanation on the page and a reminder on how to fill in the data are located below the navigation bar.

Light blue cells show default values based on the selected country and cannot be modified. White cells indicate where the users can introduce, delete and modify data. Grey cells found on **Herd** and **Feed** modules reflect the changes on the total animal numbers and the feed ration, respectively.

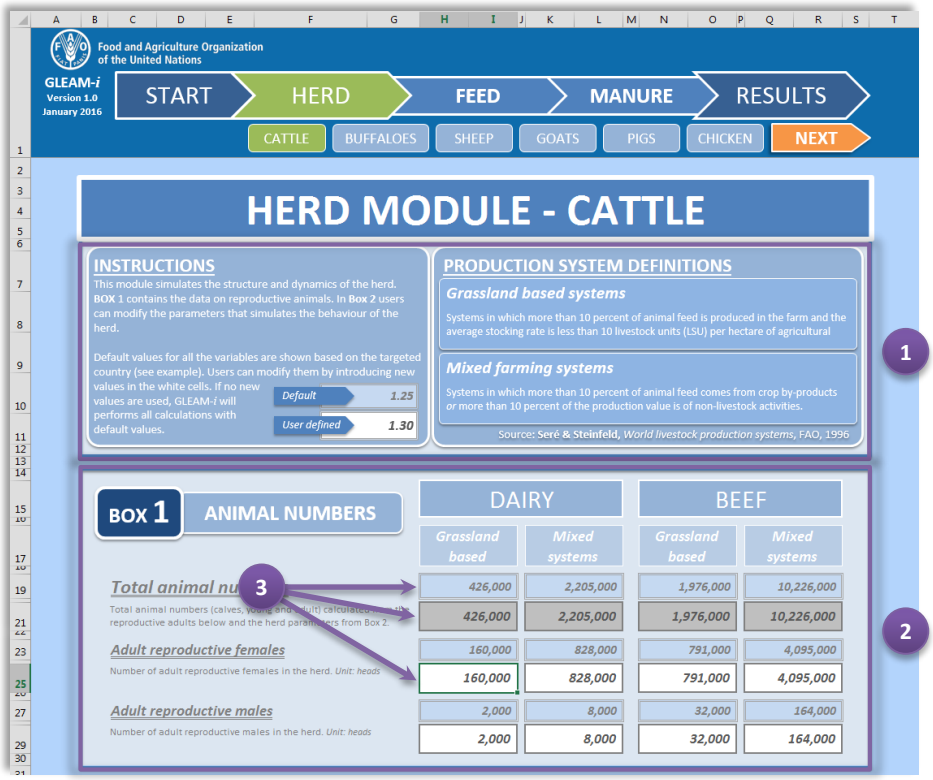


Figure 3. *Page structure and color code example, where heading section (1), area for data insertion (2) and color codes (3) are shown.*

2.1.3 Livestock production systems and herd types

GLEAM-*i* distinguishes between two production systems for cattle, buffaloes, sheep and goats (grassland based and mixed farming systems), three for pigs (backyard, intermediate and industrial) and three for chicken (backyard, layers and broilers). In addition, ruminant species are split into dairy and meat herds (Figure 4). Tables 1 to 3 summarize the characteristics of each production system.

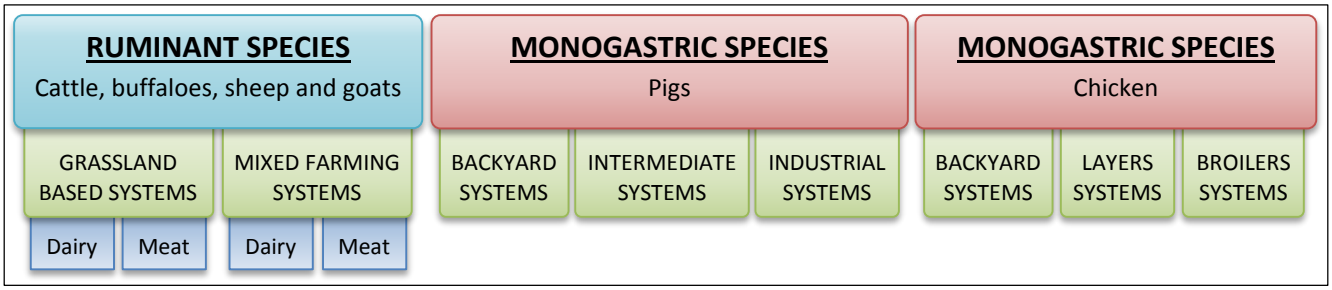


Figure 4. *Schematic view on livestock production systems (green boxes) and herds (blue boxes) considered in GLEAM-*i.

TABLE 1. Summary of ruminant production systems

System	Characteristics
Grassland based (or grazing) systems	Livestock production systems in which more than 10 percent of the dry matter fed to animals is farm-produced and in which annual average stocking rates are less than ten livestock units per hectare of agricultural land.
Mixed systems	Livestock production systems in which more than 10 percent of the dry matter fed to animals comes from crop by-products and/or stubble or more than 10 percent of the value of production comes from non-livestock farming activities.

Source: Gerber, P. *et. al.*, *Tackling climate change through livestock. A global assessment of emissions and mitigation opportunities.* FAO, 2013.

TABLE 2. Summary of pig production systems

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

Source: Gerber, P. *et. al.*, *Tackling climate change through livestock. A global assessment of emissions and mitigation opportunities.* FAO, 2013.

TABLE 3. Summary of chicken production systems

System	Housing	Characteristics
Backyard	Simple housing using local wood, bamboo, clay, leaf material and handmade construction resources for supports plus scarp wire netting walls and scrap iron for roof.	Animals producing meat and eggs for the owner and local market, living freely. Diet consists of swill and scavenging (20 to 40 percent) while locally-produced feed constitutes the rest.
Layers	Layers housed in a variety of cage, barn and free-range systems, with automatic feed and water provision.	Fully market-oriented; high capital input requirements; high level of overall flock productivity; purchased non-local feed or on-farm intensively produced feed.
Broilersl	Broilers assumed to be primarily loosely housed on litter, with automatic feed and water provision.	Fully market-oriented; high capital input requirements; high level of overall flock productivity; purchased non-local feed or on-farm intensively produced feed.

Source: Gerber, P. *et. al.*, *Tackling climate change through livestock. A global assessment of emissions and mitigation opportunities.* FAO, 2013.

2.2. START PAGE

After downloading the GLEAM-*i* tool from the website, users will first encounter the **Start** page:

1. *Welcome to GLEAM-i* message from the team.
2. *GLEAM-i basics*, essential information on GLEAM-*i* structure and navigation.
3. Name for the simulation. Note that it cannot contain any of the following characters: \ / : * ? < > |
4. Selection of region and country will prompt default values for all variables involved in the model.
5. Begin the simulation by clicking the *Start the simulation* button.
6. Users can find guidance on how to provide feedback about the tool in the *Providing feedback* box.
7. *Disclaimer* regarding the use of GLEAM-*i*.

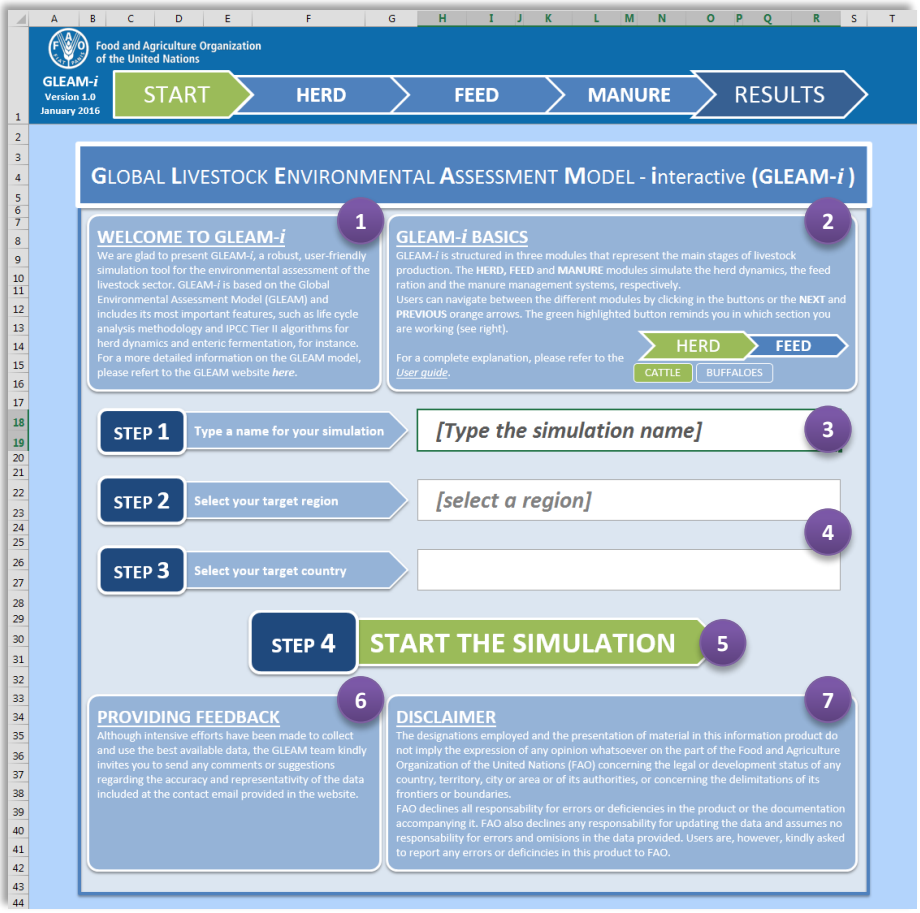


Figure 5. *Screen capture of the* ***Start*** *page.*

2.3. MODULES DESCRIPTION: HERD MODULE

The **Herd** module simulates the size and dynamics of the herd based on animal numbers and several parameters. This module impacts directly production and emissions, as it constitutes the basis for the model.

1. *Adult females*. Annual average number of adult reproductive females in the herd (cows, ewes, goats, sows and laying hens). Setting the adult females number to 0 deactivates the emissions coming from that specific species, production system or herd. This feature can be used to focus the simulation on a particular species or production system.

2. *Adult males*. Annual average number of adult reproductive males in the herd (bulls, rams, bucks, boars and roosters).

3. Herd parameters that determine the dynamic of the herd such as age at first calving, fertility of adult females, weight at birth or hatchability. The complete set can be found in Tables A1 to A4.

