Agri-footprint 4.0

Part 1: Methodology and basic principles

DATE: 14-12-2017

agri›footprint‹

Agri-footprint is a high quality and comprehensive life cycle inventory (LCI) database, focused on the agriculture and food sector. It covers data on agricultural products: feed, food and biomass and is used by life cycle assessment (LCA) practitioners. In total the database contains approximately 8,500 products. In the last years Agri-footprint is widely accepted by the food industry, LCA community, scientific community and governments worldwide and has been critically reviewed.

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Part 1: Methodology and basic principles

agri footprint

Table of Contents

1 Introduction ... 3
1.1 Change log ... 3
1.2 Project team ... 4
1.2.1 Project partners ... 4
1.3 Life Cycle Assessment (LCA) framework ... 6
1.3.1 Methodological challenges in agricultural LCAs ... 7
1.3.2 Methodological guidelines for agricultural LCAs ... 7
2 Goal ... 8
2.1 Reasons for development ... 8
2.2 Intended applications ... 8
3 Scope ... 10
3.1 Definition of included processes ... 10
3.2 Consistency of methods, assumptions and data ... 10
3.3 Function, functional unit and reference flow ... 10
3.4 Cases of multi-functionality / Allocation ... 11
3.4.1 Allocation types applied in Agri-footprint ... 11
3.5 System boundaries ... 13
3.6 Cut-off ... 16
3.7 Basis for impact assessment ... 16
3.8 Treatment of uncertainty ... 17
3.8.1 Which uncertainty types are included and how ... 17
3.8.2 Overview of applied uncertainty information ... 20
3.8.3 Technical note on the modelling of output uncertainties ... 23
4 Data quality procedure ... 24
4.1 Selection data sources ... 25
4.1.1 Establish a consistent baseline dataset as a starting point ... 25
4.1.2 Fill data gaps using best available data ... 27
4.1.3 Improve baseline data whenever possible using the data quality hierarchy ... 27
4.2 Data quality checks during modelling ... 28
4.3 Data Quality Assessment using PEF methodology ... 29
4.3.1 Technological Representativeness (TeR) ... 29
4.3.2 Geographical Representativeness (GR) ... 29
4.3.3 Time-related Representativeness (TiR) ... 29
4.3.4 Completeness (C) ... 30
4.3.5 Parameter uncertainty (P) ... 30
4.3.6 Methodological appropriateness and consistency (M) ... 30

4.4 External review 30
5 Limitations of Agri-footprint 31
6 References 33
Appendix A. Review letter from the Centre for Design and Society 35
Appendix B. Response to the comments in the review letter 38
Appendix C. Review letter from RIVM – Agri-footprint 2.0 40
Appendix D. Self-declarations Agri-footprint 2.0 reviewers 41
Appendix E. Decision trees for Data Quality Assessment 43

1 Introduction

The main objective of Agri-footprint is to bring data and methodology together to make it easily available for the LCA community.

This document contains background information on the methodology, calculation rules and data that are used for the development of the data published in the Agri-footprint database and on the website (www.agri-footprint.com). This document will be updated whenever new or updated data is included in Agri-footprint.

Agri-footprint is available as a library within SimaPro. Information, FAQ, logs of updates and reports are publicly available via the website www.agri-footprint.com. Agri-footprint users can also ask questions via this website. The project team can also be contacted directly via info@agri-footprint.com , or the LinkedIn user group.

1.1 Change log

Significant updates and changes are reported in the table below (Table 1-1).

Table 1-1: Version history and change log

Date	Document Version	Changes
1-8-2013	0.1	First set-up of document
20-05-2014	1.0	First version released to public
09-12-2014	1.1	Start Documentation for Agri-footprint 2.0 update
Autumn 2015	2.0	Agri-footprint 2.0 released to public
28-02-2017	3.0	Agri-footprint 3.0 release
December 2017	4.0	Agri-footprint 4.0 release

1.2 Project team

The development of Agri-footprint was executed by Blonk Consultants. The development team consisted out of the following members:

Agri-footprint 1.0 (2013-2014):

1. Jasper Scholten
2. Bart Durlinger
3. Marcelo Tyszler
4. Roline Broekema
5. Willem-Jan van Zeist
6. Hans Blonk

Agri-footprint 2.0 (2014-2015):

1. Jasper Scholten
2. Bart Durlinger
3. Roline Broekema
4. Lody Kuling
5. Elsa Valencia-Martinez
6. Laura Batlle Bayer

Agri-footprint 3.0 (2016-2017):

1. Bart Durlinger
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1.2.1 Project partners

There was not a specific commissioner of Agri-footprint, however a number of parties have been involved in sponsoring the development either financially or by delivering data.

Development support and implementation in SimaPro:

- PRé Sustainability: www.pre-sustainability.com

Implementation in openLCA

- Greendelta: www.greendelta.org

Provision of data:

- Suiker Unie: www.suikerunie.nl
- OCI Nitrogen: www.ocinitrogen.com
- Meatless: www.meatless.nl/en
- Vitens: www.vitens.nl
- USDA LCA commons: www.lcagcommons.gov
- RIVM: www.rivm.nl

1.3 Life Cycle Assessment (LCA) framework

Life cycle assessment (LCA) is a methodological framework for assessing the environmental impacts that can be related to the life cycle of a product or service. Examples of environmental impacts are climate change, toxicological stress on human health and ecosystems, depletion of resources, water use, and land use.

Historically, most LCAs had a strong focus on consumer goods originating from industrial processes, such as packaging, diapers, plastic and metal goods. LCAs on agricultural goods were performed less often and methodology development on LCA of agricultural products received also less attention. During the 1990s, some publications on methodology for LCAs of agricultural products appeared (Wegener Sleeswijk, *et al.* 1996; Blonk *et al.*, 1997; Audsley *et al.*, 1997).

Nowadays there are several LCA protocols, such as the ISO standards and guidelines for practitioners that give directions on how to conduct an LCA. Important LCA standards and handbooks that were used as a basis for the LCIs in Agri-footprint are:

- The ISO 14040/44 series (ISO, 2006a, 2006b)
- The ILCD handbook (JRC-IES & European Commision, 2010)
- Product Environmental Footprint (PEF) framework

The ISO 14040 series (ISO, 2006a) describe the basic requirements for performing an LCA study. This includes, amongst others, directions on how to define the functional unit of a product, how to determine which processes need to be included or excluded, and how to deal with co-production situations where elementary flows need to be allocated to the different products. However, the ISO standard can still lead to different methodological decisions, depending on the LCA practitioner's interpretation. This means that applying the ISO standards properly may still result in different approaches and different quantitative results.

