Life Cycle Inventories of Agriculture, Forestry and Animal Husbandry - Brazil

For the SRI project

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Part III – Animal husbandry

6 Life cycle inventories for beef cattle in Brazil

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6.1 Introduction to the sector

This chapter presents information on the main resources and emissions considered in the life cycle inventory for beef cattle production in Brazil. The beef cattle industry in Brazil was responsible for around 5 billion dollars in exports (IBGE, 2015).

There are several alternatives for characterizing Brazilian beef cattle production systems. This work adopted two basic parameters: i) phases of the production cycle carried out in a production unit, i.e., in a farm; ii) level of intensification of cattle system, especially related to supplementary feeding and pasture fertilization. As for the phases of production cycle at farm level, three categories were used: full cycle systems, cow-calf systems, and growing-finishing systems. In full-cycle systems, cattle leaving the system for slaughtering are born in the system[11], including cull cows and bulls from breeding herd. Cow-calf systems produce calves which are transferred at weaning to growing-finishing systems. In full-cycle and cow-calf systems, heifers not used for replacing culled cows from the breeding herd can either be finished for slaughter or sold at weaning to other systems. In growing-finishing systems, weaned male calves and heifers from other systems enter the farm where they are grown and finished until slaughter.

6.2 Description of the product

6.2.1 Yield

Table 6.1 presents yield data for the ten activity datasets submitted by the project, expressed in kilograms of cattle live weight obtained per hectare of pasture per year. Yields of cow-calf and full cycle systems are lower than those of growing-finishing systems because of larger grazing area needed for the breeding herd, especially cows throughout pregnancy and milking, in order to produce calves, which are a light-weighted product of the system. In other words, feeding the breeding herd aims maintenance of cows and bulls, not properly generating weight gains in these animals, as in finishing systems. In growing-finishing systems, yields are higher because there is no breeding herd and, therefore, food consumption, especially of pasture, is directly reflected in animals' live weight gain, which, consequently, are kept in the system for shorter periods. However, environmental impacts of growing-finishing systems include the impact of upstream cow-calf systems. Regarding levels of intensification, intensive systems have higher yields per hectare than extensive

[11] Except for breeding bulls; more on this later.

systems, however, higher productivity is achieved by adding inputs to pastures and animal feeding, which add up to upstream environmental impacts.

Table 6.1 Brazilian beef cattle datasets and their yields (kg ha^{-1} yr^{-1}).

Type	Dataset	Product	Yield
Cow-calf	weaned calves production on native pasture, Pantanal	weaned calves, live weight	10,1
	weaned calves production on native and planted pasture, Pantanal		16,4
	weaned calves production on pasture		29,9
Full-cycle	beef cattle production on pasture	cattle for slaughtering, live weight	63,7
	beef cattle production on pasture and protein supplement		79,8
	intensive beef cattle production on pasture		154,4
	intensive beef cattle production, fat steers only, on pasture		169,2
	beef cattle production on pasture and feedlot		190,9
Growing and finishing	fattening of heifers for beef cattle production, on pasture		320,4
	fattening of calves for beef cattle production, on pasture		381,6

6.2.2 By-products and crop residues

For the activity datasets representing full cycle systems, the reference product adopted was the one already in the ecoinvent database for beef cattle production: “cattle for slaughtering, live weight”, i.e., 1 kg of live weight of adult animal at farm gate, ready to be transported to slaughter. This is also the reference product for growing and finishing systems.

In full cycle systems, in addition to males grown and finished for slaughter, culled cows and bulls from the breeding herd are included in the reference product “cattle for slaughtering, live weight”.

In cow-calf systems, weaned male calves are the product, so one new exchange was defined: “weaned calves, live weight”, i.e., 1 kg of live weight of weaned male[12] calf at farm gate, ready to be transported to growing-finishing systems. In these systems, culled bulls and cows from breeding herd are sold to slaughterhouses as by-product “cattle for slaughtering, live weight”.

In cow-calf and full cycle systems heifers might be used as replacement for culled cows, and the heifers in excess may be sold, so one new exchange have been defined for this by-product: “weaned heifers, live weight”, i.e., 1 kg of live weight of weaned heifer at farm gate, ready to be transported to growing-finishing systems.

[12] Although “calf” may designate both male and female calves before weaning, for the sake of convenience the exchange “weaned calves” means only weaned male calves. For female calves after weaning, the term chosen was “weaned heifers”.

6.2.3 Production classification

The two new products “weaned calves, live weight” and “weaned heifers, live weight” were given the same classification of “cattle for slaughtering, live weight”. Other wastes and emissions mentioned in the datasets were already available in ecoinvent database.

6.2.4 Production volume

Figure 6.1 shows the annual total carcass yield from cattle slaughtered in 2015 (IBGE, 2015) for each Brazilian region, in million metric tons per year and as a percentage of the country's total.