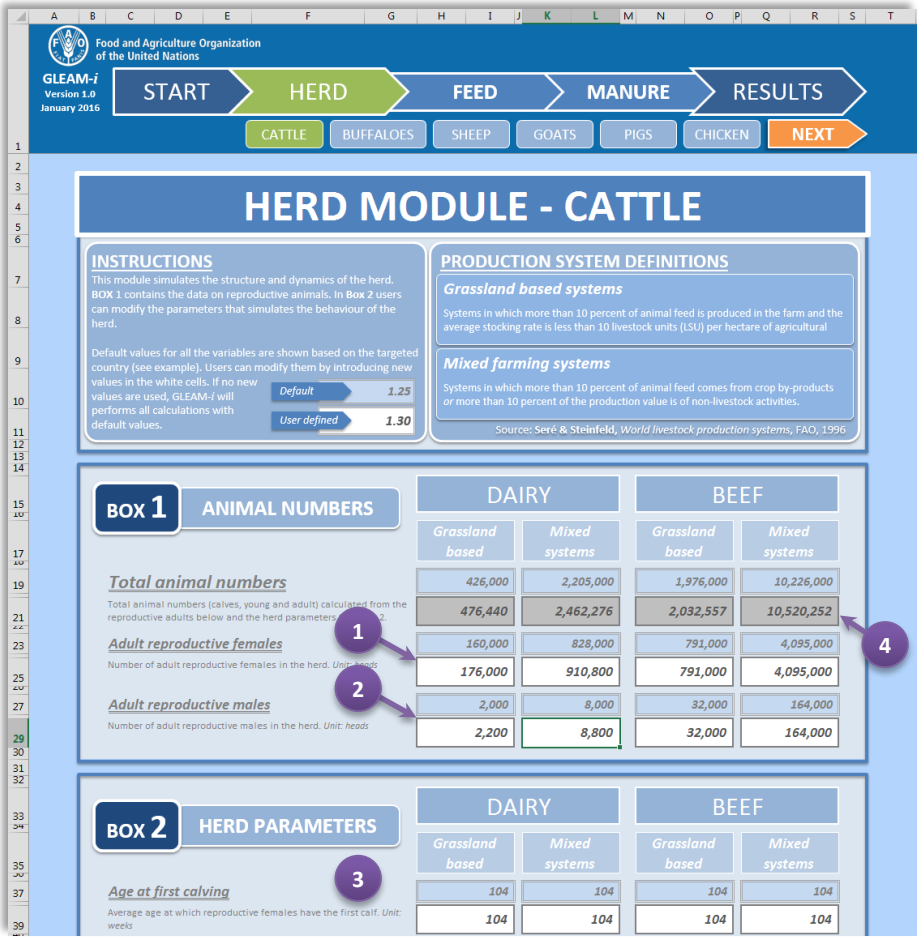


Figure 6. Herd *module page example. Users can modify reproductive animal numbers (1 and 2), herd parameters (3) or both. The complete set of herd parameters for all species can be found in Tables A1 to A4. The effect of changes is immediately displayed in the* Total animal numbers *cells (4).*

2.4. MODULES DESCRIPTION: FEED MODULE

Data on feed rations can be modified in the **Feed** module, directly impacting the emissions related to feed production and enteric fermentation. N_2O emissions from manure are also affected through the nitrogen content of the ration.

For ruminant species, rations are defined for each unique combination of species, production systems, herd and feeding groups. For monogastrics, rations are defined at species and production system level. Users will find a *Summary ration* by main feed category and the total percentage (Box 1) and a list with individual feed components (Box 2). Navigation buttons are provided to quickly switch between the two (see Figure 7). Users can modify the default ration percentages for each item in the *Detailed ration* section in terms of percentage over the total dry matter intake. A detailed description of each feed item is provided in Tables A5 and A6.

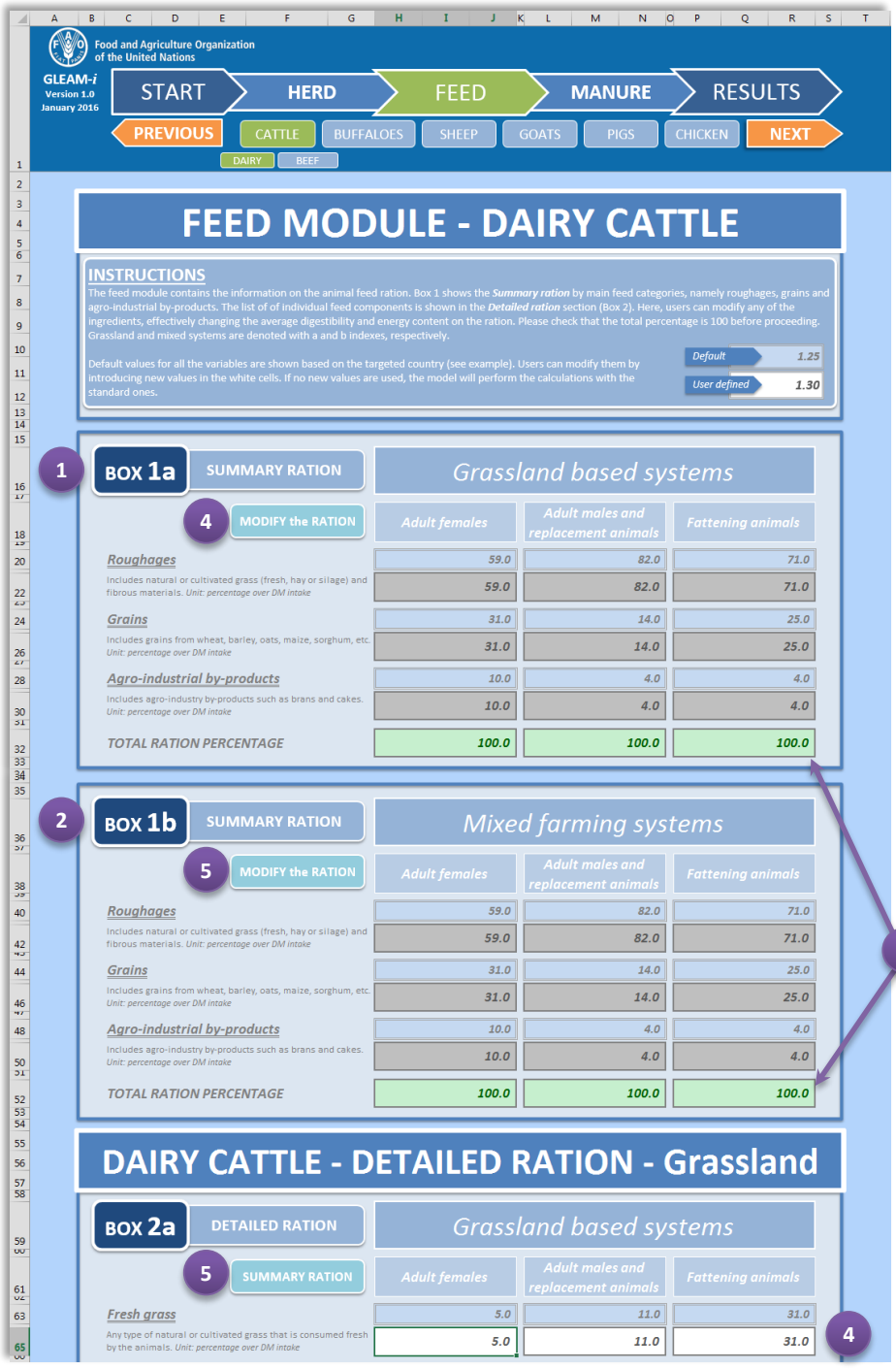


Figure 7. Feed *module example page. Summary rations for grassland (1) and mixed systems (2), as well as total percentages (3) are shown. Users can modify the individual share of each feed component in the* Detailed raiont box *(4). The complete list of feed items can be found in Tables A5 and A6. Navigation buttons are also shown (5).*

2.5. MODULES DESCRIPTION: MANURE MODULE

The **Manure** module contains the information on the storage and handling of urine and dung (collectively referred to as manure). This module impacts directly the methane and nitrous oxide emissions from manure and, indirectly, the emissions related to feed through the use of manure as fertilizer.

The manure management systems (MMS) used in this module are taken from the 2006 IPCC guidelines. For a detailed description of each system, please refer to Table A7 in the Annex. The module shows the share under each MMS with respect to the total amount generated within each production system (and herd in the case of ruminants). The total percentage for each production systems is also provided to minimize errors when modifying the default values.

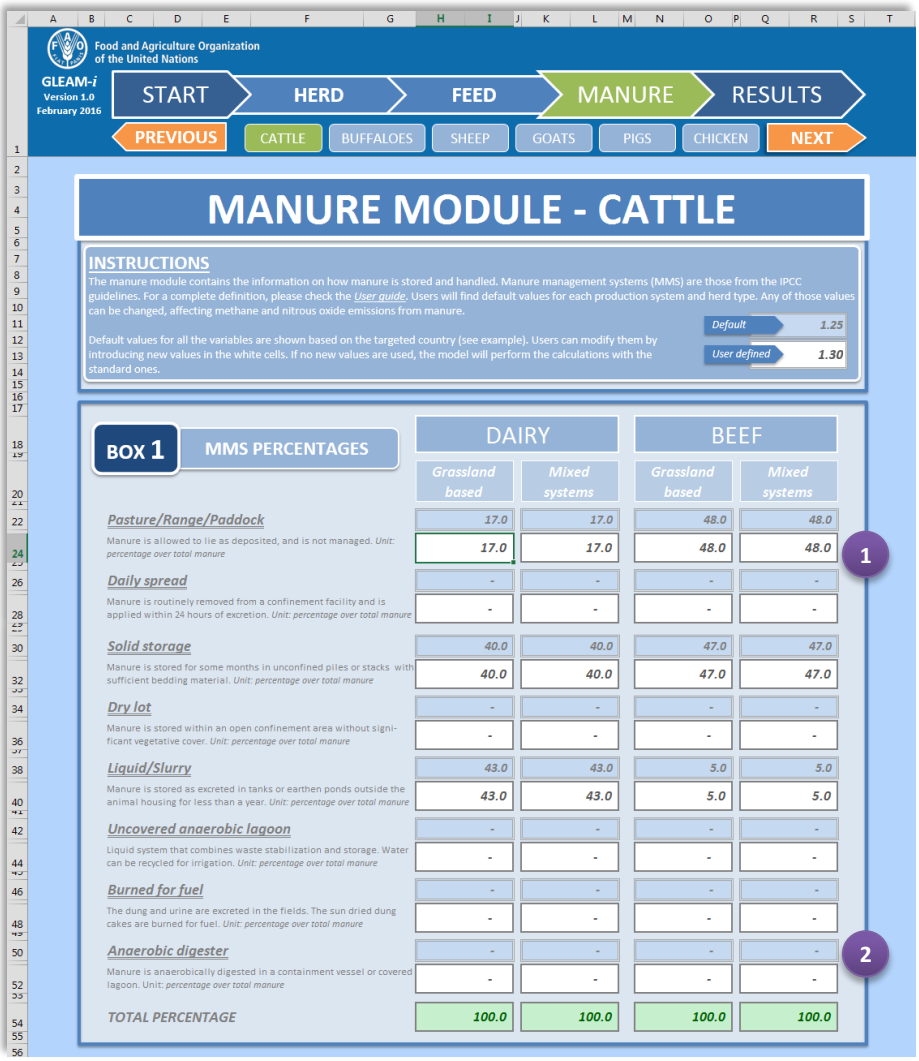


Figure 8. Manure *module page example. Relative shares (1) and total percentage (2) for different production systems.*

2.6. RESULTS PAGE

GLEAM-*i* provides two set of results. First, a series of figures allows for a fast and visual overview. Second, further results are found in seven spreadsheets.

2.6.1 Navigation bar

1. *Modules bar*. Users can quickly return to any of the modules by using this bar.
2. *Detailed numeric results* for all species and data used to generate the summary graphs can be found here.
3. With macros enabled, the *Export results* button generates a separate copy of detailed numeric results.