For applying ISO standards as properly and as unambiguously as possible, further guidelines on interpretation are needed. The ILCD handbook (JRC-IES & European Commision, 2010) gives these guidelines on a practical level. One of the most valuable methodological additions in the ILCD handbook is the division between consequential and attributional LCA, which is not made in the ISO standard. The data provided by Agri-footprint are primarily meant to support attributional LCA studies.

1.3.1 Methodological challenges in agricultural LCAs

Performing LCAs of agriculture production systems introduces some specific topics that hardly prevail in LCAs of non-agricultural products. It concerns the following generic inventory and impact modelling issues:

- The definition of the system boundary between nature and the economy (*for example: Is agricultural soil part of the economic or the environmental system? How should be dealt with the emissions of living organisms?*).
- Some environmental impacts that are specifically important for agriculture are still under development (*for example: soil erosion and soil degradation, water depletion, biodiversity loss due to land use and land use change or depletion of (fish) stocks*).
- There is a large heterogeneity in time and place of cultivation induced emissions, depending on various local conditions
- The limited data availability for modelling toxicity impacts.
- Relation between soil emissions and differences in climate and soil types (e.g. peat, sand).

Next to these issues, LCAs of agricultural products have to cope with specific allocation issues not existing elsewhere:

- Segregation between animal and plant production systems (*e.g. allocation of manure emissions*).
- Rotation schemes and fallow land (*how to allocate share benefits and emissions to a single crop in crop rotation schemes*).

1.3.2 Methodological guidelines for agricultural LCAs

Wegener Sleeswijk et al (1996) published the first set of guidelines on methodological topics for LCAs of agricultural products in the Netherlands. As the same need for agricultural specifications was also felt in other European countries, a number of European research institutes took concerted action to draw up an harmonised approach for use by European agricultural LCA practitioners (Audsley & Alber, 1997). A specific PAS 2050 guidance for horticultural products is developed in 2012 (BSI, 2012) and in 2013 the Environmental Assessment of Food and Drink Protocol (ENVIFOOD) was published by the European Food Sustainable Consumption and Production Round Table (Food SCP, 2012).

In the coming years, many food related LCAs will be performed due to the special attention from the European Commission for food, feed and beverages in the Product Environmental Footprint (PEF) program. Also the European research and innovation programme Horizon 2020 focuses on more sustainable food production systems which have to include a LCA in line with the ILCD handbooks. A recently methodological development is Livestock Environmental Assessment and Performance Partnership (LEAP, coordinated by FAO). LEAP publishes sector specific LCA guidelines for livestock production systems and feed. This document and the database are drafted as much as possible in line with the guidelines from the ILCD handbook “Specific guide for Life Cycle Inventory data sets” (JRC-IES & European Commision, 2010). The treatment of methodological issues such as allocation, naming conventions and modelling principles will be discussed in this document.

2 Goal

2.1 Reasons for development

The main reason for development of Agri-footprint is the database developer perspective (JRC-IES & European Commision, 2010); to develop descriptive high-quality generic LCI data on a range of products. These LCI data can subsequently be used for a multitude of LCAs. By having these generic LCIs readily available, future LCAs can be developed more efficiently. Also, some company specific life cycle inventories are included in Agri-footprint (see section 1.2.1). By making the better performance of specific companies visible, LCA users can more easily identify improvement options in a lifecycle.

The target audiences are LCA practitioners and environmental specialists in the agricultural, food production, environmental and related sectors. Agri-footprint is intended to be used in the public domain and is available to LCA and sustainability experts that have a SimaPro license. It is expected that this audience has at least a basic understanding of life cycle concepts.

2.2 Intended applications

Agri-footprint aims to support both type A ("Micro level decision support") and C ("Accounting") applications, including interactions with other systems (C1) as well as isolated systems (C2), as described in the ILCD guidelines (JRC-IES & European Commision, 2010). Agri-footprint is based on an attributional approach. This means that the results give an impression of the environmental impact of a product in the current situation. Agri-footprint does not aim to support type B ("Meso/macro-level decision support"), where LCI modelling exclusively refers to those processes that are affected by large-scale consequences. The processes in Agri-footprint are not modelled in a consequential way.

Agri-footprint can be used as a secondary data source to support comparisons or comparative assertions across systems (e.g. products). In case an LCA should be used to make public claims, it is the responsibility of the practitioner to ensure ISO 14040:2006/14044:2006 compliance (through an ISO review of the study). This document provides all relevant information to facilitate this process, through transparent documentation of methodological choices and through description of data sources and modelling (see Agri-footprint 4.0 - Part 2 – Description of data). In some comparative LCA cases, a consequential approach may be more appropriate. In that case, the user may need to modify the LCIs to accurately reflect marginal effects.

More specifically, potential applications of Agri-footprint may be:

- The identification of key environmental performance indicators of a product group
- Hotspot analysis of a specific agricultural product.
- Benchmarking of specific products against a product group average.
- To provide policy information by basket-of-product type studies or identifying product groups with the largest environmental impact in a certain context.
- Carbon footprints
- Environmental product declarations (EPD)
- Product Environmental (PEF) screenings

Agri-footprint also supports other applications; however additional modelling (or modification of datasets) will be required:

- Strategic decision making by providing the possibility of forecasting and analysis of the environmental impact of raw material strategies and identifying product groups or raw materials with the largest environmental improvement potential.
- Agri-footprint supports detailed product design of food products, in which the data from Agri-footprint can be used as a starting point.
- Agri-footprint also supports the development of life cycle based Eco label criteria, but does not provide Eco label criteria directly.
- Agri-footprint can be referred to as a prescribed secondary data source to be used in life cycle based environmental declarations of specific (food) products under the Product Environmental Footprint (PEF) framework, or in Product Category Rules (PCRs).

Agri-footprint is not intended to be used for:

- Green public or private procurement, as Agri-footprint does not (yet) provide sufficient data on supplier or brand specific products (although this may change in the future, as incorporation of supplier specific data is desired).
- Agri-footprint is not intended for corporate or site specific environmental reporting or environmental certification of specific life cycles, although Agri-footprint may be used as a source for background data.

Agri-footprint provides LCI datasets on unit process level with fixed values. Agri-footprint unit processes are linked so that detailed, interconnected, LCI models can be applied directly as input into LCAs. Agri-footprint uses some background data that was sourced from ELCD datasets (JRC-IES, 2012). A list of these used ELCD processes is provided in the data report (Agri-footprint 4.0 - Part 2 – Description of data).

3 Scope

3.1 Definition of included processes

Agri-footprint contains LCIs of food and feed products and their intermediates. These unit processes are linked in Agri-footprint to produce commonly used food commodities. The system boundaries are from cradle to factory gate (as shown in the figures of section 3.5). Retail, preparation at the consumer and waste treatment after use are not incorporated in Agri-footprint. (Consumer) packaging is generally not included in Agri-footprint.

