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Aurélie Wilfart, Florence Garcia-Launay, S. Dauguet, A. Tailleur, S. Willmann, M. Laustriat, Morgane Magnin, Armelle Gac, Sandrine Espagnol

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Wilfart A.[1*], Garcia-Launay F.[2], Dauguet S.[3] Tailleur A.[4], Willmann S.[4], Laustriat M.[3], Magnin M.[1], Gac A.[5], Espagnol S. [6]

[1]SAS, INRA, Agrocampus Ouest, 35042 Rennes, France
[2]PEGASE, INRA, Agrocampus-Ouest, 35590 Saint-Gilles, France
[3]Terres Inovia, Centre technique des oléagineux, 33600 Pessac, France
[4]ARVALIS, Institut du végétal, 44370 la Chapelle Saint Sauveur, France
[5]Institut de l'Elevage, Monvoisin, 35652 Le Rheu Cedex, France
[6]IFIP, Institut du porc, 35651 Le Rheu, France

[*] Corresponding author: Email: *aurelie.wilfart@rennes.inra.fr*

ABSTRACT

Feeds contribute highly to the environmental impacts of livestock products. Therefore formulating low-impact feeds necessitates data of the environmental impacts of feed ingredients with consistent perimeters and methodology for life cycle assessment (LCA). We built the ECOALIM dataset of life cycle inventories (LCI) and associated impacts for feed ingredients utilised in animal production in France. It provides several perimeters for LCI (field gate, storage organization gate, plant gate and harbour gate) with homogeneous data source from R&D French institutes covering the period 2005-2012. The dataset of 149 environmental impacts is available as an Excel spreadsheet on the ECOALIM website and provides ILCD and CML climate change and acidification, eutrophication, CED non-renewable energy, phosphorus consumption, and CML land occupation. Life cycle inventories of the ECOALIM dataset are available in the Agribalyse® database in SimaPro® software. The ECOALIM dataset can be utilized by the feed manufacturer and the LCA practitioner to investigate the formulation of low-impact feeds. It also provides data for environmental evaluation of feeds and environmental evaluation of animal production systems.

Keywords: Life cycle inventory, raw material, livestock, database, formulation

1. Introduction

The Food and Agriculture Organization (FAO) argued that there is no technically or economically viable alternative to intensive animal production to feed the world (FAO, 2011). However, it is necessary to mitigate pollutant emissions related to livestock and, consequently, to estimate accurately them in order to identify mitigation options (Gerber et al., 2013).

In pig and poultry systems, the production of feeds contributes strongly to the environmental impacts of the animal product. In particular, it accounts for 50% to 85% of the climate change impact, 64% to 97% of eutrophication potential, 70% to 96% of the energy use and almost 100% of the land occupation (Basset-Mens and van der Werf, 2005; Boggia et al., 2010; Leinonen et al., 2012a, b; da Silva et al., 2014; Dourmad et al., 2014). In dairy production, enteric methane has the major contribution to GHG, but 27% to 38% of the nitrous oxide emissions are related to feed production (FAO, 2010). In beef production, the feed contribution to GHG emissions can reach up to 55% (Nguyen et al., 2010). Environmental impacts of feeds are highly determined by their composition in feed ingredients. Therefore, the investigation of mitigation strategies needs robust and accurate data on environmental impacts of feed ingredients, relying on consistent perimeters and methodologies for LCA.

Feed formulation in France involves mostly French feed ingredients that result from several cropping systems under various soil and climate conditions and cropping practices. A previous study (Nguyen et al., 2012) already highlighted the need for homogeneously developed data on environmental impacts of feed ingredients to formulate low-impact feeds and investigated mitigation options. The ECOALIM dataset is the result of a collaborative project between research and extension institutes, with the participation of animal nutrition firms. ECOALIM gathers the most accurate and representative data on life cycle inventories available to date for French feed ingredients. This

database can be utilized in France and in countries importing French feed ingredients as well. This paper presents the methodological choices and the perimeters implemented to develop the ECOALIM dataset, as well as its potential application.