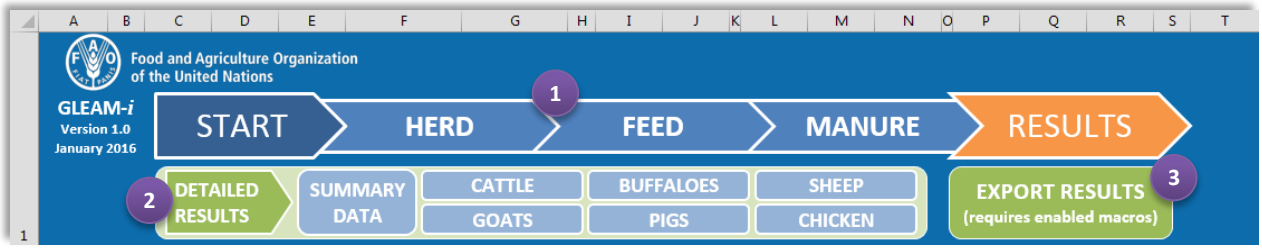


Figure 9. *Use the Module tabs to quickly return to any of them (1). Spreadsheets with detailed results for each species can be found in the Explore the detailed results bar (2). Use the Export results button (3) to generate a separated file containing all the detailed spreadsheets.*

2.6.2 Graphic results – Animal production

Estimates on animal production are shown in Figure 10:

1. **Meat**. Meat production by species, expressed in carcass weight.
2. **Milk**. Milk production by species, expressed in raw fresh weight.
3. **Eggs**. Eggs production, expressed in shell weight.

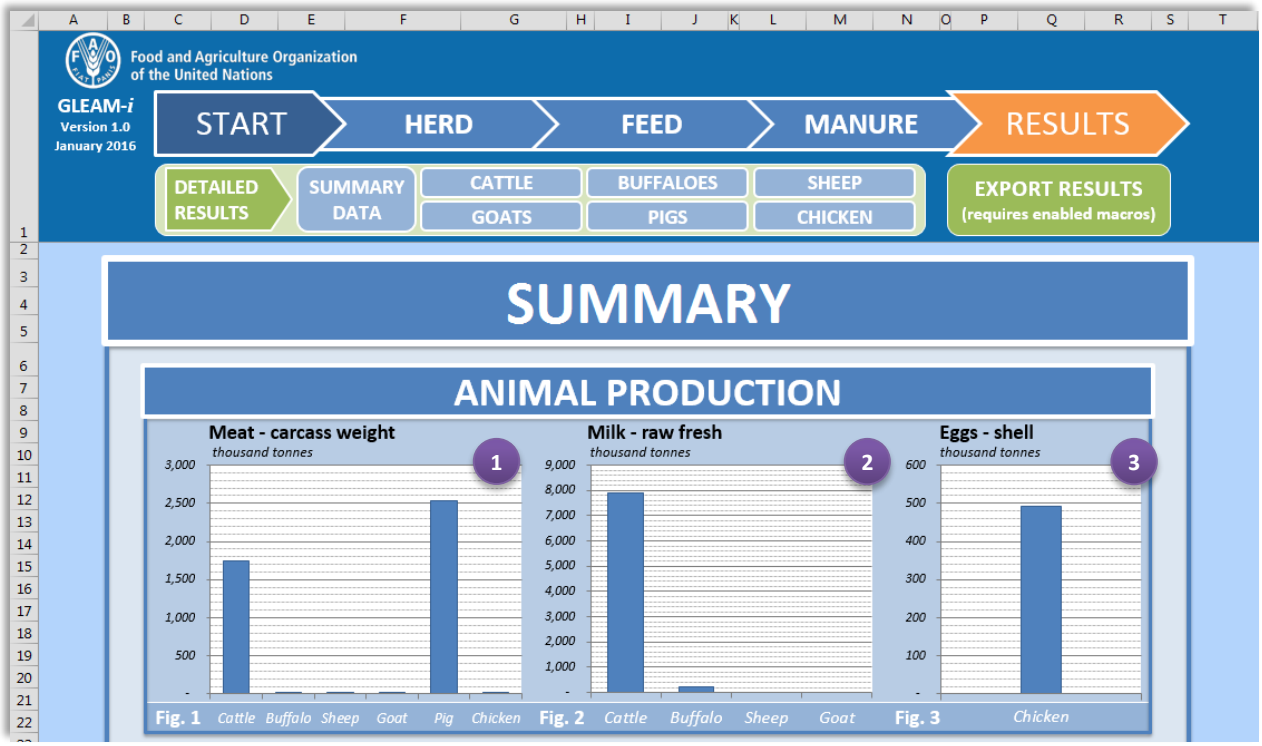


Figure 10. *Animal production with graphs for meat (1), milk (2) and eggs (3).*

2.6.3 Graphic results – Total GHG emissions

Estimates on GHG emissions are shown in Figure 11:

1. **Total emissions**. Total emissions from all species and sources, expressed in CO_2-eq. It represents the total estimated impact of the livestock sector in terms of GHG emissions.

2. **Emissions by species and source**. The chart shows the total emissions associated with each animal species and the relative share of each major source, namely feed related, enteric fermentation, manure management and energy use. Further details on emission sources can be found in the next section. For a complete definition of sources, please refer to Table A8 in the Annex.

3. **Share by gas.** Share of each gas (CO_2, CH_4 and N_2O) in the total emissions.

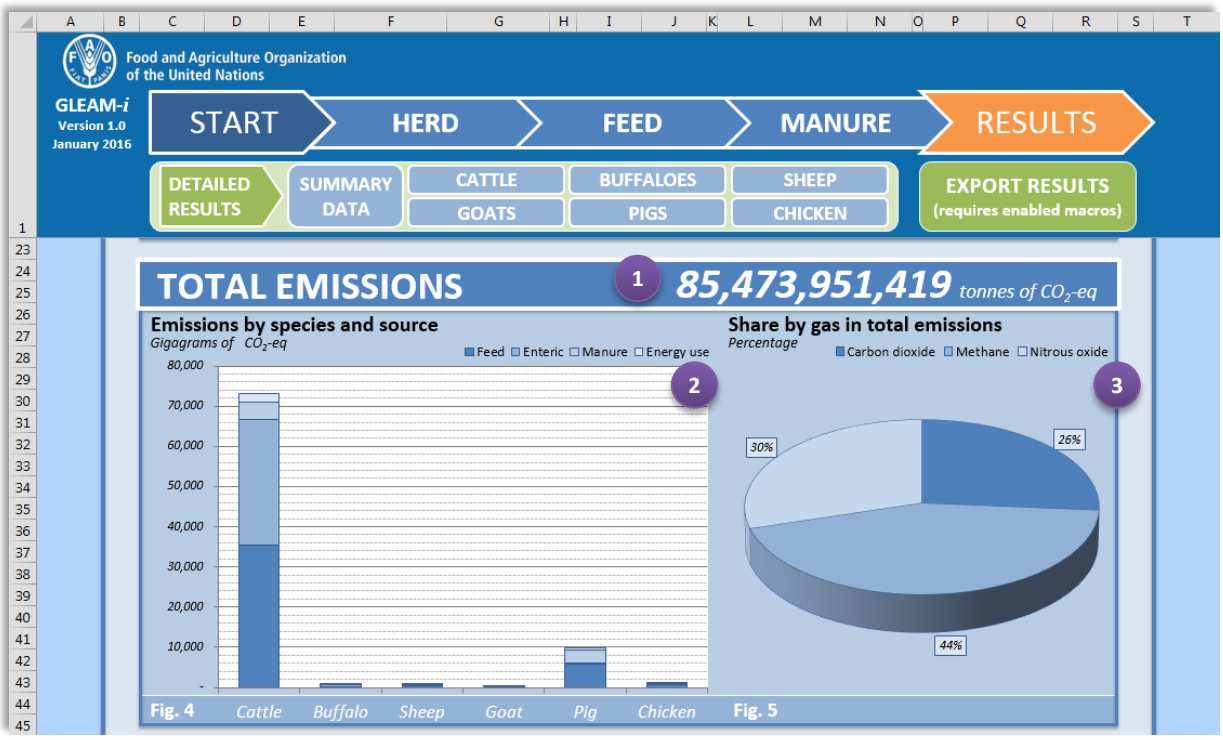


Figure 11. *Total emissions block, with total emissions (1), by species and source (2) and total share by gas (3).*

2.6.4 Graphic results – Emission sources

Estimates on GHG emissions split by source are shown in Figure 12:

1. **Source of emissions**. A more detailed look at the main sources of emissions along the livestock supply chain. For a full definition of emission sources, please refer to Table A8.

2. **GLEAM-*i* vs IPCC Tier I**. Comparison between GLEAM-*i* emission estimates (Tier 2) and IPCC Tier I methods. The comparison covers emissions from enteric fermentation and manure management. IPCC emissions are calculated using the total animal numbers from the herd module and 2006 IPCC Tier I default emission factors, parameters and equations.

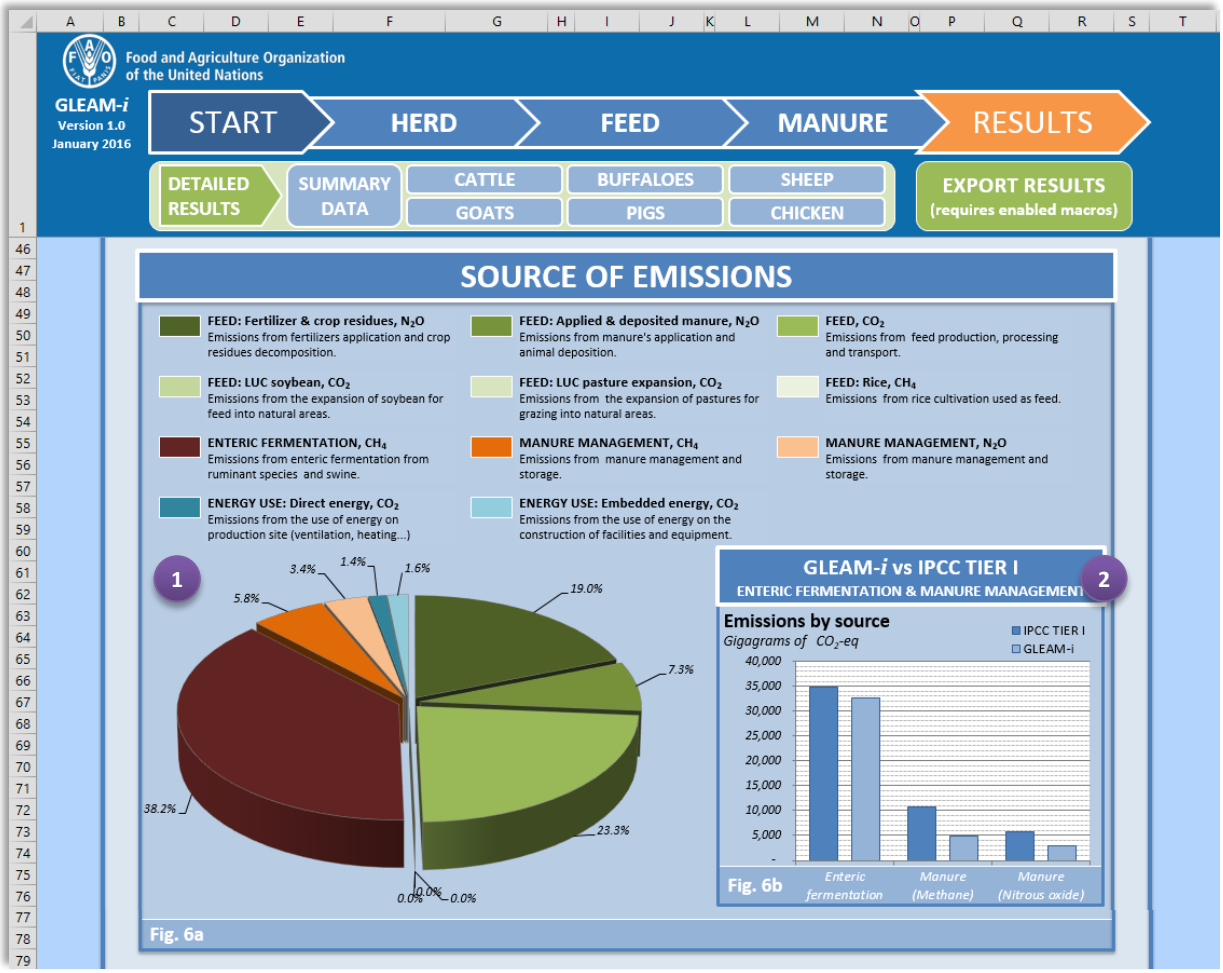


Figure 12. *Emissions sources block, where sources for the total emissions (1) and the comparison between the tool and IPCC Tier I methods (2) are shown.*

2.6.5 Graphic results – Emission intensities

Emissions related to the production of a given commodity are shown in Figure 13. In order to compare the environmental performance among different products, meat milk and eggs quantities are converted into edible protein.