The processes in Agri-footprint reflect an average performance for a defined region for a certain period of time, for instance wheat cultivation in the Netherlands, or crushing of soy beans in the United States. The data description section of the report (Agri-footprint 4.0 - Part 2 – Description of data) gives more detail on how the data is generated.

3.2 Consistency of methods, assumptions and data

The data in Agri-footprint are derived from different sources. The LCIs for the animal production systems, transport, auxiliary materials, fertilizers etc. have been developed based on previous public studies of Blonk Consultants. In these studies, data were collected mainly from the public domain (scientific literature, FAOstat, Eurostat, etc.) or from public or confidential research initiated by the industry and conducted by Blonk Consultants. Where possible, the data have been reviewed by industry experts. Data gaps were filled with estimates, which were as much as possible based on industry expert opinions. The assumptions are documented in this report, and clearly identified in the database.

3.3 Function, functional unit and reference flow

In the appendix of in 'Agri-footprint 4.0 - Part 2 – Description of data', a list of all products in Agri-footprint is provided. Products can fulfill different functions, which depend on the context in which they are used. It is therefore not possible to define a complete functional unit for every product in the database. Rather, reference flows can be defined, that can fulfill different functions in different contexts. To allow for maximum modelling flexibility, a number of properties of the reference flow are provided in the database. For example, the main reference flow for crop cultivation is 1 kg of crop, but the dry matter and energy content are given as additional properties. The general principle used in Agri-footprint is that the reference flows of products reflect 'physical' flows as accurately as possible, i.e. reference flows are expressed in kg product "as traded"; thus including moisture, formulation agents etc., with product properties listed separately in the process name and/or comment fields. Table 3-1 lists the reference flows for a number of important product groups in Agri-footprint, and the additional flow properties that are reported in addition. These additional properties may be used to construct alternative reference flows.

Table 3-1: Reference flows for a number of important product groups in Agri-footprint, and the additional product properties that are reported in addition

Process type	Reference flow	Additional flow properties
Crops	kg harvested crop	Dry matter content, gross energy (= Higher heating value).
Processed crops products	kg product	Dry matter content, gross energy (= Higher heating value).
Animal products	kg product	Dry matter content, gross energy content (= Higher heating value).
Auxiliary chemicals	kg product	Active substance percentage
Fertilizer	kg product	Nitrogen, phosphate and potassium content as NPK (N-P_2O_5-K_2O) values.
Transport	Ton*km travelled	Load factor, backhaul assumption, (dead weight tonnage, EURO emission category, terrain type where appropriate)

3.4 Cases of multi-functionality / Allocation

This chapter explains the way the inputs and outputs are allocated to the different products. According to the ISO14044:2006 standard (ISO, 2006b), allocation should be avoided whenever possible by dividing the unit multi-output process into two or more sub-processes and collecting the inventory data related to these sub-processes separately. If this is not possible allocation may be avoided by expanding the product system to include the additional functions related to the co-products. If allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system. If physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products or another property.

System expansion as such is not applied in Agri-footprint because no consistent approach exists and aspects of consequential LCA are introduced. System expansion can be applied by the user by modifying processes. The allocation percentages of the unit processes can be set to 100% and 0% and the system can be expanded. Also, allocation based on a (bio)-physical mechanism is generally not used, as these mechanisms are generally not well quantified. An exception is the PEF Cattle model working group (JRC & European Commission, 2015) compliant versions of the dairy production process, where the biophysical allocation according to IDF methodology (IDF, 2010) is implemented.

Only in some specific situations, avoidance of production is applied when the avoided product can be unambiguously determined such as electricity produced from a CHP.

It should also be realised that allocation on the basis of physical keys of the outputs is not the same as allocation on the basis of (bio) physical mechanism, but could be considered a proxy for this approach. Likewise, economic allocation may be regarded as a proxy for a market based approach (substitution through system expansion). If allocation keys are not directly related to a physical mechanism, they should be treated as allocation on the basis of another causality (ISO step 3). Therefore all three allocation types in Agri-footprint should be regarded as 'allocation based on another causality'.

3.4.1 Allocation types applied in Agri-footprint

Agri-footprint currently contains three types of allocation: *mass allocation, energy allocation and economic allocation*.

1. **Mass allocation**: For the crops and the processing of the crops, mass allocation is based on the mass of the dry matter of the products. For the animal products, mass allocation is based on the mass as traded.
2. **Gross energy allocation**: Water has a gross energy of 0 MJ/kg. The gross energy for protein, fat and carbohydrates are respectively: 23.6, 39.3 and 17.4 MJ/kg which are based on USDA (1973). Nutritional properties for gross energy calculations of products are based on a nutritional feed material list (Centraal veevoederbureau, 2010). For the other products, the references to the gross energy are given in the chapters on these products in in 'Agri-footprint 4.0 - Part 2 – Description of data'.
3. **Economic allocation**: For the crops and the processing of the crops the economic value of the products is based on Vellinga et al. (2013). For the other products, the references to the economic value are given in the chapters on these products in 'Agri-footprint 4.0 - Part 2 – Description of data'.

Allocation is applied without the use of cut-offs for so called residual product streams whenever possible. There are three exceptions to this allocation rule:

- Citrus pulp dried, from drying, at plant
- Brewer's grains, wet, at plant
- Animal manure

The reason for these exceptions is pragmatism. These products are required for the LCI of a couple of animal production systems and were derived from the Feedprint database where the upstream processes were not modelled because of the application of the residual principle. This may be adapted in a future update of Agri-footprint. Dried citrus pulp and wet brewer's grain do not include any inputs from previous life cycle stages. Dried citrus pulp only includes the energy required for drying.

Animal manure is considered to be a residual product of the animal production systems and does not receive part of the emissions of the animal production system[1] when animal manure is applied.

[1] The animal production systems are single farming systems and not mixed farming systems.

3.5 System boundaries

Agri-footprint covers potential impacts on the three areas of protection (Human Health, Natural Environment and Natural Resources) that are caused by interventions between technosphere and ecosphere that occur during normal operation (thus excluding accidents, spills and other unforeseeable incidents).

The LCI data is 'cradle-to-gate', where the gate is dependent on the process analysed. No data on distribution to retail, retail, consumer use and end of life (after the use phase) are provided (but treatment of waste generated during processing is included). All processes that are relevant for analysis on an attributional basis are included. Any omission or deviation is documented in the documentation of the specific process.