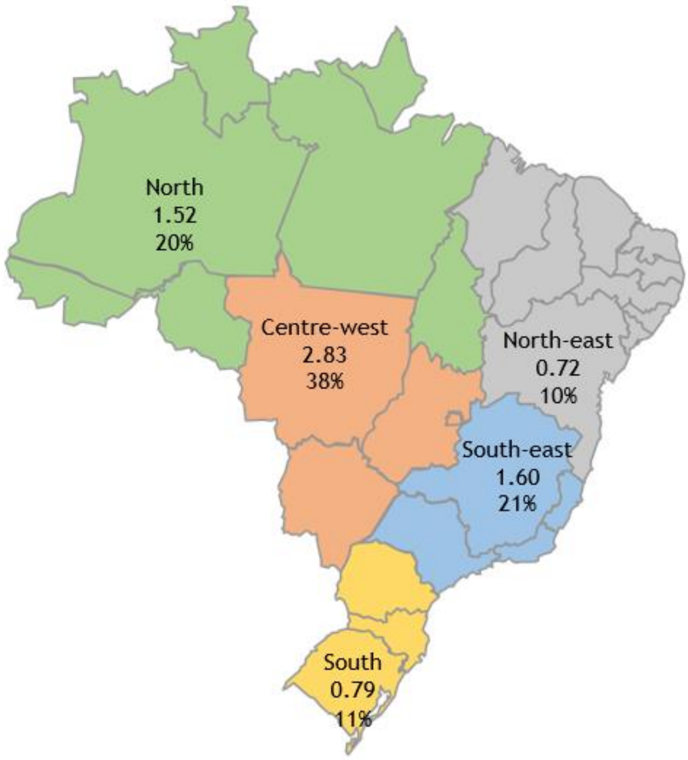

Figure 6.1 Carcass production in 2015, per Brazilian region, in million ton per year (IBGE, 2015).

In order to estimate Brazilian beef cattle live weight production, first the meat production was deducted from cull dairy animals, which, in Brazil, corresponds to approximately 10% of carcass production. Then, total carcass weight was converted to live weight considering average yield of 50% carcass from live weight. Proportional participation of each production system in the total of the country was estimated as defined in item “6.3.1. Activity Description”. Brazilian calf production from each cow-calf and full-cycle systems was estimated by proportionality with the production of animals for slaughter. Table 6.2 presents the Brazilian production volumes for each of the ten activity datasets, for the corresponding reference product.

Table 6.2 Brazilian beef cattle datasets and their production volumes (kg yr^{-1}).

Type	Dataset	Product	Volume
Cow-calf	weaned calves production on native pasture, Pantanal	weaned calves, live weight	7,416E+07
	weaned calves production on native and planted pasture, Pantanal		5,185E+07
	weaned calves production on pasture		6,183E+08
Full-cycle	beef cattle production on pasture	cattle for slaughtering, live weight	6,064E+08
	beef cattle production on pasture and protein supplement		8,426E+08
	intensive beef cattle production on pasture		4,883E+09
	intensive beef cattle production, fat steers only, on pasture		2,708E+09
	beef cattle production on pasture and feedlot		6,274E+08
Growing and finishing	fattening of heifers for beef cattle production, on pasture		2,441E+09
	fattening of calves for beef cattle production, on pasture		2,082E+09

6.2.5 Properties

Animal product and by-products properties (carbon content, calorific value, moisture, etc.) per unit of product were assumed equal to those already available in the ecoinvent database for “cattle for slaughtering, live weight”. Prices were adjusted to average for Brazil for the modelling period (2006 to 2015).

6.3 Technical description of activities

6.3.1 Activity description

Elaboration of datasets was based on mathematical models for biologic and economic performance of ten current beef cattle production systems in Cerrado and Pantanal biomes. These mathematical models are available in spreadsheets produced by Embrapa scientists with adjustments made by the Pecus project (Embrapa, 2015). For the elaboration of the datasets, other adjustments were made on assumptions from original models, adding information needed for dataset composition through expert judgment and relevant literature. Upstream processes already available in ecoinvent database were adopted. Some upstream processes have been included from processes developed by this same project and are described below. Adjustments, assumptions and solutions proposed to complete missing information from economic models are also described below. The approach used was “cradle-to-gate”.

The diagram on Figure 6.2 shows the main material and energy exchanges for one of the complete cycle datasets, which was picked as example, since it includes most of the exchanges present in the other beef cattle datasets.

Inputs

Production of urea for pasture fertilisation considered process already available in the ecoinvent database for the GLO region. Production of urea for animal feeding considered this same process, although in Brazil urea for animal feeding requires specific quality assurance standards.

Production of soybean meal and maize grain for animal feeding was modelled on other datasets prepared for Brazil and described in this report. Production of maize silage for animal feeding required elaboration of a specific dataset described below (6.3.7).