2. Methods

For the ECOALIM database, several system boundaries have been defined (Figure 1): field gate, storage organization gate, plant gate, and harbour gate. Field gate is relevant for assessment of feed impacts in the case of on-farm feed production (e.g. crops produced on-farm and directly utilized by animal production unit). Feed formulation by feed companies necessitates some other boundaries: plant gate for coproducts of cereals, oilseeds and protein crops (e.g. meals) as well as for industrial products (e.g. amino acids) processed in France; storage organization gate for cereals, and harbour gate for imported feed ingredients.

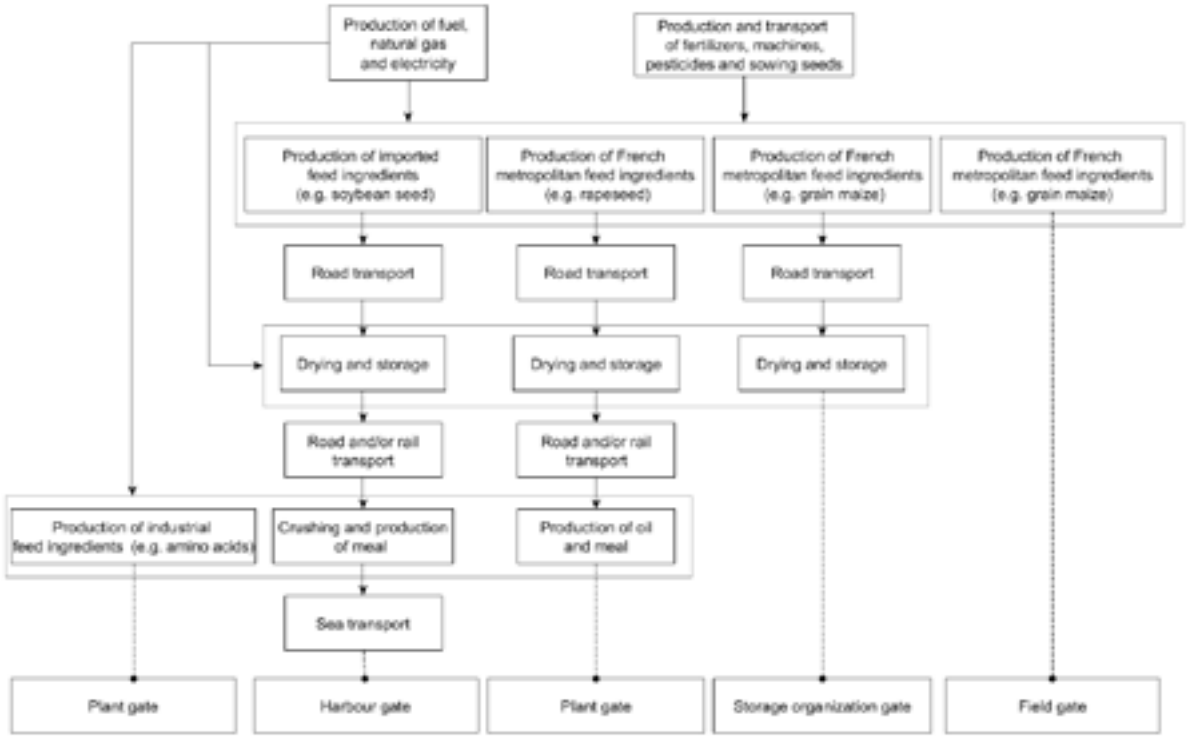

Figure 1. Flow diagram for production of the feed ingredients included in the ECOALIM dataset, with main processes for the production of crop inputs, crop production and feed ingredient production. System boundaries include all sub-processes.

In the ECOALIM dataset, the impacts of the coproducts of cereals and maize as well as oils and meals were calculated homogeneously with an economic allocation using the olympic five-year (2008-2012) average price of each coproduct. The functional unit considered is the kilogram of feed ingredient at the reference humidity rate, which is the usual functional unit for feed ingredients.