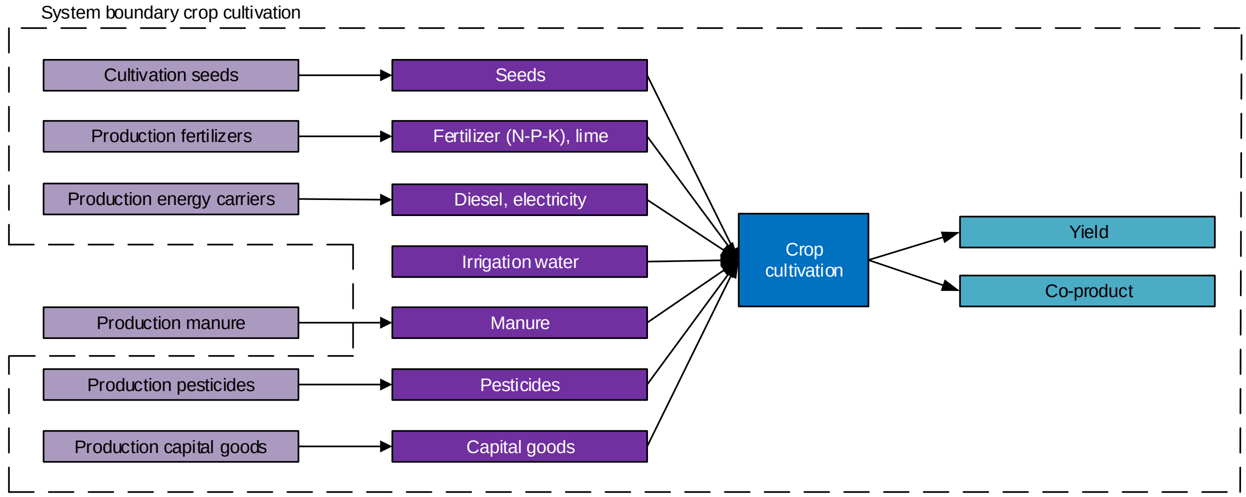

Figure 3-1: System boundary for crop cultivation.

Crop cultivation (Figure 3-1) is modelled on country level (with country specific crop yields, fertilizer composition and application rates and energy use). Carbon storage in crops for feed, animals and milk are not included in Agri-footprint because this carbon is part of the short term carbon cycle. Because of this, the carbon dioxide emissions at the end of the life cycle (e.g. emitted during fermentation or digestion) should also not be modelled except when the stored carbon is released as methane due to enteric fermentation or manure management and storage, which is inventoried as 'methane, biogenic'. After cultivation some crops undergo a country specific processing stage (e.g. crushing of palm fruit bunches), see Figure 3-2.

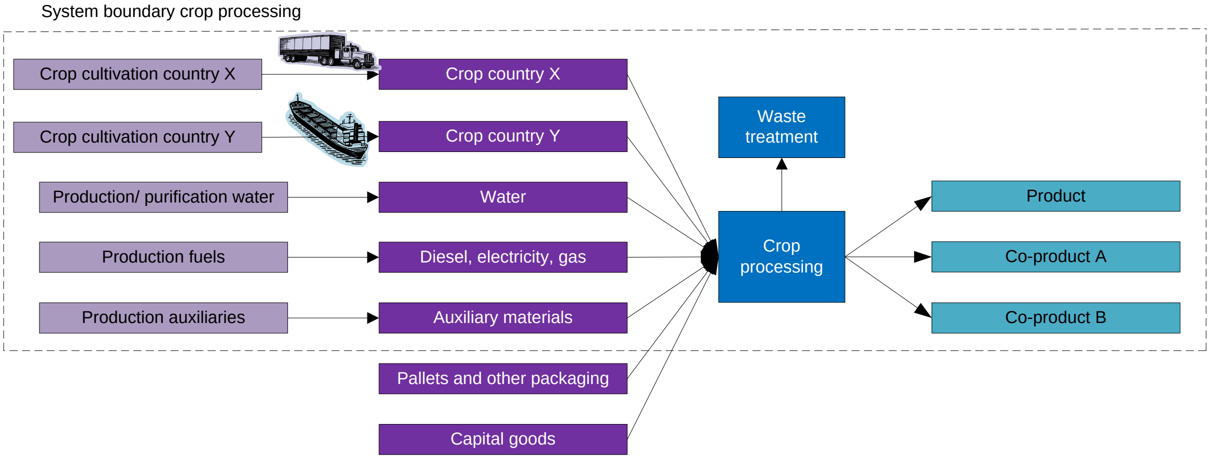

Figure 3-2: System boundary for crop processing.

Production of fuels, auxiliaries as well as transport of crops and materials to the crop processing site are included. Intermediate packaging and capital goods are excluded from the system boundaries. The partially processed product may then be exported to another country for further processing, or be processed further domestically (e.g. palm oil refining). After this second processing step, country specific crop product mixes may flow into various feed ration mixes (e.g. cattle feed compound). The feeds are an input for the animal husbandry, see Figure 3-3.

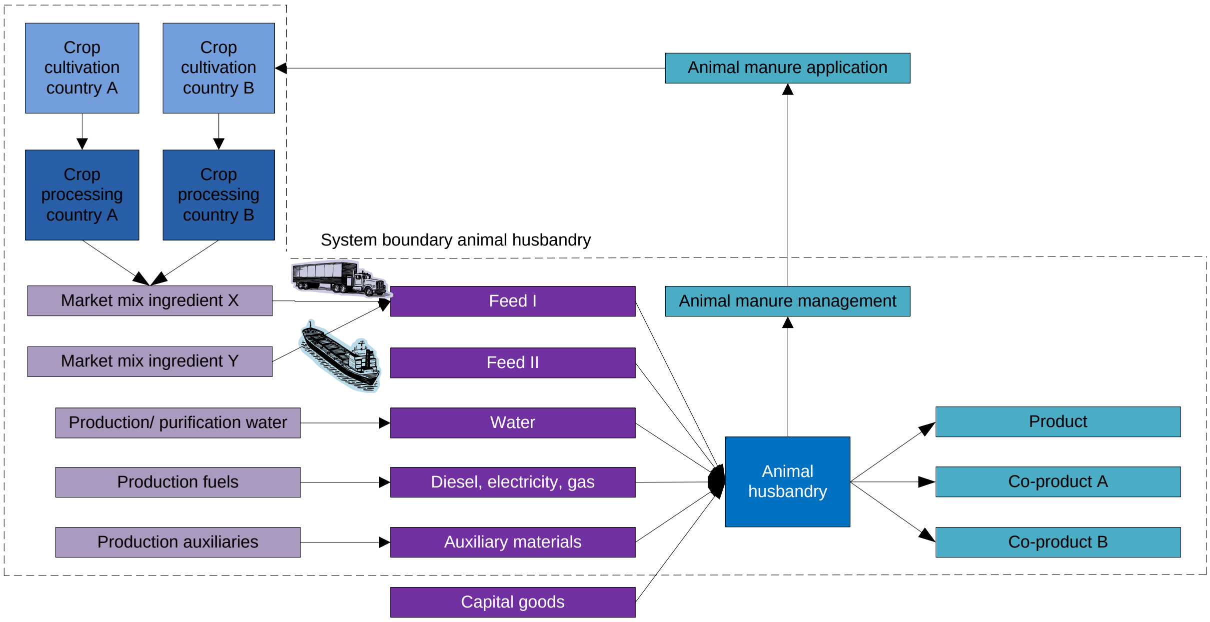

Figure 3-3: System boundaries for animal husbandry.