Regarding infrastructure of production systems, only wire fences were modelled, using eucalyptus (described in Chapter 5 of this report) for poles, plus other processes for processing fence poles and coated steel wires. Machinery and equipment sheds were modelled on operation datasets.

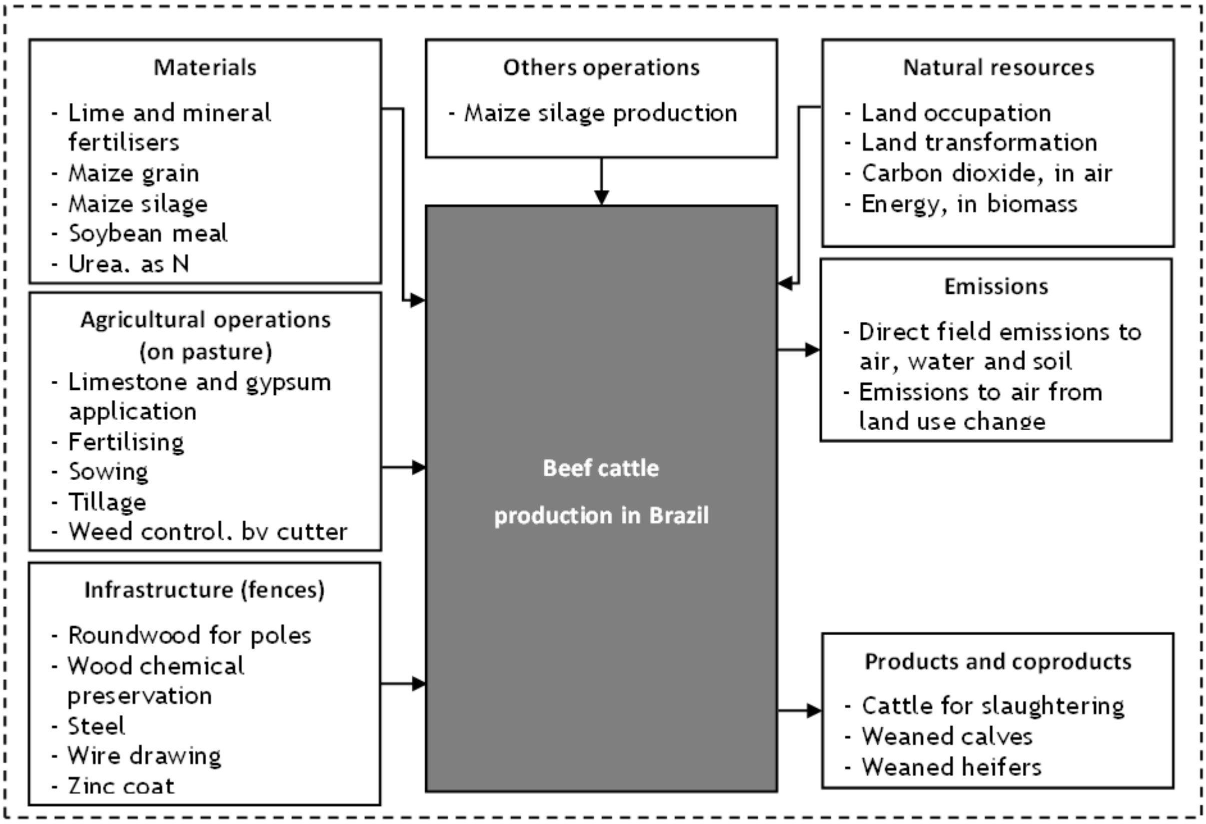

Figure 6.2 Processes covered by in the beef cattle production datasets.

The main characteristics of activities are presented in Table 6.3, for an activity chosen as example. The attributes “Time period”, “Classification ISIC”, “Geography” and “Technology” are the same for the ten datasets.

Table 6.3 Activity description metadata of beef cattle production in Brazil.

Dataset	beef cattle production on pasture, BR 2015
Activity name	Beef cattle production on pasture
Reference product	cattle for slaughtering, live weight
Time period	2006 – 2015
Classification ISIC	0141 - Raising of cattle and buffaloes
Geography	BR
Technology	Current