1 **Emission intensities**. Amount of emissions, expressed in CO_2 equivalents, per kilogram of edible protein for different livestock commodities are shown. Regional values from GLEAM are also displayed for reference.

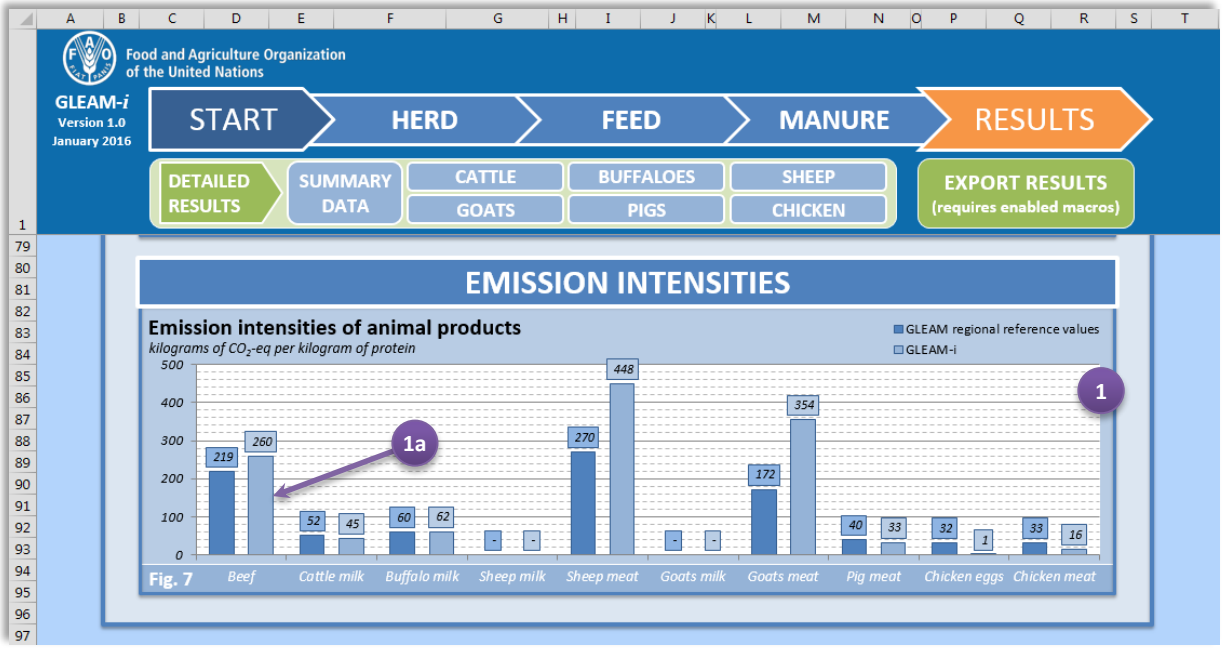
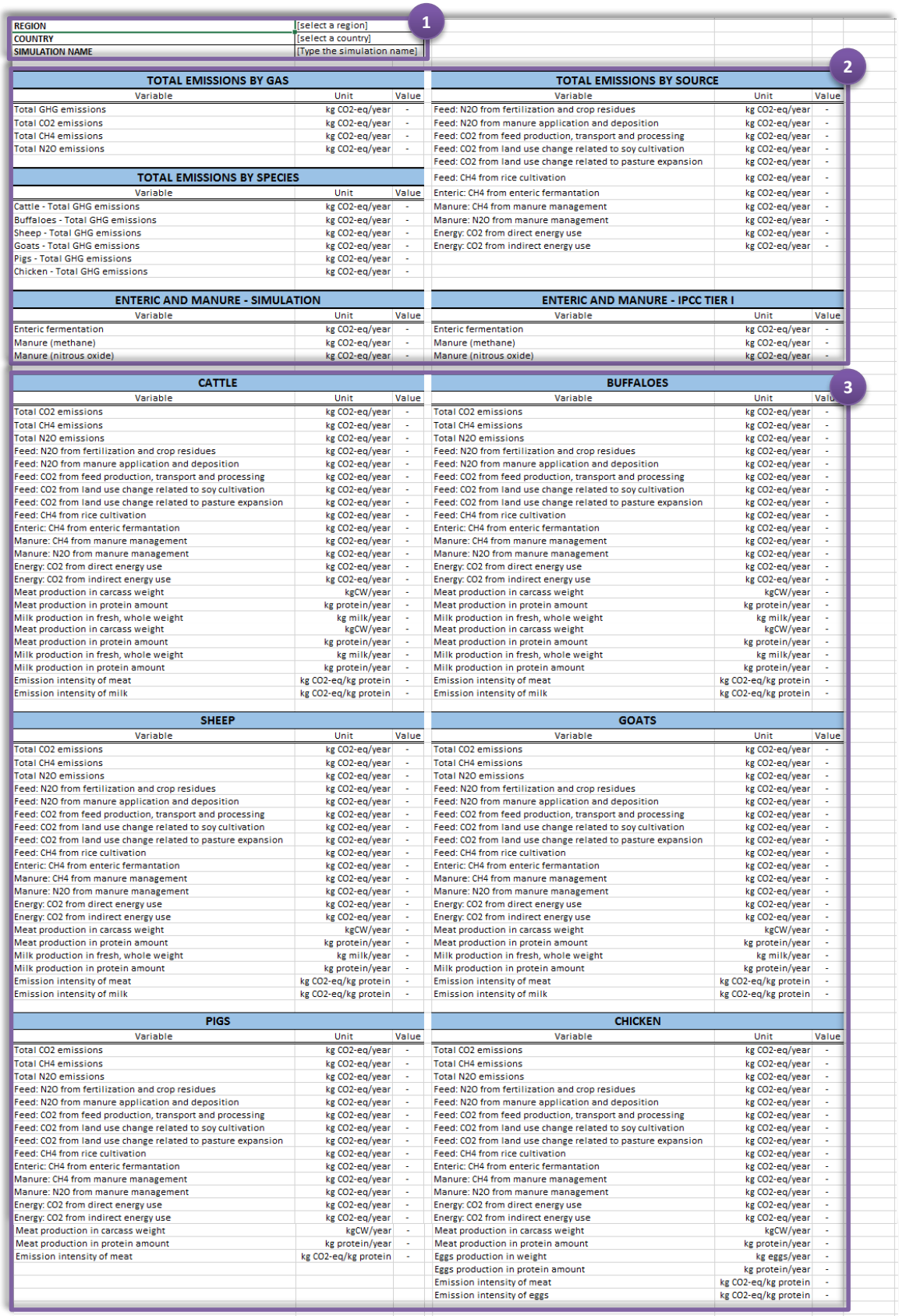


***Figure 13**. Graph showing the simulation emission intensities for livestock commodities (1). Regional average values from GLEAM are also shown for reference purposes (1a).*

2.6.6 Detailed results – Summary data

The spreadsheet below contains the numeric data that constitutes the summarized results.



REGION	[select a region]
COUNTRY	[select a country]
SIMULATION NAME	[Type the simulation name]

TOTAL EMISSIONS BY GAS

Variable	Unit	Value
Total GHG emissions	kg CO2-eq/year	-
Total CO2 emissions	kg CO2-eq/year	-
Total CH4 emissions	kg CO2-eq/year	-
Total N2O emissions	kg CO2-eq/year	-

TOTAL EMISSIONS BY SPECIES

Variable	Unit	Value
Cattle - Total GHG emissions	kg CO2-eq/year	-
Buffaloes - Total GHG emissions	kg CO2-eq/year	-
Sheep - Total GHG emissions	kg CO2-eq/year	-
Goats - Total GHG emissions	kg CO2-eq/year	-
Pigs - Total GHG emissions	kg CO2-eq/year	-
Chicken - Total GHG emissions	kg CO2-eq/year	-

TOTAL EMISSIONS BY SOURCE

Variable	Unit	Value
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-
Manure: CH4 from manure management	kg CO2-eq/year	-
Manure: N2O from manure management	kg CO2-eq/year	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-

ENTERIC AND MANURE - SIMULATION

Variable	Unit	Value
Enteric fermentation	kg CO2-eq/year	-
Manure (methane)	kg CO2-eq/year	-
Manure (nitrous oxide)	kg CO2-eq/year	-

ENTERIC AND MANURE - IPCC TIER I

Variable	Unit	Value
Enteric fermentation	kg CO2-eq/year	-
Manure (methane)	kg CO2-eq/year	-
Manure (nitrous oxide)	kg CO2-eq/year	-

CATTLE

Variable	Unit	Value
Total CO2 emissions	kg CO2-eq/year	-
Total CH4 emissions	kg CO2-eq/year	-
Total N2O emissions	kg CO2-eq/year	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-
Manure: CH4 from manure management	kg CO2-eq/year	-
Manure: N2O from manure management	kg CO2-eq/year	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-
Meat production in carcass weight	kgCW/year	-
Meat production in protein amount	kg protein/year	-
Milk production in fresh, whole weight	kg milk/year	-
Meat production in carcass weight	kgCW/year	-
Meat production in protein amount	kg protein/year	-
Milk production in fresh, whole weight	kg milk/year	-
Milk production in protein amount	kg protein/year	-
Emission intensity of meat	kg CO2-eq/kg protein	-
Emission intensity of milk	kg CO2-eq/kg protein	-

BUFFALOES

Variable	Unit	Value
Total CO2 emissions	kg CO2-eq/year	-
Total CH4 emissions	kg CO2-eq/year	-
Total N2O emissions	kg CO2-eq/year	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-
Manure: CH4 from manure management	kg CO2-eq/year	-
Manure: N2O from manure management	kg CO2-eq/year	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-
Meat production in carcass weight	kgCW/year	-
Meat production in protein amount	kg protein/year	-
Milk production in fresh, whole weight	kg milk/year	-
Milk production in protein amount	kg protein/year	-
Emission intensity of meat	kg CO2-eq/kg protein	-
Emission intensity of milk	kg CO2-eq/kg protein	-