The market mixes are the basis for the compound feeds fed to chicken, pigs and cattle. Emissions due to the management of manure on the farm are included within the system boundaries, but the emissions due to application of manure are attributed to the crop cultivation stage. This is not done via a loop, but when a crop is cultivated using manure this is modelled within the crop cultivation itself, not taking into account any emissions from the animal husbandry. So the manure is treated via a cut-off. Emissions due to animal manure transport to the field are 100% allocated to crop cultivation.

Plant and animal products can be further processed into food ingredients, see Figure 3-4. For food ingredients that originate from processing of crops, the system boundary is drawn after the processing into 'generic' ingredients (e.g. into starch, sugar, vegetable oil etc.). These products are often processed further into food products (e.g. bread, soft drinks). This further processing is not included in Agri-footprint.

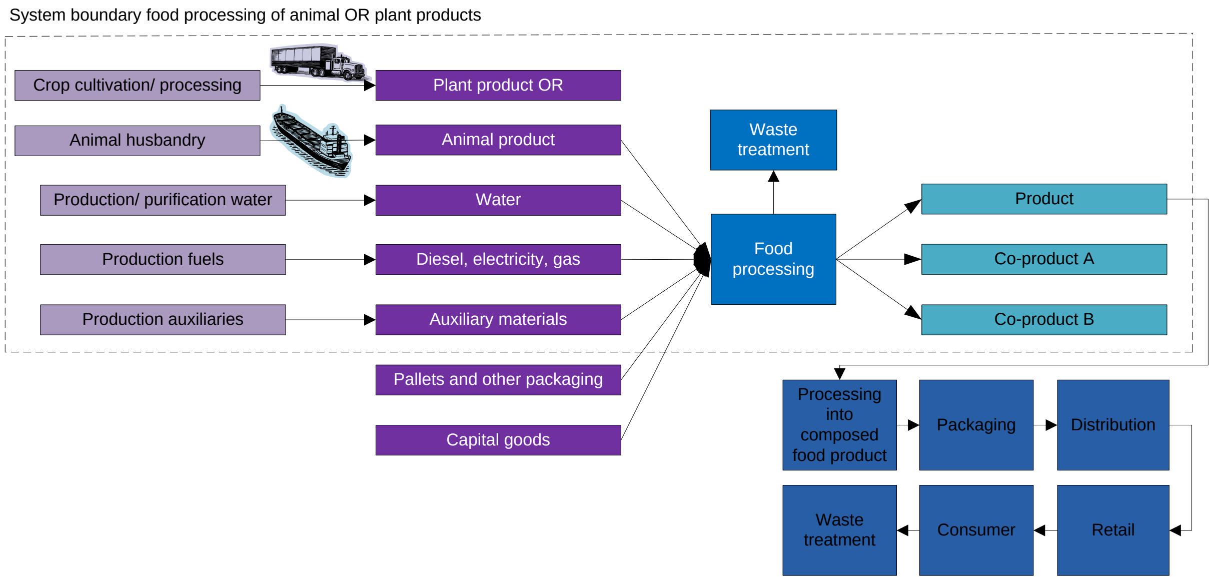

Figure 3-4: System boundaries for food processing.

For meat, for instance, the processing to fresh product means that the animal is slaughtered and fresh meat is produced, but further processing into specific meat products and packaging for retail is not included. Agri-footprint excludes packaging, distribution, retail, consumer handling and waste treatment of the final product.

Some processes may be excluded from the system, because there is only a remote relation to the most important processes in the lifecycle of the product. A key consideration here is the use of capital goods (e.g. tractors, barns, farmstead, processing plants, mills, trucks, ships). The energy and materials production in the supply chain of capital goods often make a negligible (not substantial or significant) contribution to the LCA results, and have not been incorporated into Agri-footprint.

3.6 Cut-off

The cut-off criteria for the inclusion of inputs and outputs were based on mass and/or energy consumption. It is estimated that elementary flows representing not more than 2% of the cumulative mass and energy flows were omitted.

3.7 Basis for impact assessment

The LCIA methods ReCiPe 1.11 (PRé Consultants, Radboud University Nijmegen, Leiden University, & RIVM, 2014) and ILCD 1.09 (the most recent version at the time of writing, basic principles described in JRC-IES, (2014)) were taken into account when developing Agri-footprint, but Agri-footprint may also support other impact assessment methods.

In Agri-footprint, climate change due to land use change has been modelled separately in the emissions to air: Carbon dioxide, land transformation. This makes it possible to report on the effects of land use change separately. Land use change is also modelled in m^2 land transformation in the known inputs from nature. Although m^2 land transformation contributes to other environmental indicators than carbon dioxide, please keep in mind that double counting of the impact of land use change should be avoided.

Agri-footprint makes use of other databases like ELCD to provide data for some background processes. If LCIs of other databases are used, it is possible that errors have occurred during the implementation of those datasets into third party LCA-software. It remains to the user of Agri-footprint to select the impact categories that are environmentally relevant for the analysed products or systems and to check which impact categories are endorsed by other bodies of the relevant region. The inventories in Agri-footprint support the calculation of the midpoint impact categories being proposed in the EU PEF (Product Environmental Footprint) and ENVIFOOD protocol.

3.8 Treatment of uncertainty

Uncertainty in inventory data exists in many ways and there are many factors determining the level of uncertainty in LCA (Huijbregts et al., 2001). The majority of the inventory data in Agri-footprint are not the result of actual measurements but of models that compute inventory data in relation to activity data that are on its turn measured or estimated. We use the following classification derived from (Huijbregts, 2001) to explain the different types of uncertainties and how we have treated and estimated uncertainties:

1. Uncertainty due to LC modelling choices which are related to the simplifications made in modelling the lifecycles, for instance by using cut off rules for marginal inputs and outputs or excluding not common situations in defining the average lifecycle;
2. Data uncertainty which encompasses inaccuracy of data and lack of (representative) data;
3. Emission model and parameter uncertainty which refers to the many emissions which are calculated by combining primary activity data with an emission factor that is the result of a parameterized model;
4. Spatial variability refers to the variation in conditions (soil, climate) and applied technologies (age, type, abatement techniques, etc.) the region under study
5. Temporal variability refers to variation in time related to variation in natural conditions over the years (climate, pests, capacity usage, calamities, et cetera).