6.3.2 Data quality

Elaboration of datasets was based on mathematical models for biologic and economic performance of ten current production systems in the Cerrado and Pantanal biomes, developed in electronic spreadsheets as a result of investigations carried out at Embrapa Beef Cattle (Correa et al., 2006 , Costa et al., 2005, Pereira et al., 2014) and Embrapa Pantanal (Crespolini, 2017). These models were reviewed and expanded in the Pecus project, finished in 2015 (Embrapa, 2015). The Pecus project used data from the Brazilian livestock census conducted by the Brazilian Institute of Geography and Statistics (IBGE) in 2006, being the most recent data available at the time (IBGE, 2006). These data were used to estimate the share of each system in the beef cattle production in Cerrado and Pantanal biomes in 2006 and the participation of the total production of these biomes in Brazilian total production. The Pecus project also updated these estimates using mathematical simulations with support from experts from Embrapa. Two datasets represent cow-calf systems considered exclusive for the lower wetlands in Pantanal biome (less than 0.5% of Brazilian total production). The other eight datasets modelled production systems used in Cerrado biome and in the nearby plateaus of Pantanal biome, representing 42% of Brazilian production. These eight datasets were assumed to be a good approximation of the systems used for the remainder of Brazilian production, at the same proportion that each of these eight systems represented the Cerrado and Pantanal production. Information needed for dataset composition was added from expert judgment and relevant literature. The temporal coverage corresponded to the time period of most of the data collected for this dataset. The Pedigree Matrix for exchanges and properties was adjusted considering the simplifications assumed, especially time and geography.

6.3.3 Inputs from Environment

Regarding the use of natural resources, land occupation and land transformation were considered, but water consumption was not, since pasture irrigation practice is rare in Brazil and does not occur in modelled production systems, and the consumption of water by animals is mostly from natural source, i.e., surface water, groundwater or rain. Land occupation by each system occurs almost entirely in pasture area and it is the inverse of yield described in Table 6.1. Land use change emissions is dealt with in section 6.3.6.

6.3.4 Inputs from Technosphere

Datasets included inputs of lime for reducing soil acidity, mineral fertilisers, soybean meal, maize grain, maize silage and urea for pasture fertilisation and for animal feeding. The only organic fertiliser applied is manure deposited naturally by grazing cattle.

Datasets did not include transport of animals or supplies within farm boundaries. The only infrastructure included was fences: chemically treated eucalyptus poles and galvanised (zinc coated) steel wire. Eucalyptus for fencing is obtained from Brazilian production, described in Chapter 5. Weaned calves and heifers are by-products in some datasets and inputs in others. Not all entries here mentioned apply to all datasets.

Fertilisers and Packaging

Amount and frequency for mineral fertilisers application vary by intensification level and are broken down in the respective datasets, as well as the composition of the fertilisers used. Packaging was added considering the amounts of fertilisers and pesticides in the dataset.

Agricultural Mechanized Operations

Agricultural mechanized operations represented in the datasets are summarized as pasture establishment or renewal. Those that were adapted to Brazilian conditions are described in the Chapter 7 of this report. Since Brazilian markets for these operations were not modelled, these operations in the beef cattle datasets were directly linked to the activity datasets for these operations.

Animal feeding

Two relevant inputs for animal feeding come from market datasets for BR region described in the Chapter 2 of this report: soybean meal and maize grain. A dataset representing production of maize silage was also elaborated, adapting the maize production dataset for BR region, described later in this section. Some systems use urea as a component in animal feeding. Urea for animal feeding is more expensive than the one used for pasture fertilisation because a higher degree of purity is required by law, but for the purpose of modelling the animal production datasets, the urea used as fertiliser for the GLO region was considered for both pasture fertilisation and animal feeding.

6.3.5 Direct field emissions

Emissions from liming and fertilisation of pasture

This project has followed recommendations from ecoinvent (Nemecek, et al., 2015) for calculating emissions from liming and fertilisation of pastures, with the exception for: emission of heavy metals, for which the Canals model was adopted (2003); phosphorus leaching, a physical process that does not occur in Brazilian soils (Novais and Smyth, 1999); nitrate leaching into groundwater, where the SQCB-NO_3 model was calibrated according to Bernardi et al. (2012) and Cunha et al. (2010). Once adjusted, the emission models for liming and fertilisation of pastures are the same used for grains production and are detailed in Chapter 2 (section 2.1.3.5).

CH_4 emission from enteric fermentation

The IPCC tier 2 model (IPCC, 2006) was used for estimating emissions from enteric fermentation, with some of the technical parameters adjusted to values from Brazilian publications.

Equation 6.1

$$\boldsymbol{CH_4E_i = \frac{18.45}{55.65} \times DMI_i \times Ym_i \times Days_i}$$

where:

CH_4E_i is the enteric fermentation CH_4 emission factor for animal in category i, in kg.year^{-1}.animal^{-1};

18.45 is the energy intensity of feed, IPCC default value, in MJ.kg^{-1}

55.65 is the energy value of CH_4, IPCC default value, in MJ.kg^{-1};

DMI_i is the average Dry Matter Intake of animal in category i, in kg.day^{-1}.animal^{-1};

Ym_i is the average methane conversion rate of animal in category i, in %;

$Days_i$ is the number of days per year each herd stay in category i, in days.year^{-1}.

DMI_i (Dry Matter Intake) from pasture for animal in category i was obtained from Barioni et al. (2007), using their mean live weight, daily weight gain and corporal condition. Dry matter intake from forage, mean live weight, daily weight gain, corporal condition and herd composition by animal category each day of the year were obtained from the economic mathematical models of beef cattle production systems of the Cerrado and Pantanal biome elaborated by the project Pecus (Embrapa, 2015). Ym_i (methane conversion rate) was assumed to be 3% for calves and 6% for other categories, as proposed by Brazil (2015), pg. 56.