SHEEP

Variable	Unit	Value
Total CO2 emissions	kg CO2-eq/year	-
Total CH4 emissions	kg CO2-eq/year	-
Total N2O emissions	kg CO2-eq/year	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-
Manure: CH4 from manure management	kg CO2-eq/year	-
Manure: N2O from manure management	kg CO2-eq/year	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-
Meat production in carcass weight	kgCW/year	-
Meat production in protein amount	kg protein/year	-
Milk production in fresh, whole weight	kg milk/year	-
Milk production in protein amount	kg protein/year	-
Emission intensity of meat	kg CO2-eq/kg protein	-
Emission intensity of milk	kg CO2-eq/kg protein	-

GOATS

Variable	Unit	Value
Total CO2 emissions	kg CO2-eq/year	-
Total CH4 emissions	kg CO2-eq/year	-
Total N2O emissions	kg CO2-eq/year	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-
Manure: CH4 from manure management	kg CO2-eq/year	-
Manure: N2O from manure management	kg CO2-eq/year	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-
Meat production in carcass weight	kgCW/year	-
Meat production in protein amount	kg protein/year	-
Milk production in fresh, whole weight	kg milk/year	-
Milk production in protein amount	kg protein/year	-
Emission intensity of meat	kg CO2-eq/kg protein	-
Emission intensity of milk	kg CO2-eq/kg protein	-

PIGS

Variable	Unit	Value
Total CO2 emissions	kg CO2-eq/year	-
Total CH4 emissions	kg CO2-eq/year	-
Total N2O emissions	kg CO2-eq/year	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-
Manure: CH4 from manure management	kg CO2-eq/year	-
Manure: N2O from manure management	kg CO2-eq/year	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-
Meat production in carcass weight	kgCW/year	-
Meat production in protein amount	kg protein/year	-
Emission intensity of meat	kg CO2-eq/kg protein	-

CHICKEN

Variable	Unit	Value
Total CO2 emissions	kg CO2-eq/year	-
Total CH4 emissions	kg CO2-eq/year	-
Total N2O emissions	kg CO2-eq/year	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-
Manure: CH4 from manure management	kg CO2-eq/year	-
Manure: N2O from manure management	kg CO2-eq/year	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-
Meat production in carcass weight	kgCW/year	-
Meat production in protein amount	kg protein/year	-
Eggs production in weight	kg eggs/year	-
Eggs production in protein amount	kg protein/year	-
Emission intensity of meat	kg CO2-eq/kg protein	-
Emission intensity of eggs	kg CO2-eq/kg protein	-

Figure 14. *Export spreadsheet summary page. Region, country and simulation name are shown in (1). Aggregated values are found at the top of the page (2), while species data can be found below (3).*

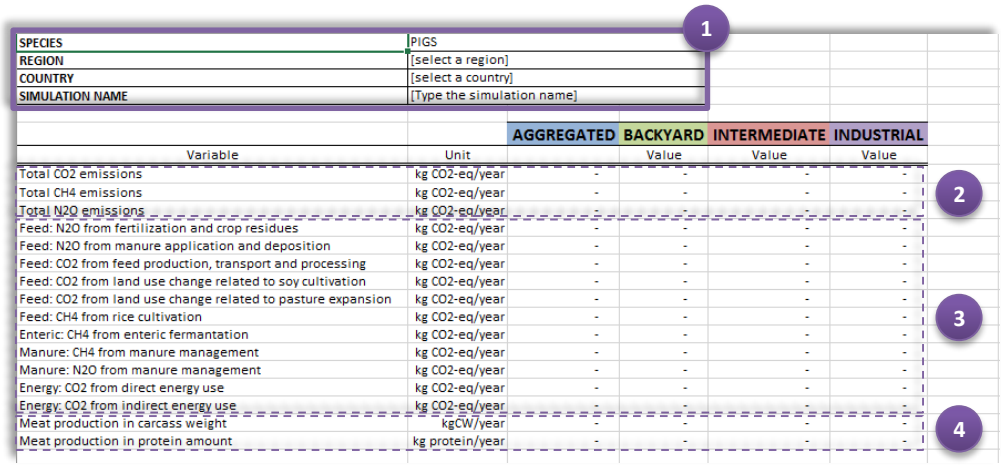
2.6.7 Detailed results – Ruminant species

Export spreadsheets for cattle, buffalo, sheep and goats have the same structure. They all contain detailed data on total emissions by gas, emission sources and animal production as shown below.

Figure 15. *Export spreadsheet example for ruminant species. Species, region, country and simulation name are shown in (1). Data on emissions and animal production, aggregated over production systems, can be found at the top of the page (2). The same data split by grassland and mixed systems is found below (3). Each 'block' of data (4) contains numbers on total emissions by gas (4a), emission sources (4b) and animal production (4c).*

2.6.8 Detailed results – Monogastric species: pigs

Data on emissions and production from pigs can be found in this spreadsheet. Similarly to ruminants, data are shown aggregated and disaggregated by production systems.



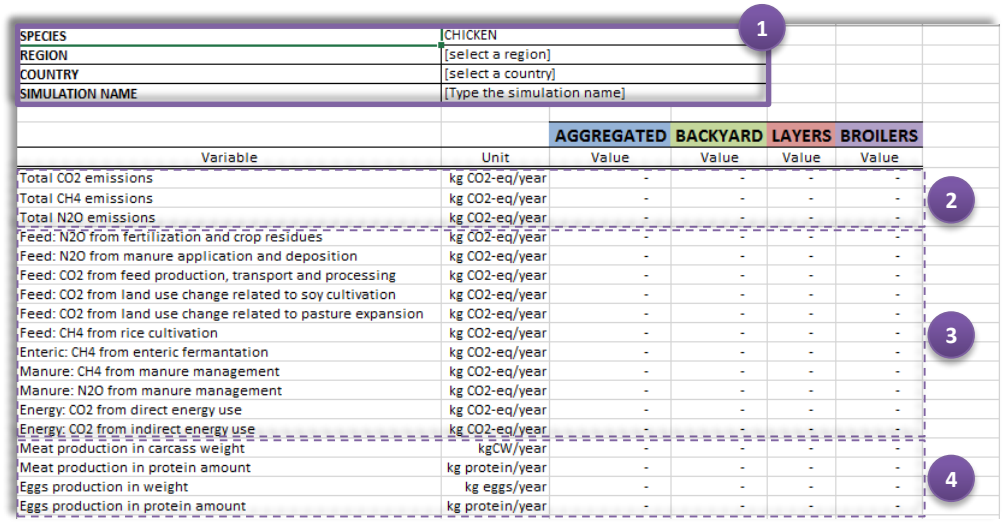
SPECIES	PIGS
REGION	[select a region]
COUNTRY	[select a country]
SIMULATION NAME	[Type the simulation name]

Variable	Unit	AGGREGATED	BACKYARD	INTERMEDIATE	INDUSTRIAL
			Value	Value	Value
Total CO2 emissions	kg CO2-eq/year	-	-	-	-
Total CH4 emissions	kg CO2-eq/year	-	-	-	-
Total N2O emissions	kg CO2-eq/year	-	-	-	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-	-	-	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-	-	-	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-	-	-	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-	-	-	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-	-	-	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-	-	-	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-	-	-	-
Manure: CH4 from manure management	kg CO2-eq/year	-	-	-	-
Manure: N2O from manure management	kg CO2-eq/year	-	-	-	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-	-	-	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-	-	-	-
Meat production in carcass weight	kgCW/year	-	-	-	-
Meat production in protein amount	kg protein/year	-	-	-	-

Figure 16. *Export spreadsheet for pigs. Species, region, country and simulation name are shown in (1). Data on total emissions by gas (2), emission sources (3) and animal production (4) can be found for both aggregated and disaggregated fields.*

2.6.9 Detailed results – Monogastric species: chicken

Data on emissions and production from chicken are located in this spreadsheet. Data are shown aggregated and disaggregated by production systems.



SPECIES	CHICKEN
REGION	[select a region]
COUNTRY	[select a country]
SIMULATION NAME	[Type the simulation name]

Variable	Unit	AGGREGATED	BACKYARD	LAYERS	BROILERS
		Value	Value	Value	Value
Total CO2 emissions	kg CO2-eq/year	-	-	-	-
Total CH4 emissions	kg CO2-eq/year	-	-	-	-
Total N2O emissions	kg CO2-eq/year	-	-	-	-
Feed: N2O from fertilization and crop residues	kg CO2-eq/year	-	-	-	-
Feed: N2O from manure application and deposition	kg CO2-eq/year	-	-	-	-
Feed: CO2 from feed production, transport and processing	kg CO2-eq/year	-	-	-	-
Feed: CO2 from land use change related to soy cultivation	kg CO2-eq/year	-	-	-	-
Feed: CO2 from land use change related to pasture expansion	kg CO2-eq/year	-	-	-	-
Feed: CH4 from rice cultivation	kg CO2-eq/year	-	-	-	-
Enteric: CH4 from enteric fermantation	kg CO2-eq/year	-	-	-	-
Manure: CH4 from manure management	kg CO2-eq/year	-	-	-	-
Manure: N2O from manure management	kg CO2-eq/year	-	-	-	-
Energy: CO2 from direct energy use	kg CO2-eq/year	-	-	-	-
Energy: CO2 from indirect energy use	kg CO2-eq/year	-	-	-	-
Meat production in carcass weight	kgCW/year	-	-	-	-
Meat production in protein amount	kg protein/year	-	-	-	-
Eggs production in weight	kg eggs/year	-	-	-	-
Eggs production in protein amount	kg protein/year	-	-	-	-

Figure 17*. Export spreadsheet for chicken. Species, region, country and simulation name are shown in (1). Data on total emissions by gas (2), emission sources (3) and animal production (4) can be found for both aggregated and disaggregated fields.*

3. STEP-BY-STEP EXAMPLE

This section provides a full example on how to set the baseline and how to implement a scenario.

3.1. SAVING THE RESULTS

To save the results of either the baseline or a scenario, please follow one of the two options below:

- **Macros are enabled.** Go to the **Results** page and click on the *Export results* button. This will create a new file with a copy of all detailed spreadsheets which can be saved into any folder. It will suggest the name of the simulation as the name for the saved file.
- **Macros are not enabled.** Save the file using the *Save as* instruction from Excel. This will create an entire copy of GLEAM-*i*.

3.2. SETTING THE BASELINE

The baseline scenario represents the situation where no intervention or project is taking place, and sets the reference level to which any other scenario has to be compared against. When defining the baseline, users should consider two possibilities:

- **Case 1.** Sufficient and reliable data is scarce or non-existing. The baseline should be set using the default values from GLEAM-*i*.
- **Case 2.** Sufficient and reliable information on a given aspect of the model is available. Users should define the baseline by introducing the known data on the model. For instance, if herd parameters for cattle are known and data is considered reliable, users should overwrite the GLEAM-*i* default values on that particular aspect.

Once the baseline is set, save it following the steps described in the previous section.

3.3. SCENARIO DESCRIPTION

The details on the scenario are shown in Tables 4 to 6. The example assumes that changes are equally applied to both grassland based and mixed farm systems. However, any scenario can be applied to a specific production system.