3.8.1 Which uncertainty types are included and how

In Agri-footprint, uncertainty distributions are defined for specific input or output data of LCI processes that incorporate some main factors defining uncertainty and variability around the average. There we focus on key parameters related to the average efficiency of processes in the regions for which average process data are derived. This overall distribution combines the variability in technology, processing conditions and management, which may have a spatial correlation in that region (see Table 3-2 for further explanation).

Table 3-2: Overview of applied uncertainty models and parameters in Agri-footprint

Process group	Parameters that define process efficiency	Explanation
Cultivation	Yield (kg crop/ha)	In a defined cropping system where agricultural practice is more or less the same (for instance conventional winter wheat growing in the Netherlands), the differences in emissions and resource use per unit product are strongly related to differences in yield. Yields vary in relation to differences in climate and local growing conditions with same inputs and related emissions per hectare (at least if we assume that emissions are not related to factors that also explain the variation in yield, e.g. rainfall can effect yields but also runoff of N-fertilizer). Of course yields are also correlated with agronomic inputs such as fertilizers. This change in yields per hectare caused by a change in inputs per hectare causes mostly a smaller effect on emissions and resource use per kg product, because the yield responses to marginal inputs. Since emissions in cultivation are all related to agronomic inputs and these inputs are on its turn related to yield we decided not to introduce variations on inputs and yields at the same time. The distribution around the average yield gives a first proxy for many of the inputs and related emissions. In future versions of Agri-footprint we will explore if this method can be further specified also taking into account the relation between inputs and yields.
Transport	Performance (tkm) per unit fuel	Also here many factors determine emissions and resource use of a specific transport modality over a certain distance. Similar to cultivation there are many interrelations between inputs emissions and performance. In this version of Agri-footprint we only set a distribution on the fuel efficiency (same as yield in cultivation).
Processing of food crops	Energy use per unit production	LCA contribution analysis of processing show that energy use is for many environmental impacts the most important contributor. From our industry assessments of variation in energy use in European sectors we know that a factor 2 difference between the best and worst performing factories is quite common. This variation is explained by the applied technology, age of equipment, plant management and capacity/production rate. All these factors can differ considerably. In Agri-footprint we apply different estimates for variation and distribution depending on the available information.
Production of fertilizers	Energy use per unit production	The average LCA impact of fertilizer production is mainly determined by energy use, type of energy source and efficiency of production of this energy source and N_2O emissions. Only for energy use we include an uncertainty distribution in Agri-footprint.
Animal production	Yield (kg milk/cow; piglets/sow; kg pig/kg feed; kg broilers/feed, number of eggs/kg feed)	The main parameter explaining environmental performance of animal production systems is the Feed Conversion Rate, how efficient feed inputs are transferred to the animal product.

In Agri-footprint we included not all uncertainties:

1. Uncertainty due to LCA modelling arising when modifications are made in process information to simplify or generalize the process was neglected. Examples are neglecting small inputs and outputs of the dairy farm system and assuming that the dairy farm is on average a closed system or only taking into account a limited set of technologies for housing systems in defining the average pig farming system.
2. Model uncertainty is especially important for the calculation of N_2O, CH_4, NH_3 to air emissions, N to water, P to water and agricultural soil, heavy metals to water and soil. The literature that describes the applied models often gives estimates for uncertainty in the relations between input and output (e.g. the N_2O emission to air due to N-fertilizer application to the soil). These uncertainties are not included and can be quite high in some specific cases, such as N_2O and NO_3. Also the choice for specific emission models is not considered.
3. Not included data uncertainties around the average process are:
    - 3.a. Variation in mass balances of multi-output processes and the variation in the balance of input products and output products, for instance the yield of wheat flour and wheat bran that can vary in relation to the composition of the incoming wheat. Secondly, the variation in composition of product mixes, such as the market mixes, the energy mix, the mix of transport modality and the mix of feed ingredients in a compound feed.
    - 3.b. Variation in the allocation parameters, energy content and price. Most variable are the prices, although by using five years averages the variation is not so big (see Blonk & Ponsioen, 2009). Energy values used for allocation can also slightly vary.
    - 3.c. Uncertainty in emissions that are related to specific techniques, such as ammonia releases of pig housing systems, emissions of pesticides in relation to spraying conditions, etc.

3.8.2 Overview of applied uncertainty information

In Table 3-3, an overview is given of applied uncertainty models and parameters. Most of these estimates are based on expert judgements using the following principles regarding distribution and variation:

- If there is only information about the range, for instance from literature describing the performance of technologies in practices (such as the BREF reports), a triangular distribution is assumed around the average of this range (min, max, average).
- If there is more information available, such as more data on performance and representativeness of this performance in the total range of practices that define the average,
  - A normal or a lognormal distribution is derived using the following rules of thumb:
    - A normal distribution is assumed for farming (cultivation and animal farming).
    - A lognormal distribution is assumed for all other processes.
  - To determine the size of the distribution:
    - If specific information is available of the distribution and standard deviation of the average process, then this is applied.
    - If there is no specific information available, information is derived from other processes that are similar based on expert judgment using the following information:
      - In processing industry, the distance between the best and worst performing industry in a region lays in general between a factor 2 to 3. The higher the share of energy costs in the total costs of an industry the smaller the distribution.
      - In non-land based animal production systems (broilers, pigs and egg production) there is a very big pressure on having a good feed conversion rate (FCR). So the distributions around the FCR are small.
      - In land based farming, the cost breakdown and also natural conditions are more defining variability, so there is a wider distribution around the average.

Table 3-3: Overview of applied uncertainty models and parameters

Process	Data point	Uncertainty model and parameters	Source
Cultivation	Kg crop production (main + co-products)/ha	Normal distribution, standard deviation is derived from statistical analysis of FAO yield data of the years 2006-2013.	FAOstat (FAO, 2012)
Transport	Tonne*km	Lognormal distribution, sd = 1.3	Qualified estimate based on sample of primary data of truck fuel consumption and expert judgement
Processing of food crops	Energy use	Mostly Lognormal distributions with a standard deviation varying from 1.1 to 1.4 Sometimes triangular or uniform distributions based on min and max values.	Expert judgement as applied in Feedprint documentation
Production of fertilizer	Energy use	Energy use for ammonia production has a lognormal distribution with sd of 1.35. This value is applied to all fertilizer production energy inputs.	(International Fertilizer Industry Association, 2009)
Animal production	Dairy farm	Normal distribution, coefficient of variation 0.144 of average for the outputs (milk, calves and slaughter cows) as a group.	Based on inventory of a sample of 100 something farmers of a Dutch co-operation (Kramer, Broekema, Tyszler, Durlinger, & Blonk, 2013)
	Piglet farm	Outputs piglet and slaughter sows: Normally distributed. Coefficient of variation 0.077	Based on Agrovision benchmark reporting (Agrovision, 2013)
	Pig farm	Outputs fattening pigs: Normally distributed. Coefficient of variation 0.061	Based on Agrovision benchmark reporting (Agrovision, 2013)
	Raising laying hens	Output laying hens: Normally distributed. Coefficient of variation 0.03	Based on uncertainties around FCR (Wageningen UR, 2013)
	Egg production	Outputs eggs: Normally distributed. Coefficient of variation 0.06	Same value taken as for Pigs and broiler parent hens, assuming that margins are similar tight and that FCR is key to realize margins
	Broiler parent hens	Outputs broiler parent hens: Normally distributed. Coefficient of variation 0.06	Based on uncertainties around FCR (Wageningen UR, 2013)