CH_4 emission from manure decomposition

The IPCC tier 2 model (IPCC, 2006) was used for estimating emissions from manure decomposition on pasture and feedlot, with some of the technical parameters adjusted to values from Brazilian publications.

Equation 6.2

$$CH_4M_i = 0.67 \times Bo \times MCF \times VS_i \times Days_i$$

where:

CH_4M_i is emission factor for CH_4 from decomposition of manure from animal in category i, in kg.year^{-1}.animal^{-1};

0.67 is the conversion factor of m^3 CH_4 to kg CH_4;

Bo is the maximum production capacity of methane by manure, in m$^3CH_4$.kg^{-1};

MCF is the methane conversion factor, in %;

VS_i is daily volatile solid excreted for animal on category i, kg.animal-1.day-1;

$Days_i$ is the number of days per year each animal stay in category i, in days.year^{-1}.

MCF (methane conversion factor) was assumed to be 1.5% for pasture and feedlot and Bo (maximum production capacity of methane by manure) was assumed to be 0.1 m$^3CH_4$.kg^{-1}, as recommended by IPCC (2006), Table 10A-5, for an average annual temperature in 22-23ºC. VS_i was calculated as shown below:

Equation 6.3

$$VS_i = DMI_i \times (1 - DE + UE) \times (1 - ASH)$$

DMI_i is the Dry Matter Intake of animal in category i, in kg.day^{-1}.animal^{-1};

DE is the digestibility of the feed, in %;

UE is the urinary energy, as a fraction of gross energy intake;

ASH*:* is the ash content of manure, as a fraction.

DMI_i (Dry Matter Intake) was obtained from Barioni et al. (2007) and Pecus (Embrapa, 2015). DE (digestibility of the feed) was assumed as 56.3% for pasture and 80.0% for forage, as recommended by Brazil (2015), pg. 67. UE (urinary energy as a fraction of gross energy intake) was assumed to be 0.04 and ASH (ash content in manure) was assumed to be 0.08, as in IPCC (2006), pg. 42.

N_2O emissions to air from pasture fertilisation

Emissions of N_2O to air include those from pasture fertilisation, using the same model adjusted for the datasets on Brazilian grain production (Equation 2.3, Chapter 2, section 2.1.3.5).

N_2O emissions from management of animal waste (manure)

Manure on pasture or feedlot emits **N_2O** directly and contributes with **N** and **NH_3** to indirect emissions of **N_2O**. IPCC tier 1 assumptions were used for **N_2O** direct and indirect emissions from manure.

Equation 6.4

$$N_2O_i = \frac{44}{28} \times \left(F_{P,i} \times E_{DP} + F_{F,i} \times E_{DF} + F_{P,i} \times E_N \times N_P + F_{F,i} \times E_N \times N_F\right)$$

N_2O_i is the annual direct and indirect N_2O emissions from manure on pastures or feedlot of animals of category i, in $kg.year^{-1}.animal^{-1}$;

$F_{P,i}$ is the annual amount of N from manure on pastures of animals of category i, in $kg.year^{-1}.animal^{-1}$;

$F_{F,i}$ is the annual amount of N from manure on feedlot of animals of category i, in $kg.year^{-1}.animal^{-1}$;

E_{DP} is the N_2O-N (i.e., N in N_2O) direct emission factor for manure on pastures.

E_{DF} is the N_2O-N direct emission factor for manure on feedlot.

E_N is the N_2O-N indirect emission factor for N that volatilises as NH_3 and NO_x from manure.

N_P is the fraction of N from manure on pastures that volatilises as NH_3 and NO_x.

N_F is the fraction of N from manure on feedlot that volatilises as NH_3 and NO_x.

44/28 is the conversion factor from kg N_2O-N to kg N_2O.

$F_{P,i}$ and $F_{F,i}$ were calculated as:

Equation 6.5

$$F_{s,i} = \frac{1}{1000} \times Nex \times W_{s,i} \times \frac{Days_{s,i}}{365}$$

where:

$F_{s,i}$ is the annual amount of N from manure from animals of category i in pasture (s=P) or feedlot (s=F), in kg.year^{-1}.animal^{-1};

Nex is the excretion rate of N per 1000 kg of animal live weight, in kg N/1000 kg.day^{-1};

$W_{s,i}$ is the average live weight of animals of category i in pasture (s=P) or feedlot (s=F), in kg.animal^{-1};

$Days_{s,i}$ is the number of days per year each animal stay in category i, in pasture (s=P) or feedlot (s=F), in days.year^{-1}.

Nex (excretion rate of N) was assumed to be 0.36 kg N/1000 kg.day^{-1} for all beef cattle categories, as recommended by IPCC tier 1 (2006), Table 10.19.