TABLE 4. Example scenario description

HERD TYPE	HERD MODULE	FEED MODULE	MANURE MODULE
Dairy	• Sector growth: increase of reproductive animals by 10% • Vaccination campaign: reduction of 30% in mortality of calves.	• Increase in feed quality for adult dairy animals: 15% increase of energy rich feed items.	• 50% reduction of deposited manure in the fields and reallocation under anaerobic lagoon.
Beef	• Breeding program resulting in heavier animals at slaughter (+1.5% live weight). • Vaccination campaign: reduction of 30% in mortality of calves.	• Increase in feed quality for adult fattening animals: increase of 25% of energy rich feed items.	• Higher adoption (+20%) of dry lot system to the detriment of liquid/slurry.

[1] The scenario includes cattle only, illustrating the possibility of focusing on a particular species. Similar scenarios can be implemented for all species.

TABLE 5. Feed ration example for lactating adult females in dairy cattle

Feed item	Default value	Scenario
Roughages		
Fresh grass	5.0	5.0
Hay or silage from grass	14.0	14.0
Silage from whole grain plants	20.0	17.0
Silage from whole maize plant	20.0	17.0
Grains		
Maize	19.0	20.0
Grains	12.0	13.0
Agro-industrial by-products		
By-products from soy	4.0	5.0
By-products from rape (canola)	1.0	-
Maize gluten meal	-	5.0
Dry by-products from grain industries	3.0	2.0
Wet by-products from grain industries	2.0	2.0

TABLE 6. Feed ration example for fattening animals in beef herd

Feed item	Default value	Scenario
Roughages		
Fresh grass	31.0	26.0
Hay or silage from grass	24.0	20.0
Silage from whole grain plants	8.0	5.0
Silage from whole maize plant	8.0	5.0
Grains		
Maize	5.0	20.0
Grains	20.0	20.0
Agro-industrial by-products		
By-products from soy	1.0	1.0
By-products from rape (canola)	1.0	1.0
Dry by-products from grain industries	1.0	1.0
Wet by-products from grain industries	1.0	1.0

3.4. IMPLEMENTING THE SCENARIO: HERD MODULE

Introduce the new values in the white cells according to the scenario:

1. **DAIRY.** Increase of 10% in the number of reproductive animals.
2. **DAIRY and BEEF.** Reduction of 30% in mortality rate of calves, both male and female.
3. **BEEF.** Increase of 1.5% in the live weight of both male and female fattening animals at slaughter.

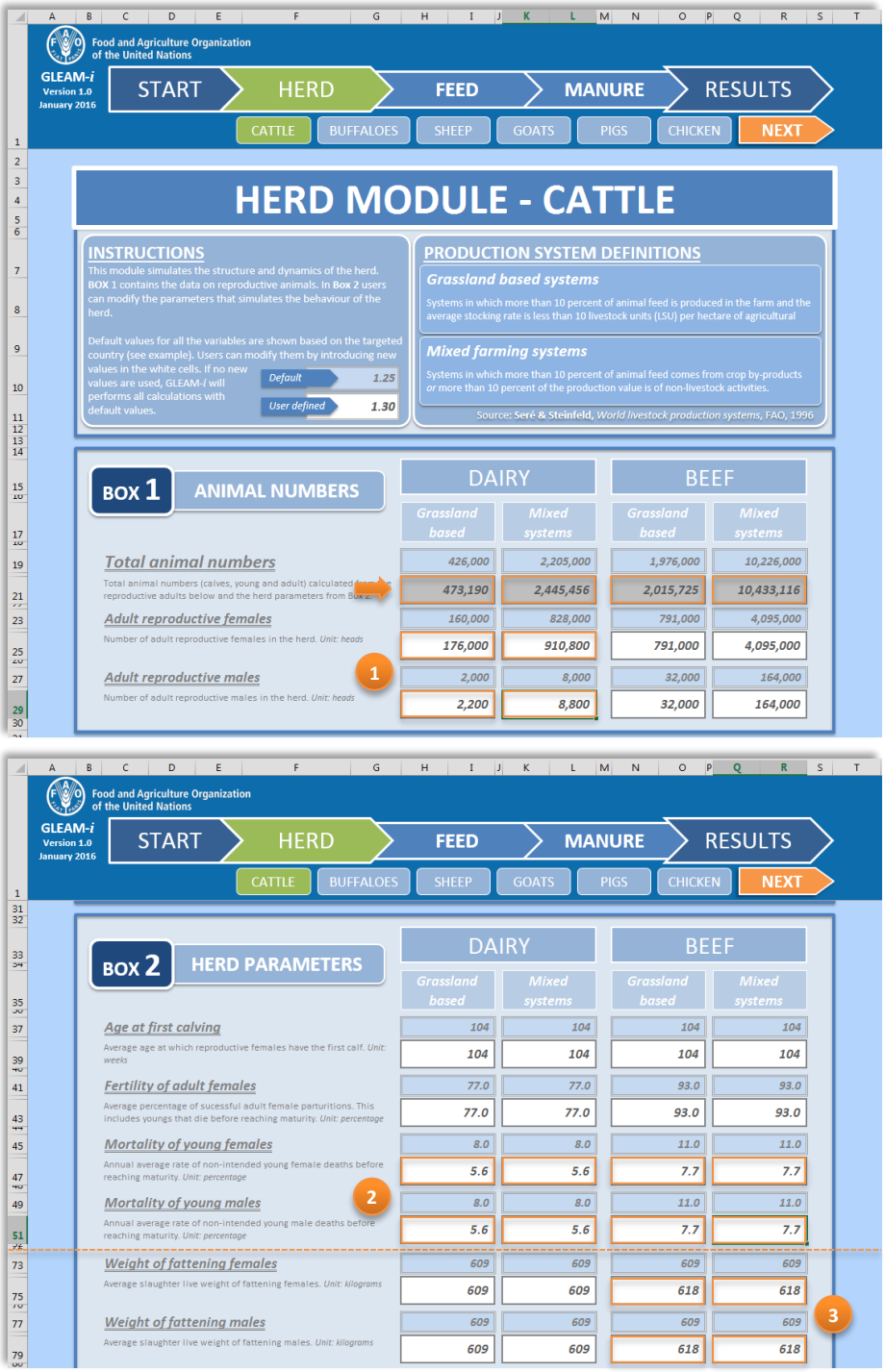


***Figure 18**. Implementing the scenario example. New values for adult reproductive animals (1), mortality of calves (2) and live weight at slaughter (3) are shown. Notice the change in the total number of animals due to the new values (arrow). Some parts of the page are not shown for clarity purposes (dotted line).*

3.5. IMPLEMENTING THE SCENARIO: FEED MODULE

Introduce the new values in the white cells according to the scenario:

1 **DAIRY.** Increase of 15% in energy rich ingredients for lactating animals.

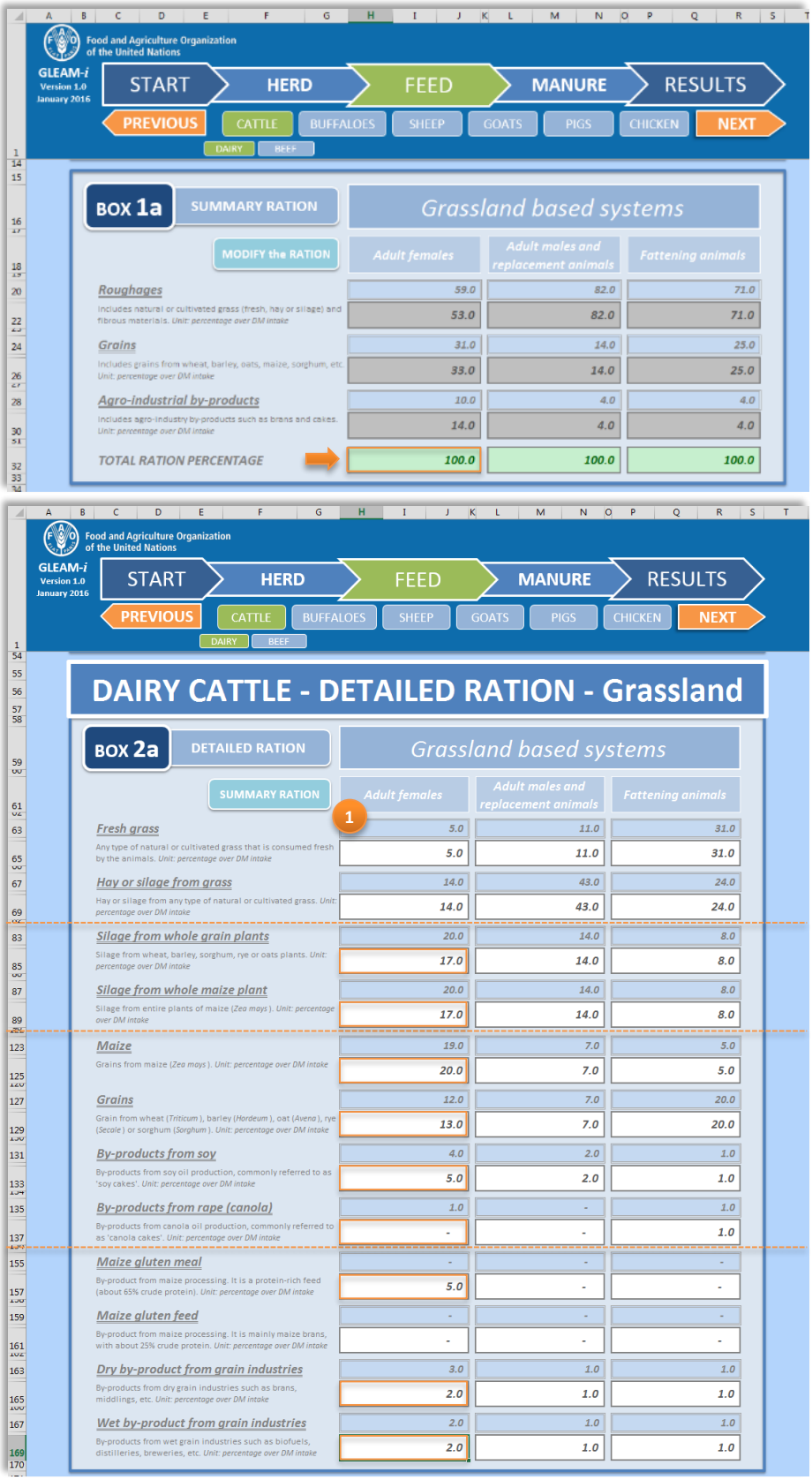


***Figure 19**. Implementing the scenario example. Cells with new values for lactating animals are depicted (1). When modifying the feed ratio, make sure that it adds to 100%, as shown in the Summary ration (arrow). Some parts of the page are not shown for clarity purposes (dotted line).*

1 **BEEF.** Increase of 25% in energy rich ingredients for fattening animals.