	Broilers	Output: broiler; Normally distributed. Coefficient of variation 0.05	Based on uncertainties FCR. Leinonen, Williams, Wiseman, Guy, & Kyriazakis (2012) gives an estimate between 0.3 and 0.5
	Irish beef	Outputs: Normally distributed. Coefficient of variation 0.144	Derived from Dutch dairy farming

3.8.3 Technical note on the modelling of output uncertainties

SimaPro, does not allow for a direct definition of a probability distribution of outputs. This is solved by defining a parameter with a probability distribution and use this parameter as the value of the output, when only one output is defined for a process.

For the multi-output processes a similar strategy was used. We do not include variation in the relative mass balances of the multiple outputs nor the variation on the allocation factors. Thus it is assumed that the ratios among the multiple outputs are constant. To keep the ratio between outputs constant (during an uncertainty analysis) one of the multiple outputs is selected to describe the variability of the process (reference output). A parameter with the corresponding probability distribution is created for the reference output. For each additional output, two parameters are created: a parameter which describes the constant ratio between the additional output and the reference output and a calculated parameter which multiplies the reference output value by the constant ratio. This construction allows for variation of the outputs during Monte Carlo analyses, while keeping the ratio between the outputs fixed.

4 Data quality procedure

To ensure a database with consistent data, a four stage data quality procedure has been used. Each stage of the procedure focusses on different aspects, to ensure an efficient but at the same time robust work procedure. Each step of the procedure has been done by a different researcher.

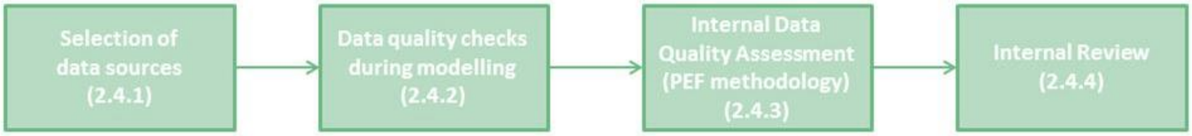

Figure 4-1: Data quality procedure

4.1 Selection data sources

During the development of Agri-footprint, the following procedure was used to develop the inventories:

1. Establish a consistent baseline dataset
2. Fill data gaps with best available data
3. Improve baseline data whenever possible using data quality hierarchy

Table 4-1: Applied Data quality hierarchy

<table>
<tr><th></th><th>Data collection method</th><th>Geography</th><th>Time</th><th>Completeness</th><th>Technology</th></tr>
<tr><td>Most preferred</td><td>Data from all companies</td><td rowspan="2">Specified geographic region</td><td rowspan="2">A year within the last 5 years</td><td rowspan="2">All relevant input and output flows</td><td rowspan="2">Almost all of the common technologies</td></tr>
<tr><td rowspan="5"></td><td>Sample of companies made on target LCI data performance

Verified/non verified</td></tr>
<tr><td>Sample of companies based on other performance (e.g, economic)

Verified/non verified</td><td rowspan="3">Similar geographic region</td><td rowspan="3">Different years within the last 10 years</td><td rowspan="3">Some major flows are missing</td><td rowspan="3">A commonly used technology</td></tr>
<tr><td>Documented expert data describing technology inputs and environmental performance</td></tr>
<tr><td>Statistical data having a broader scope</td></tr>
<tr><td>Anecdotal data from other sources</td><td rowspan="2">Geographic region dissimilar</td><td rowspan="2">More than 10 years</td><td rowspan="2">Many major flows are missing</td><td rowspan="2">An alternative technology</td></tr>
<tr><td>Least preferred</td><td>Assumptions, proxies using analogous processes, partial modelling</td></tr>
</table>

4.1.1 Establish a consistent baseline dataset as a starting point

During the development of Agri-footprint, the first step was to create data that was of consistent quality for all crops and regions covered. For example, all fertilizer application rates, fertilizer types, water use etc. is based on the same methodologies for all crops. To create this consistent baseline dataset, data were derived from documented expert data or data from statistics (i.e. data source in the middle of the data hierarchy).

Agri-footprint contains attributional LCIs, so generally average mixes are considered that are representative for the specific crop, process, transport modality, product or location.

The main baseline data source is the public domain (Scientific literature, FAOstat, Eurostat, etc.). Data from the public domain are assessed based on representativeness (time-related coverage, technical coverage and geographical coverage), completeness, consistency and reproducibility. When data from public or confidential research initiated by the industry and conducted by Blonk Consultants are more representative, complete or consistent, these data were used. Where possible, the data have been reviewed by industry experts.

Fertilizers production was modeled based on the latest available literature and the modeling of a specific fertilizer product was based on primary data from a large Dutch fertilizer producer (Calcium Ammonium Nitrate produced by OCI Nitrogen in the Netherlands). Auxiliary materials were based on the ELCD 3.0 database or literature sources. For some background processes, estimates had to be made (e.g. the production of asbestos used in sodium hydroxide production which is used in vegetable oil refining), and these processes are of lower quality and representativeness.

Processing inventories were initially drawn from the feedprint study (Vellinga et al., 2013). These inventories are generic for all provided countries and regions. These processes are either largely similar between countries or the data available was not specific enough to create country/ region specific processes. These generic processes are regionalised by adapting the inputs for energy consumption to the country or region where the processing takes place. This means that the processing (mass balances, inputs etc.) is the same for all regions. Therefore that the representativeness may have decreased for these processes (as the geography of the data is "other region assumed similar"). During the development of Agri-footprint 2.0, some of these 'feedprint' processes have been replaced by higher quality processes using region specific / higher quality data (see Part 2 of the report).

Transport distances and modes from and to the processing plant are also country specific. The geographical representativeness will be improved in future upgrades of Agri-footprint.

The aim for the LCI data is to be as recent as possible, which means that when better quality data or statistics on the processes/ systems are available, these will be incorporated in Agri-footprint, generally using five year averages. To ensure the best time related representativeness, data will be updated regularly. In Table 4-2, an overview is given of regularly updated data sources in Agri-footprint, and their place in the data hierarchy.