W_i (average live weight of animals from category i) and $Days_i$ (the number of days per year each animal stay in category i) were obtained from the economic mathematical models of beef cattle production systems of the Cerrado and Pantanal biome elaborated by the project Pecus (Embrapa, 2015).

The other parameters followed IPCC tier 1 (2006), for all animal categories:

Table 6.4 Parameters used to calculate N_2O emissions from management of animal waste.

Parameter	Description	Source	Amount	Source (IPCC, 2006)
E_{DP}	N_2O direct emission factor	Pastures	0.02	Table 11.1
E_{DF}	N_2O direct emission factor	Feedlot	0.02	Table 10.21
E_N	Emission factor of N from NH_3 and NO_x	Pastures or feedlot	0.01	Table 11.3
N_P	fraction of N from NH_3 and NO_x	Pastures	0.20	Table 11.3
N_F	fraction N from NH_3 and NO_x	Feedlot	0.30	Table 10.22

NH3 emissions to air

Ammonia emissions from pasture corrective and fertilisers application were estimated using the emission model for grain production (Equation 2.5, section 2.1.3.5, Chapter 2). Ammonia emissions from manure deposited on pasture were estimated according to Nemecek et al. (2015).

Equation 6.6

$$NH_{3_{s,i}} = \frac{17}{14} \times F_{s,i} \times 0.6 \times 0.06$$

where:

NH_{3_i} is the emission of ammonia from of animals of category i in pasture (s=P) or feedlot (s=F), in kg.year^{-1}.animal^{-1};

$F_{s,i}$ is the annual amount of N from manure from of animals of category i in pasture (s=P) or feedlot (s=F), in kg.year^{-1}.animal^{-1};

17/14 is the conversion factor from kg NH_3-N in NH_3.

NO_x emissions to the atmosphere

NO_x emissions from management of animal waste to air were calculated from N_2O emissions (Equation 2.4, Chapter 2, section 2.1.3.5).

N in crop residues

Nitrogen contained in crop residues was not considered for pastures because root does not die (semi-perennial).

Emissions of fossil CO_2 to air

After application of urea ($CO(NH_2)_2$) and calcitic ($CaCO_3$) or dolomitic ($CaMg(CO_3)_2$) lime in arable soils, bicarbonate (HCO_3^-) is formed which is subsequently converted to water and CO_2 emitted to air. These emissions of CO_2 fossil derived from urea and lime application were estimated according to Tier 1 of IPCC (2006), detailed on Chapter 2 (section 2.1.3.5, Equation 2.6).

Nitrate leaching to groundwater

The calculation of nitrate leaching to groundwater used the model SQCB-NO_3 as described in Equation 2.7 (see Chapter 2, section 2.1.3.5). Parameters used for the calculation of nitrate leaching to groundwater was based on geometric mean of the states of MT, MS and GO (see Table 2.17).

Heavy metal emissions to surface water and soil

Emissions of heavy metals to surface water and soil from correctives and fertilisers application (only mineral) were calculated according to the model proposed by Canals (2003), considering all metals intake by the plants to be emitted in the manure. Heavy metal emissions considered were: cadmium (Cd); lead (Pb); copper (Cu); chromium (Cr); nickel (Ni) and zinc (Zn). The heavy metal content in agricultural inputs considered are in Table 2.19. The details of the model and its use for all datasets for Brazil are described in Chapter 2 (section 2.1.3.5).

6.3.6 Land use change

Land use change in Brazil is directly related to the country’s agricultural expansion borders and has an important participation in GHG emissions. These emissions were calculated according to the “BRLUC” model (Novaes et al., 2017). The temporal coverage considered in the expansion of planted pasture areas was the period from 1996 to 2015. The results of these emissions may vary according to the assumptions, therefore, the authors recommend uncertainty analysis.

As mentioned in Chapter 2 (section 2.1.3.6), the inclusion of land use change (LUC) aspects in datasets can occur through the crop-specific approach and the shared-responsibility approach. Table 6.4 shows the expansion of planted pasture areas and values of land use change for the livestock systems under study.

Table 6.5 Expansion of planted areas and values of land use change for beef cattle production systems, according to the crop-specific and shared-responsibility approaches (temporal coverage: 1996-2015).

Dataset	Crop-specific approach		Shared-responsibility approach	
	Crop expansion	Land use change (ha kg^{-1} $year^{-1}$)	Crop expansion	Land use change (ha kg^{-1} $year^{-1}$)
weaned calves production on native pasture, Pantanal	8%	1.58E-04	17%	3.27E-04
weaned calves production on native and planted pasture, Pantanal	8%	1.46E-03	17%	3.03E-03
weaned calves production on pasture	8%	2.68E-03	17%	5.55E-03
beef cattle production on pasture	8%	1.26E-03	17%	2.61E-03
beef cattle production on pasture and protein supplement	8%	1.00E-03	17%	2.08E-03
intensive beef cattle production on pasture	8%	5.18E-04	17%	1.07E-03
intensive beef cattle production, fat steers only, on pasture	8%	4.73E-04	17%	9.80E-04
beef cattle production on pasture and feedlot	8%	4.19E-04	17%	8.69E-04
fattening of heifers for beef cattle production, on pasture	8%	2.50E-04	17%	5.18E-04
fattening of calves for beef cattle production, on pasture	8%	2.10E-04	17%	4.35E-04

Source: adapted from Novaes et al. (2017).