Life cycle inventories for French crops were based on the inventories of the French national database of the main agricultural products Agribalyse® (Koch and Salou, 2015), with updating emission factor for ammonia (EMEP/EEA, 2013) and also the references for agricultural practices when available. One major improvement relatively to Agribalyse® is the distribution of the impacts associated to phosphorus fertilization and nitrate leaching among the various crops involved in the same crop rotation (according to crop requirements and removal for phosphorus, and equally among crops for nitrate leaching).

For all the French crops, the average inventories (yields, amounts of fertilisers, pesticides and seeds) were obtained from French agricultural data (UNIP, 2005-2009; Agreste, 2005-2012, 2006). For the main agricultural ingredient (maize, wheat, barley, rapeseed and sunflower), additional specific inventories were constructed for systematic covercropping, systematic organic fertilization, and introduction of protein crop in the crop rotation. For these specific inventories, data came from the experimental farm network of the French agricultural institute dedicated to cereals (Arvalis-Institut du Végétal) in order to assess the variability of the results in function of the crop management.

For European and non-European crops, data for resources used came from scientific publications (Nemecek and Kägi, 2007; Prudêncio da Silva et al., 2010; Roeder et al., 2014) and statistics from national databases (Service, 2010; Ukraine, 2012; Service, 2014b, a) or FAOStat (FAO, 2013). Resources and emissions inventories were calculated according to previously published methodologies (Prudêncio da Silva et al., 2010; Boissy et al., 2011). Concerning industrial products, the dataset includes products directly issued from crops and their coproducts associated to processes of extrusion, crushing, milling, distillation…such as oils, meals, Dried Distilled Grains with Solubles (DDGS), molasses, pulps, flours Products secondary issued from crops are starch and gluten feeds. Transformation plants have been surveyed to collect the relevant underlying data in 2013-2014, excepted for French oils and meals and non-French feed ingredients (Weidema et al., 2013). Inventories for the other industrial products come from Garcia-Launay et al. (2014) for feed-use amino acids, industrial confidential data for minerals, French Technical Centre for Meat (ADIV) data for animal byproducts, and from Ecoinvent data adapted to the French context for vitamins (Weidema et al., 2013).

The ECOALIM dataset uses the ILCD characterization method recommended by the Joint Research Centre (JRC, 2012) as well as the CML IA characterization method (PréConsultants, 2015) which is the most popular in agricultural LCA. Energy demand is calculated according to the CED 1.8 method (PréConsultants, 2015).

Therefore, climate change with (CCLUC) or without land use change (CC) are expressed in kg CO_2-eq, acidification (AC) in both molc H^+-eq (AC_{ILCD}) and kg SO_2-eq (AC_{CML}), terrestrial eutrophication (EU) in molc N-eq, freshwater EU in kg P-eq, Marine EU in kg N-eq, EU_{CML} in kg PO_4^{3-}eq, land occupation (LO) in m².y, and non-renewable (CEDNR) and total energy demand (CEDTOT) in MJ. Phosphorus demand (PD) is expressed in kg P and sums up all the phosphorus and phosphate inputs along the life cycle.

Calculations were made using SimaPro software v8.0.5.13 (PRé Consultants, Amersfoort, The Netherlands) and the Ecoinvent v3.1 database attributional for background data (Weidema et al., 2013).

3. Dataset description

Table 1 contains the number of inventories and impacts available in the dataset for each type of feedstuffs. The whole dataset contains 149 average feed ingredients and 16 feed ingredients from specific crop itineraries. It offers a wide range of feedstuffs for utilization in various livestock productions (cattle, pig and poultry) and different perimeters for LCA, for feed formulation by feed manufacturers, farm cooperatives as well as for on-farm feed production.

Table 1: Number of data points available in the ECOALIM dataset according to the type of feed ingredients and the perimeter.

Types of feedstuffs	At field	At french harbour	At mill or transformation plant	At storage agency
Cereals	8	2	0	17
Coproduct from food industry	0	0	2	0
Coproduct of maize	0	1	5	0
Coproduct of wheat	0	0	5	0

Fats	0	6	22	0
Industrial amino acids	0	0	5	0
Minerals	0	0	10	0
Oil seeds and protein crops	6	0	4	13
Oilmeals	0	7	22	0
Other coproduct of animal origin	0	0	2	0
Other coproduct of plant origin	1	1	4	0
Silage	5	0	0	0
Vitamin	0	0	1	0

Table 2 provides an extract of the dataset for the main cereals, oil and protein crops produced in France. It highlights the relative homogeneity of impacts among cereals and the higher variability for oil and protein crops.