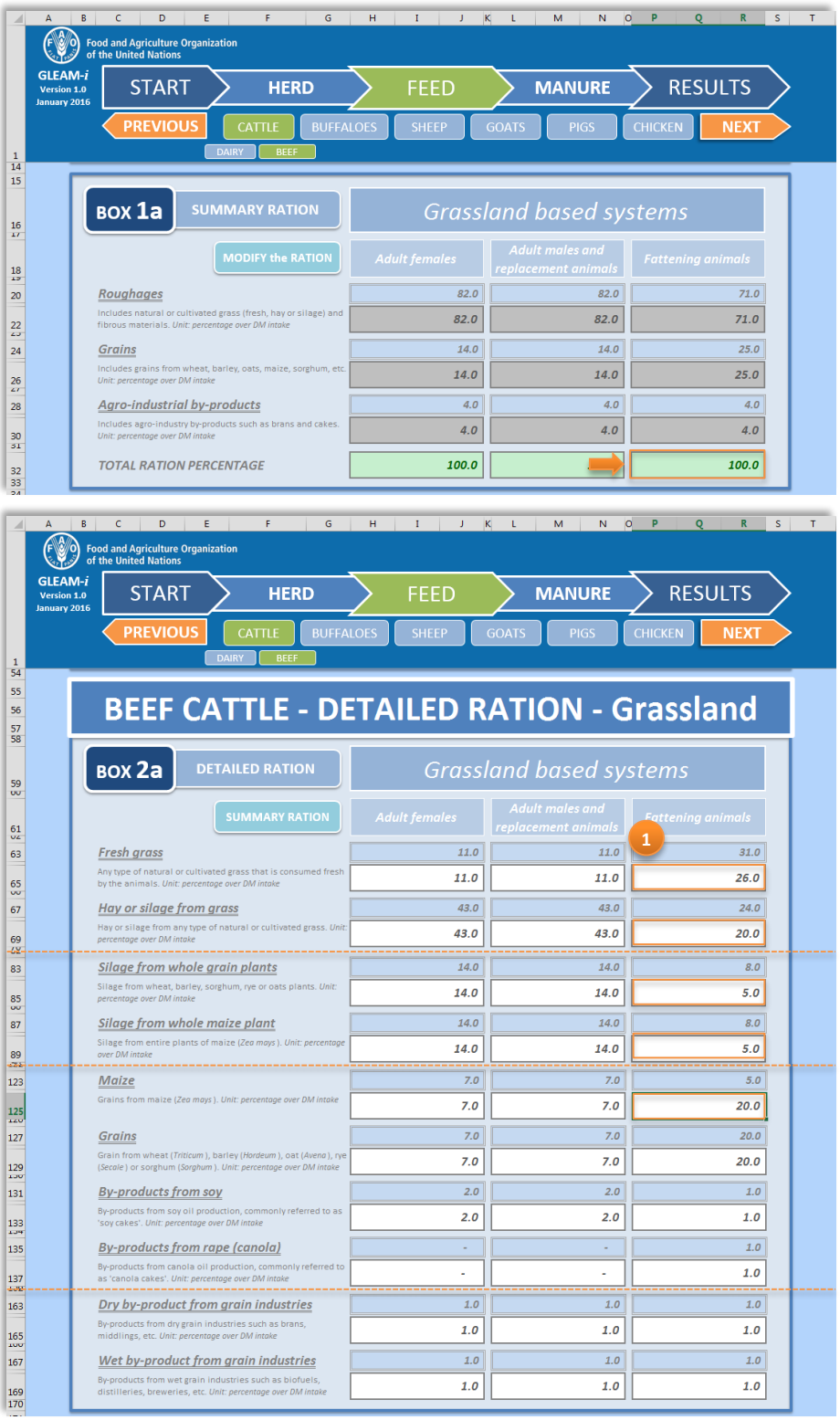


Figure 20. *Implementing the scenario example. Cells with new values for fattening animals are depicted (1). When modifying the feed ratio, make sure that it adds to 100%, as shown in the Summary ration (arrow). Some parts of the page are not shown for clarity purposes (dotted line).*

3.6. IMPLEMENTING THE SCENARIO: MANURE MODULE

Introduce the new values in the white cells according to the scenario:

1. **DAIRY.** Increase of 50% in uncovered anaerobic lagoon system and same magnitude reduction in pasture**.**

2. **BEEF.** Reduction of 20% in liquid/slurry system and same magnitude increase in drylot system.

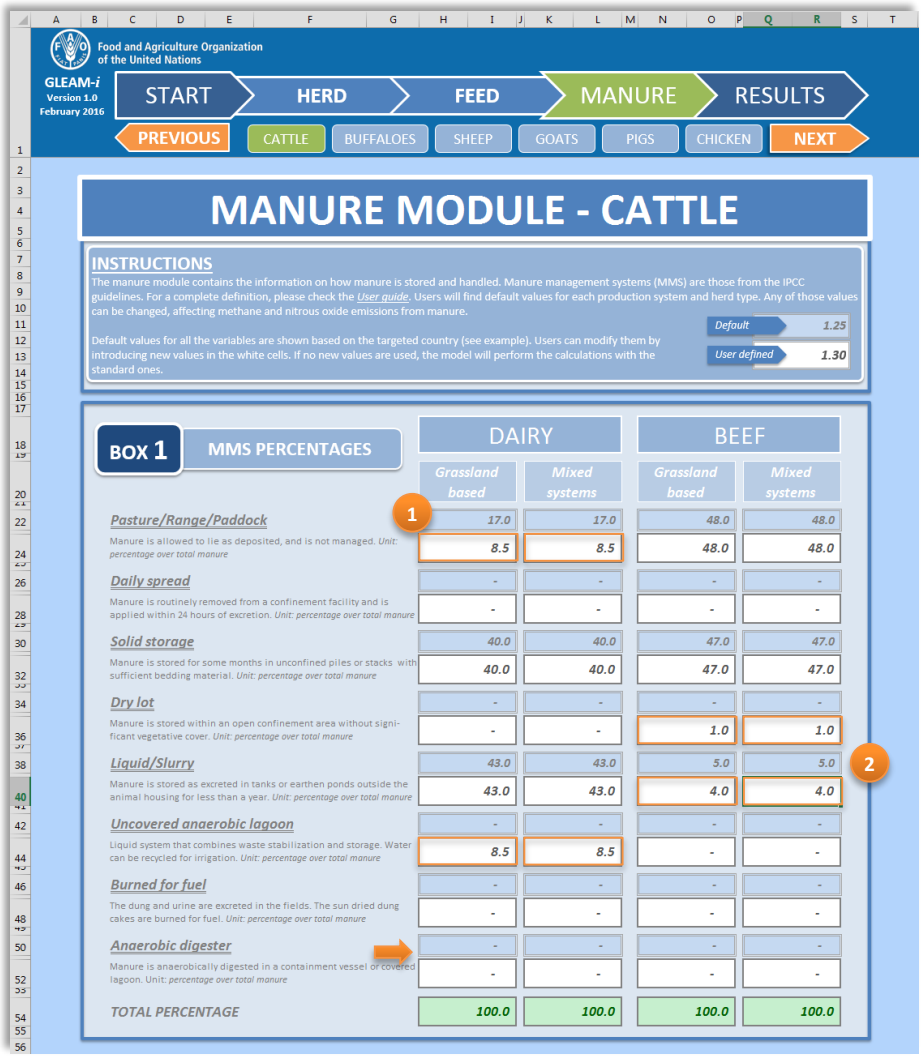


Figure 21*. Implementing the scenario example. Cells with new values for manure management systems for dairy (1) and beef herds (2) are depicted. When modifying the share of any system, make sure that it adds to 100%, as shown in the Total percentage (arrow).*

3.7. BASELINE AND SCENARIO COMPARISON

It is highly recommended to save each simulation into separate files as described in section 3.1. Comparing any scenario against the baseline can be easily done given the identical layout of the data between files.

4. ANNEX

This Annex presents the list of parameters used in the various modules.

TABLE A1. HERD module – Herd parameters: cattle and buffaloes

Parameter	Description	Unit
Age at first calving	Average age at which cows have their first parturition, either it is a successful one or not.	Weeks
Fertility of adult females	Average percentage of successful parturitions, including born calves that die before reaching maturity.	Percentage
Mortality of young females	Annual average percentage of non-intended deaths of female animals before they reach maturity.	Percentage
Mortality of young males	Annual average percentage of non-intended deaths of male animals before they reach maturity.	Percentage
Mortality of adult animals	Annual average percentage of non-intended deaths of animals, both males and females, after they reached maturity.	Percentage
Adult females replacement	Annual average percentage of adult females' replacement.	Percentage
Weight at birth	Average live weight of calves at birth.	Kilograms
Weight of adult females	Average live weight of cows once they reach maturity.	Kilograms
Weight of adult males	Average live weight of bulls once they reach maturity.	Kilograms
Weight of fattening females	Average live weight at slaughter of adult females culled for meat.	Kilograms
Weight of fattening males	Average live weight at slaughter of adult males culled for meat.	Kilograms
Milk yield	Annual average milk yield per milking cow.	Kilograms/head
Milk fat	Average milk total fat content.	Percentage
Milk protein	Average milk total protein content.	Percentage

Source: Authors

TABLE A2. HERD module – Herd parameters: sheep and goats

Parameter	Description	Unit
Age at first calving	Average age at which does/ewes have their first parturition, either it is a successful one or not.	Weeks
Fertility of adult females	Average percentage of successful parturitions, including born lambs/kids that die before reaching maturity.	Percentage
Parturition interval	Average interval between two consecutive parturitions.	Days
Litter size	Average number of lambs/kids born in each parturition, including those that die before reaching maturity.	Number
Mortality of young animals	Annual average percentage of non-intended deaths of animals before they reach maturity.	Percentage
Mortality of adult animals	Annual average percentage of non-intended deaths of adult animals after reaching maturity.	Percentage
Adult females replacement	Annual average percentage of adult females' replacement.	Percentage
Weight at birth	Average live weight of lambs/kids at birth.	Kilograms
Weight of adult females	Average live weight of does/ewes once they reach maturity.	Kilograms
Weight of adult males	Average live weight of rams/bucks once they reach maturity.	Kilograms
Weight of fattening females	Average live weight at slaughter of adult females culled for meat.	Kilograms
Weight of fattening males	Average live weight at slaughter of adult males culled for meat.	Kilograms
Milk yield	Annual average milk yield per milking doe/ewe.	Kilograms/head
Milk fat	Average milk total fat content.	Percentage
Milk protein	Average milk total protein content.	Percentage

Source: Authors

TABLE A3. HERD module – Herd parameters: pigs

Parameter	Description	Unit
Age at first parturition	Average age at which sows have their first parturition, either it is a successful one or not.	Weeks
Fertility of adult females	Annual average of parturitions per sows, including all the sows in the herd.	Number/head
Gestation period	Average duration of the gestation period.	Days
Litter size	Average number of piglets born in each parturition, including those that die before reaching maturity.	Number
Lactation period	Average amount of time that piglets are lactated.	Days
Idle period	Average amount of time between one parturition and the consecutive pregnancy.	Days
Mortality of piglets before weaning	Annual average mortality of non-intended piglets' deaths before weaning.	Percentage
Weaning age	Average age at which piglets are weaned.	Days
Mortality of juvenile replacement animals	Annual average mortality of replacement animals with ages comprised between weaning and maturity.	Percentage
Mortality of adult replacement animals	Annual average mortality of replacement animals after reaching maturity.	Percentage
Mortality of fattening animals	Annual average mortality of adult fattening animals.	Percentage
Replacement of adult females	Rate of reproductive adult females' replacement.	Percentage
Replacement of adult males	Rate of reproductive adult males' replacement.	Percentage
Weight of piglets at birth	Average live weight of piglets at birth.	Kilograms
Weight of weaned piglets	Average live weight of piglets at weaning age	Kilograms
Weight of adult females	Average live weight of sows once they reach maturity.	Kilograms
Weight of adult males	Average live weight of boars once they reach maturity.	Kilograms
Weight of fattening animals	Average live weight at slaughter of fattening animals culled for meat.	Kilograms
Average daily weight gain	Average daily weight gain of fattening animals.	Kilograms/head/day