6.3.7 Market activities and other relevant datasets

Market datasets and transport

Figure 6.3 shows a diagram for the ten activity datasets and the three market datasets for beef cattle developed for BR region. For the sake of convenience, the five full cycle systems and the three cow-calf systems were represented by one block for each system type.

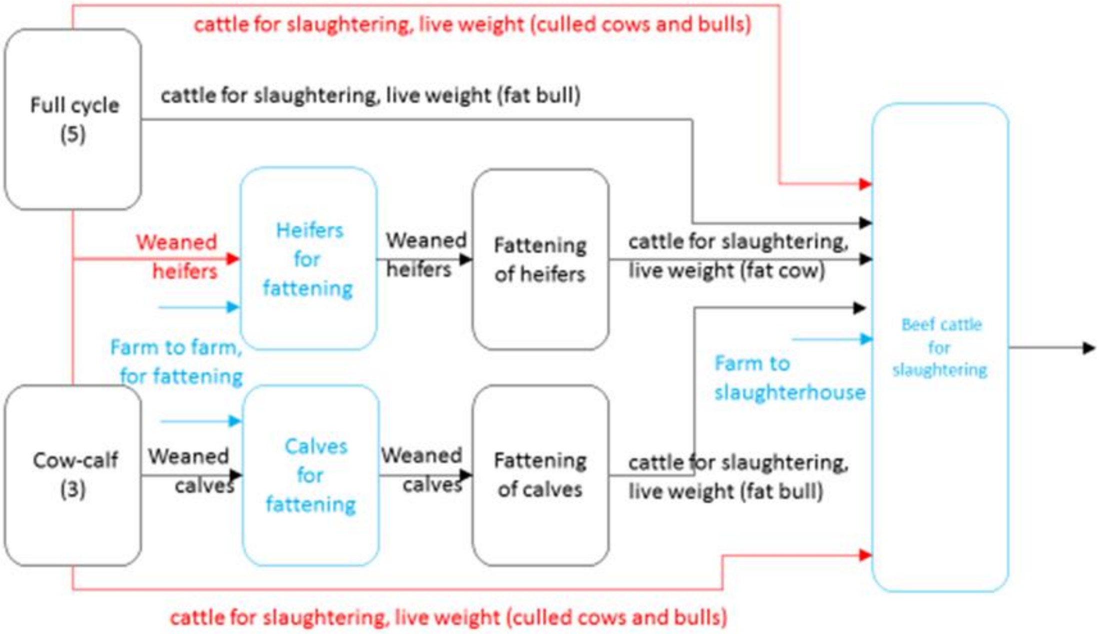

Figure 6.3 Datasets of beef cattle production.

Market datasets in ecoinvent represent the regional mix of a given product from production technologies used in the region. For example, in Figure 6.3, the market for "beef cattle for slaughtering" in BR region consolidates supply of this product coming from all "beef cattle for slaughtering" production datasets in BR region. The market datasets have as additional input the transport of products from supplier to consumer. Distances from producer to consumer (from farm to slaughterhouse or between farms) and vehicles used were determined through analysis of Animal Transport Licences ("Guias de Transporte Animal – GTA) in the state of Mato Grosso do Sul. The result obtained was very close to the first estimate from experts (about 200 km), and it was considered a good estimation for BR region.

Maize silage

In addition to the ten animal production datasets and the three market datasets for the BR region, a dataset representing production of maize silage was elaborated, adapted from the maize grain production dataset (Chapter 2). Adjustments were made, for example, assuming "chopping" of the whole plant for the harvest, excluding grain drying and adjusting production volume and yield to consider the whole plant. Other adjustments are described in the maize silage dataset. Although maize silage production is normally nearby the cattle farm, a market dataset was defined for BR region.

6.4 Results and recommendations

6.4.1 General description of the results

Global warming potential, emissions from animals, land use change

Once the impacts were normalized, the Global Warming Potential (GWP) has been confirmed as the only relevant impact category. Results on emissions from animals (CH_4 and NO_2) are close to values normally found in publications from Brazilian beef cattle GHG emission studies (e.g., Ruviaro et, al., 2014 and Silva et. al., 2016), and represent more than half of the GWP figure in full cycle systems. Also, in full cycle systems the remainder of the GWP figure is almost completely due to Land Use Change, especially in extensive systems. In growing-finishing systems, a significant part of the environmental burden comes upstream as the purchase of weaned calves and heifers produced by cow-calf and full cycle systems.