Table 2: Impact values of the main French feed ingredients at storage organization gate, for 1 kg of feedstuff.

Feedstuff	**CCLUC, kg CO_2eq ILCD**	**CEDNR, MJ**	**EU, g PO_4^{3-}eq CML**	**AC, g molc H^+eq ILCD**	**LO, m².an CML**	**PD, g P**
Oat	0.52	3.07	5.1	12.6	2.09	3.6
Soft wheat	0.43	2.85	3.7	10.7	1.34	4.1
Barley	0.39	2.71	3.7	9.5	1.48	4.1
Maize grain	0.46	4.47	3.6	13.4	1.23	3.5
Sorghum	0.36	2.53	3.6	4.8	2.12	5.2
Triticale	0.50	2.95	5.3	8.7	1.84	2.6
Pea	0.19	2.21	3.7	2.5	2.32	2.9
Faba bean	0.19	1.70	3.2	2.0	1.99	5.2
Rapeseed	0.94	5.49	7.6	21.0	3.12	7.3
Flaxseed	0.93	6.27	10.4	19.1	5.53	11.0
Soya bean	0.30	5.08	6.0	3.4	3.81	4.6
Sunflower seed	0.56	4.21	8.8	10.8	4.76	6.6

4. Discussion

The ECOALIM dataset can be mobilized for the environmental assessment of feeds, animal production systems and mitigation options (Figure 2). The dataset for impacts is available in an Excel file (available online at http://www6.inra.fr/ecoalim) and also in the Agribalyse® V1.3. database in SimpaPro®.

Both the feed manufacturer and the LCA practitioner can formulate feeds through classical least-cost formulation and calculate the environmental impacts of the obtained feeds through the ECOALIM Excel dataset. To investigate mitigation options they can also formulate eco-feeds through simultaneous economic and environmental formulation, using the ECOALIM Excel dataset in formulation software. The ECOALIM dataset in the Agribalyse® database in SimaPro® can be mobilised by the LCA practitioner in a more detailed farm inventory for the environmental evaluation of the animal product at farm gate using either the formulas of least-cost formulated feeds or the formulas of the eco-feeds. For these applications, the ECOALIM dataset offers harmonized, updated and reviewed data. It covers a range of feed ingredients that was not previously available in Agribalyse® and is to date the only dataset that relies on reliable foreground data representative for

France, collected with various surveys gathered in a common framework. To our knowledge, ECOALIM is the first dataset available for feed ingredients inventories and impacts that provides the whole set of the feed ingredients utilized in livestock production in France and specific inventories for systematic covercropping, systematic organic fertilization, and introduction of protein crop. It also applies to other European countries for several imported feed ingredients as well as for French feed ingredients exported. The incorporation of the ECOALIM dataset into the Agribalyse® database will allow further updating of the life cycle inventories and the addition of new feed ingredients such as fish meal and oil for aquaculture production. Furthermore, the integration of Agribalyse® database into Simapro® software ensures appropriate maintenance of the data and a wider dispersion among LCA practitioners.