Source: Authors

TABLE A4. HERD module – Herd parameters: chicken

Parameter	Description	Unit
Age at first parturition	Average age at which sows have their first parturition, either it is a successful one or not.	Weeks
Fertility of adult females	Annual average of parturitions per sows, including all the sows in the herd.	Number/head
Gestation period	Average duration of the gestation period.	Days
Litter size	Average number of piglets born in each parturition, including those that die before reaching maturity.	Number
Lactation period	Average amount of time that piglets are lactated.	Days
Idle period	Average amount of time between one parturition and the consecutive pregnancy.	Days
Mortality of piglets before weaning	Annual average mortality of non-intended piglets' deaths before weaning.	Percentage
Weaning age	Average age at which piglets are weaned.	Days
Mortality of juvenile replacement animals	Annual average mortality of replacement animals with ages comprised between weaning and maturity.	Percentage
Mortality of adult replacement animals	Annual average mortality of replacement animals after reaching maturity.	Percentage
Mortality of fattening animals	Annual average mortality of adult fattening animals.	Percentage
Replacement of adult females	Rate of reproductive adult females' replacement.	Percentage
Replacement of adult males	Rate of reproductive adult males' replacement.	Percentage
Weight of piglets at birth	Average live weight of piglets at birth.	Kilograms
Weight of weaned piglets	Average live weight of piglets at weaning age	Kilograms
Weight of adult females	Average live weight of sows once they reach maturity.	Kilograms
Weight of adult males	Average live weight of boars once they reach maturity.	Kilograms
Weight of fattening animals	Average live weight at slaughter of fattening animals culled for meat.	Kilograms
Average daily weight gain	Average daily weight gain of fattening animals.	Kilograms/head/day

Source: Authors

TABLE A5. FEED module – List of feed items for ruminant species

Feed item	Description
Roughages	
Fresh grass	Any type of natural or cultivated fresh grass grazed or fed to the animals.
Hay or silage from grass	Hay (grass is cut, dried and stored) or silage (grass is cut and fermented) from any natural or cultivated grass.
Fresh mixture of grass and legumes	Fresh mixture of any type of grass and leguminous plants that is fed to the animals.
Hay or silage from grass and legumes	Hay or silage produced from a mixture of any type of grass and leguminous plants.
Hay or silage from alfalfa (Lucerne)	Hay or silage from alfalfa (*Medicago sativa*)
Silage from whole grain plants	Silage from whole wheat (*Triticum spp.*), barley (*Hordeum vulgare*), sorghum (*Sorghum spp.*), rye (*Secale cereale*) or oat (*Avena sativa*) plants.
Silage from whole maize plant	Silage from whole maize (*Zea mays*) plants.
Crop residues from wheat	Residual plant material such as straw, brans, leaves, etc. from wheat (*Triticum spp.*) cultivation.
Crop residues from maize	Residual plant material such as straw, brans, leaves, etc. from maize (*Zea mays*) cultivation.
Crop residues from millet	Residual plant material such as straw, brans, leaves, etc. from millet (*Pennisetum glaucum, Eleusine coracana, Panicum miliaceum, etc*) cultivation.
Crop residues from sorghum	Residual plant material such as straw, brans, leaves, etc. from sorghum (*Sorghum spp.*) cultivation.
Crop residues from rice	Residual plant material such as straw, brans, leaves, etc. from rice (*Oryza spp.*) cultivation.
Crop residues from other grains	Residual plant material such as straw, brans, leaves, etc. from barley (*Hordeum vulgare*), rye (*Secale cereale*) or oat (*Avena sativa*) cultivation.
Crop residues from sugarcane	Residual plant material such as straw, brans, leaves, etc. from sugarcane (*Saccharum spp.*) cultivation.
Fodder beet	Fodder beet (*Beta vulgaris*), also known as mangel beet or field beet, used as animal feed.
Grains	
Maize	Grains from maize (*Zea* mays) plant.
Grains	Grains from wheat (*Triticum spp.*), barley (*Hordeum vulgare*), sorghum (*Sorghum spp.*), rye (*Secale cereale*) or oat (*Avena sativa*) plants.
Agro-industrial by-products	
By-products from soy	By-product from soy (*Glycine max*) oil production, commonly referred to as 'soy cakes' or 'soybean meal'.
By-products from rape (canola)	By-product from rape (*Brassica napus*) oil production, commonly referred to as 'rape cakes' or 'rapeseed meal'.
By-products from cottonseed	By-product from cottonseed (*Gossypium spp.*) oil production, commonly referred to as 'cottonseed meal'.
By-products from sugar beet	Also known as 'beet pulp', is the remaining material after the juice extraction for sugar production from the sugar beet (*Beta vulgaris*).
Oil palm kernel expeller	By-product from the extraction of palm oil (*Elaeis guineensis*) kernel oil production, commonly referred to as 'kernel expeller'.
Molasses	By-product from the sugarcane sugar extraction. It is a viscous, dark and sugar-rich material.
Maize gluten meal	By-product from maize processing. It is a protein-rich feed, with about 65% crude protein content.
Maize gluten feed	By-product from maize processing. Unlike the gluten meal, its protein content is lower, of about 25% crude protein content.
Dry by-products from grain industries	'Dry' by-products of grain industries such as brans, middlings, etc.
Wet by-products from grain industries	'Wet' by-products of grain industries such as biofuels, distilleries, breweries, etc.

Source: Authors

TABLE A6. FEED module – List of feed items for monogastric

Feed item	Description
Swill & roughages	
Swill	Household organic waste used as feed that would otherwise been disposed.
Fresh grass	Any type of natural or cultivated fresh grass grazed or fed to the animals.
Grains & Food crops	
Pulses	Beans from leguminous species, such as *Phaseolus spp.*, *Vicia faba*, *Pisum sativum*, etc.
Cassava	Pellets from cassava (*Manihot esculenta*) roots.
Wheat	Grains from wheat (*Triticum spp.*)
Maize	Grains from maize (*Zea mays*).
Barley	Grains from barley (*Hordeum vulgare*).
Millet	Grains from millet (*Pennisetum glaucum, Eleusine coracana, Panicum miliaceum,* etc.)
Sorghum	Grains from sorghum (*Sorghum spp.*)
Rice	Grains from rice (*Oryza spp.*)
Soybeans	Beans from soy (*Glicyne max*).
Rapeseed	Seeds from rapeseed (*Brassica napus*).
Banana fruit	Fruits from banana trees (*Musa spp.*)
Agro-industrial by-products	
Crop residues from banana	Crop residues such as steams, peels, etc. from banana (*Musa spp.*) cultivation.
Crop residues from pulses	Residual plant material such as straw, brans, leaves, etc. from pulses cultivation.
Crop residues from sugarcane	Residual plant material such as straw, brans, leaves, etc. from sugarcane (*Saccharum spp.*) cultivation.
Soybean oil	Vegetal oil extracted from soybeans (*Glicyne max*).
By-products from soy	By-product from soy (*Glycine max*) oil production, commonly referred to as 'soy cakes' or 'soybean meal'.
By-products from cottonseed	By-product from cottonseed (*Gossypium spp.*) oil production, commonly referred to as 'cottonseed meal'.
By-products from oilseeds	By-product from seed oil production other than soy, cottonseed or palm oil.
Oil palm kernel expeller	By-product from the extraction of palm oil (*Elaeis guineensis*) kernel oil production, commonly referred to as 'kernel expeller'.
Dry by-products from grain industries	'Dry' by-products of grain industries such as brans, middlings, etc.
Wet by-products from grain industries	'Wet' by-products of grain industries such as biofuels, distilleries, breweries, etc.
Molasses	By-product from the sugarcane sugar extraction. It is a viscous, dark and sugar-rich material.
Fish meal	Meal obtained by cooking, drying and milling of raw fish, by-captures or fish trimmings.
Additives	
Additives	Synthetic additives such as amino acids or minerals.
Limestone	Sedimentary stone composed mainly of calcium carbonate ($CaCO_3$). Used as a source of calcium, is commonly given to laying hens to favor the formation of the egg shell.

Source: Authors

TABLE A7. MANURE module – Description of manure management systems

Manure system	Description
Pasture/Range/Paddock	The manure from pasture and range animals is allowed to lie as deposited, and is not managed.
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year.
Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.
Burned for fuel	The dung and urine are excreted on the fields. The sun dried dung cakes are burned for fuel.
Pit storage	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.
Anaerobic digester	Animal excreta with or without straw are collected and anaerobically digested in a containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by microbial reduction of complex organic compounds into CO_2 and CH_4, which is captured and flared or used as fuel.
Poultry manure with litter	May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as high-rise manure management system and is a passive windrow composting when designed and operated properly.

Source: IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.

TABLE A8. RESULTS page – Description of emission sources

Source	Description
FEED	Emissions caused by the production, processing and transport of feed
FEED: Fertilizer & crop residues, N_2O	N_2O emissions caused by fertilizers applied to the feed crops and by the decomposition of crop residues.
FEED: Applied & deposited manure, N_2O	N_2O emissions from the manure deposited in the fields by grazing or scavenging animals or from manure applied to crop fields or pastures.
FEED, CO_2	CO_2 emissions arising from the production, transport and processing of feed. This includes emissions from fossil fuels use in fertilizer manufacture, field operations and feed manufacture in feed mills.
FEED: LUC soybean, CO_2	CO_2 emissions from the expansion of soybean used for feed into natural areas.
FEED: LUC pasture, CO_2	CO_2 emissions from the expansion of pastures into natural areas.
FEED: Rice, CH_4	CH_4 emissions from rice cultivation for feed purposes.
ENTERIC FERMENTATION	CH_4 emissions from enteric fermentation of ruminant species and pigs. During the digestive process, microbial fermentation breaks down part of the carbohydrates in the diet, generating methane as a by-product. In general, fibrous materials cause higher methane emissions.
MANURE MANAGEMENT	Emissions caused by the management of dung and urine (application and deposition are excluded)
MANURE, CH_4	CH_4 emissions from the anaerobic decomposition of organic material. This occurs mostly when manure is managed in liquid form.
MANURE, N_2O	N_2O emissions from the conversion of nitrogen compounds. It includes direct emissions (conversion of N into N_2O via combined nitrification and denitrification) and indirect emissions (nitrogen is lost in forms of ammonia and NO_x).
ENERGY USE	Emissions caused by energy consumption from fossil fuels
ENERGY USE: Direct energy, CO_2	CO_2 emissions from the use of energy in the animal production site for heating, ventilation, refrigeration, machinery, etc.
ENERGY USE: Embedded energy, CO_2	CO_2 emissions from the use of energy on the construction of facilities (animal housing) and equipment.

Source: Gerber, P. *et. al.*, *Tackling climate change through livestock. A global assessment of emissions and mitigation opportunities.* FAO, 2013.