Contributions of this study

In ecoinvent 3.4, only dairy production datasets were available, and cattle for slaughterhouse was represented only as a by-product from these systems. Inclusion of beef cattle production systems was a major contribution, especially coming from Brazil, a market belonging to the top 3 in world beef cattle production.

Adjustments to ecoinvent general recommendations for calculating emissions were required to model IPCC's Tier 2 enteric methane emissions and decomposition of waste from the national livestock and to adequately represent effect of Brazilian soils and climates on emissions of heavy metals and phosphorus leaching on pasture management.

6.4.2 Possible improvements

Some decisions made to simplify datasets can be turned into opportunities of improvement on future versions. Some of these opportunities are discussed below.

Prices

Live weight of animals sent for slaughter is not differentiated by animal category (adult males castrated or not, cull cows and bulls), all of which are registered under a single exchange in ecoinvent database: “cattle for slaughtering, live weight”. This is an approximation that does not consider price variations between animal categories, which might change results when consequential modelling is used, for example, if intensive growing-finishing systems specialized in steers are compared with full cycle systems that produce a lot of live weight derived from breeding herd culling, of lower price at slaughter.

Animal replacements on breeding herd

Replacement heifers for breeding herds are bought and sold between full-cycle and cow-calf systems, although this was not considered in the modelling because its net effect on final production of animals for slaughter is not relevant.

The modelled datasets assumed the use of bulls in natural service, which was the most common in 2006, when systems were characterized. Due to this, the modelled systems included emissions from bulls through their breeding service on farm (5 years), as well as their culling for slaughter after this period. However, the model for producing adult bulls upstream was not included, since they are in small numbers in the herd (about one for every 30 breeding cows). A future review could include datasets for producing bulls for natural service and semen production for artificial insemination, if the impact of these processes shows to be relevant.

Supplementary feeding: minerals and urea

Mineral supplements for cattle are usual in Brazilian cattle production systems. Mineral supplement mixtures usually include 50% dicalcium phosphate, 45% sodium chloride and 5% of other minerals with variations among formulations. In Brazil, sea salt is the almost exclusive source of sodium chloride and some micronutrients, and dicalcium phosphate is obtained from mining, usually by the same industries producing phosphate fertilisers. On ecoinvent database, the only available sodium chloride is the product of an industrial process that does not adequately represent sea salt extraction, and there is no dataset representing dicalcium phosphate. For this reason, mineral supplement for cattle was not included in the datasets.

In Brazil, urea used for animal supplementation has some differences on processing compared to urea used as fertiliser. In the modelled datasets, the urea production process available in GLO was considered for agricultural processes and animal supplementary feeding.

A future modelling of Brazilian production of animal supplementary feeding should consider Brazilian production and consumption of sea salt and urea.[13]

Animal handling

Animal management was not considered in the estimation of infrastructure, use of equipment and fuel consumption due to their small relevance in the modelled systems. These exchanges will become more relevant when intensive systems are adopted and modelled, for example, those with higher use of feedlots.

Water footprint

Water modelling was not included because water for herd consumption in Brazilian cattle systems comes almost exclusively from natural source, i.e., surface water, groundwater or rain with little use of irrigation or treated water, and therefore the difficulty in adequately modelling pasture and animal water consumption and evapotranspiration. The percentage of water in the products and inputs was accounted. Future revisions of datasets may include water modelling sufficient to allow water footprint accounting.

6.4.3 Considerations on the sector's future

Geography and time: biomes, regions and census

The production systems usual on Cerrado and Pantanal biomes were used as basis for elaborating the datasets submitted. Data from the 2006 IBGE agricultural census were used as reference for estimating Brazilian cattle production in the year 2015. A new Brazilian agricultural census is expected to have its results consolidated by 2018-2019. It will be a good opportunity to revise the chosen systems and expand geographic scope in order to better represent Brazilian production.

Meat as by-product of milk production

Dairy production in the BR region was not modelled, nor the production of animals for slaughter as by-product of milk production. From expert judgment, it has been estimated that around 10% of the national beef production comes from milk production. Future efforts on producing new datasets might include modelling dairy systems with cattle for slaughter as by-product.

Greenhouse gas emission models

The performance of beef cattle in the category climate change, more specifically regarding global warming potential, was penalized by the methodology adopted in the definition of land use change, more specifically, time horizon (1996-2015). If a more recent period was considered, emissions from land used change would be much lower, because of the reduction of area used for cattle ranching in the last years. Another criterion adjustment that would greatly improve beef cattle performance in this category, especially in extensive grazing systems, would be considering carbon fixed in the soil by pasture.

[13] Datasets related to the production of sea salt and mineral supplement were generated by the ecoinvent Association, and added to the ecoinvent database v3.6.

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