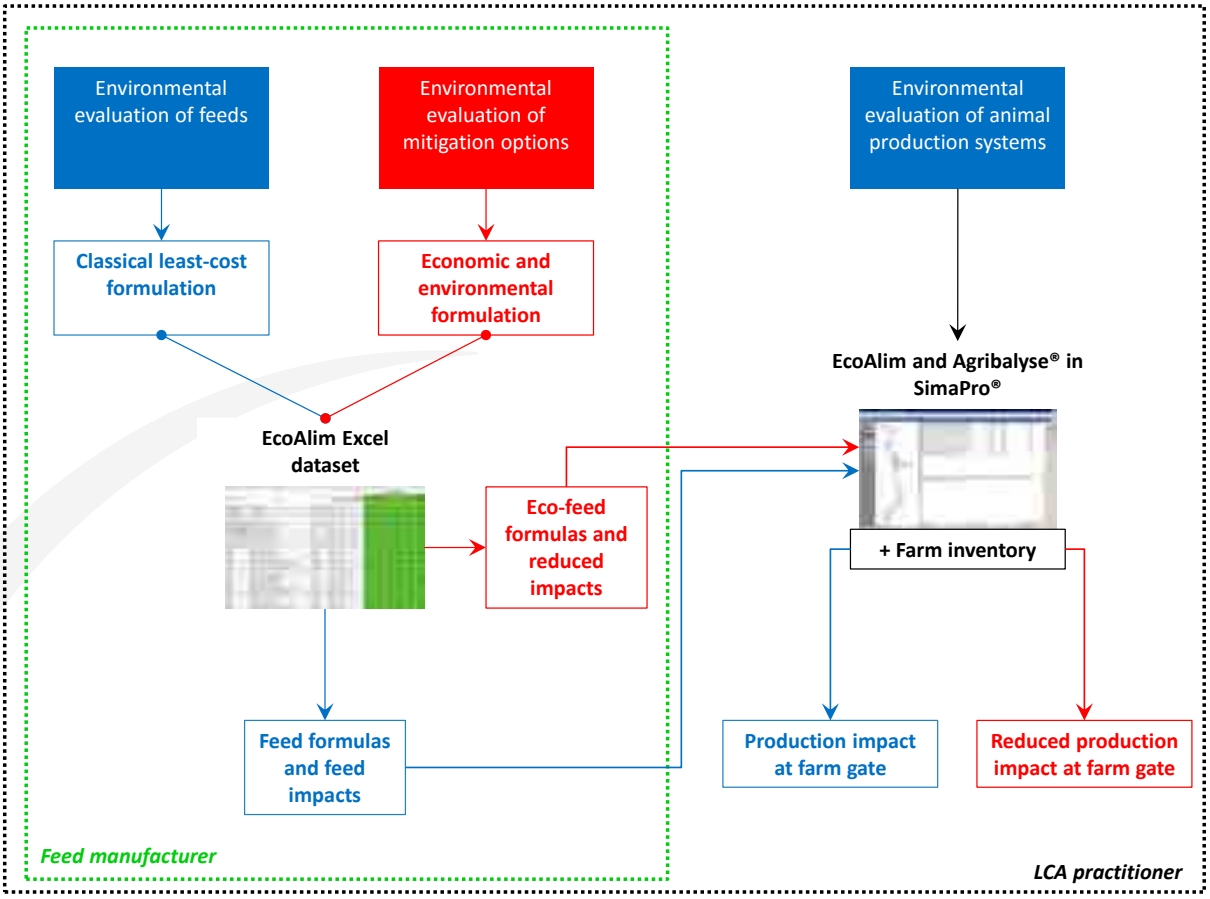

Figure 2: Diagram of the potential utilizations of the ECOALIM dataset. The blue pathway corresponds to the methodology utilized when evaluating classically the environmental impacts of feeds and animal products at farm gate. The red pathway illustrated the methodology utilized when evaluating mitigation strategies of the environmental impacts of feeds and animal products at farm gate.

5. Conclusions

The ECOALIM dataset provides life cycle impacts of feed ingredients produced with harmonized methodology, homogeneous data source and background data. This approach avoids double-counting of the environmental burden. The whole approach was developed in coherence with the Agribalyse® database that will allow further utilization of the ECOALIM dataset for environmental labelling of animal products. One opportunity will be to propose these data to the European initiative “Product Environmental Footprint” for environmental labelling of market products.

The ECOALIM dataset relies on representative and recent data that cover a wide range of production itineraries. Built with organizations including feed manufacturers, raw material producers and R&D institutes, this dataset contains feed ingredients necessary to formulate composed feeds and some French feed ingredients for which no data was available before (oat, sorghum, flaxseed, faba bean, soybean). The ECOALIM dataset will allow proposing feed formulas incorporating nutritional, economic and environmental constraints. This new approach of diet conception needs further research to evaluate its potential as a mitigation option for livestock-related impacts.

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