Table 4-2: Qualification of some often applied data sources (worst qualification determines colour)

Data source	Data type	Qualification
LEI Binternet (FDAN)	Animal production systems in the Netherlands; energy use data	Verified sample of companies based on other performance (e.g. economic); recent years and representative for animal systems under study
FAOstat	Yields of crops in certain regions	Statistical data having a broader scope
KWIN	Pesticides use of arable crops in the Netherlands	Documented expert data describing technology inputs and environmental performance, covers the most important pesticides, exclusions can be estimated by comparison to legislation

4.1.2 Fill data gaps using best available data

LCIs have been developed specifically for Agri-footprint or as part of previous confidential or public studies conducted by Blonk Consultants. These LCIs are fully reported or referred to in this report.

Data gaps are filled with estimates, which are as much as possible based on expert opinions and previous experiences. The assumptions are documented in this report, and clearly identified in the database. When fit, the uncertainty range reflects the fact that assumptions have been made.

Many unit processes require energy consumption (e.g. natural gas), fertilizers (e.g. Calcium Ammonium Nitrate) or auxiliary materials (e.g. hexane). Energy related LCIs are taken from the publicly available ELCD 3.0 database, when available. These are consumption mixes for specific countries or regions. However, not all countries in Agri-footprint are covered by this dataset (only EU countries are covered in ELCD 3.0). Therefore it was necessary to use proxy data (i.e. data from a different region or technology that was considered to be the best available when no fully representative data was available). The proxy grids were created by modelling the electricity production mix (from IEA statistics), using USLCI inventory data for electricity generated by a specific fuel type.

4.1.3 Improve baseline data whenever possible using the data quality hierarchy

The environmental impact of individual companies within an industry sector easily varies a factor 2 and sometimes much more (Canadian Fertilizer Industry, 2008). Agri-footprint supports the opportunity to include validated company specific data. The philosophy of this approach is that by making the improved performance of specific companies visible, LCA users can more easily identify improvement options in a lifecycle.

4.2 Data quality checks during modelling

As the original data has been compiled in different software programs and data structures, it is important to check consistency and correctness of all the data during the implementation process (the migration to a SimaPro database). Quality checking has been done iteratively. (Parts of) the database were exported to SimaPro, checked, errors or inconsistencies corrected and data gaps identified. When identified issues were resolved, a new SimaPro export was made, this was again checked. This process continued until all identified errors and data gaps were resolved. Different methods were used during the checking process:

- Check naming
- Remove duplicate processes, or processes that were very similar (e.g. wheat starch slurries with slightly different starch contents).
- Check correct linking
- Remove empty processes whenever possible
- Check if newly added processes or flows are applied consistently throughout the database.
- Mass balances
    - Balances; the amount of dry matter going in should be the same as dry matter going out as product or waste/emission. The total matter 'as is' should be balanced as well. Sometimes it was possible to also calculate balances of substances (e.g. hexane make-up should be balanced by hexane emissions during crushing).
    - Appropriate waste flows
- Transport included in all processes
- Logical differences between countries (yields, fertilizer application rates, et cetera)
- Consistent calculation methodology
- Compare results to existing data from other sources.

4.3 Data Quality Assessment using PEF methodology

The internal Data Quality Assessment provides insight into the quality of individual data sets to the users of Agri-Footprint. This assessment is in accordance with the 6 main indicators of data quality (briefly described in the below sections) from the ILCD handbook (JRC-IES., 2010). The calculation of the score for each data quality indicator and the overall data set has been performed in accordance with the PEF framework (European Commission, 2013), and they can be found in the comment section of each data set.

The assessment procedure was independently done by two researchers. They scored all data quality indicators from 1 (excellent) to 5 (very poor) in accordance to PEF (European Commission, 2013) . Both surveys were compared by the absolute difference of scores between the two researchers (Table 2.6). In the majority of cases (56%), both researchers came to the same score, while only in 2% of the cases the difference was 3 or higher. To resolve minor differences of 1 or 2, the average value has been used, and in the case of a difference of 1, the average is rounded upwards (e.g. a score of 2.5 becomes 3). In case of a major difference of 3 or 4, the particular indicator for that dataset has been revaluated by more in-depth research.

Table 2-6: Overview of differences in data quality scores.

Absolute difference	%	Rules for scoring
0	56	Value
1	30	Average value rounded upwards
2	12	Average value
3	2	Revaluate in-depth
4	0	Revaluate in-depth

4.3.1 Technological Representativeness (TeR)

The Technological Representativeness (TeR) of a data set is defined by the ILCD as “the degree to which the data set reflects the true population of interest regarding technology, including for included background data sets, if any.” For Agri-footprint we operationalized this indicator by defining 3 levels of technological foreground representativeness and 2 levels of technological background representativeness. The decision tree for TeR can be found in figure E.1 in appendix E.

4.3.2 Geographical Representativeness (GR)

The Geographical Representativeness (GR) of a data set is defined by the ILCD as “the degree to which the data set reflects the true population of interest regarding geography, including for included background data sets, if any.” For Agri-footprint we operationalized this indicator by defining 5 levels of geographical foreground representativeness and 2 levels of geographical background representativeness. The decision tree for GR can be found in figure E.2 in appendix E.

4.3.3 Time-related Representativeness (TiR)

The Time-related Representativeness (TiR) of a data set is defined by the ILCD as “the degree to which the data set reflects the true population of interest regarding time / age of the data, including for included background data sets, if any.” For Agri-footprint we operationalized this indicator by defining 3 levels of time-related foreground representativeness and 3 levels of time-related background representativeness. The decision tree for TiR can be found in figure E.3 in appendix E.

4.3.4 Completeness (C)

The Completeness of a data set is defined by the ILCD as "the share of (elementary) flows that are quantitatively included in the inventory. Note that for product and waste flows this needs to be judged on a system's level." For Agri-footprint we operationalized this indicator by defining 3 levels of foreground completeness and 2 levels of background completeness. The decision tree for C can be found in figure E.4 in appendix E.

4.3.5 Parameter uncertainty (P)

The Parameter uncertainty (P) of a data set is defined by the ILCD as a "measure of the variability of the data values for each data expressed (e.g. low variance = high precision). Note that for product and waste flows this needs to be judged on a system's level." For Agri-footprint we operationalized this indicator by defining 5 levels of uncertainty in accordance with the PEF (European Commission, 2013). The decision tree for P can be found in figure E.5 in appendix E.

4.3.6 Methodological appropriateness and consistency (M)

The methodological appropriateness and consistency (M) of a data set is measured in accordance to the PEF methodology (European Commission, 2013), which scales the score on this indicator relative to its standards concerning: multi-functionality, end of life modeling and system boundaries. Most data sets in Agri-Footprint are compliant with or all three requirements set by the PEF methodology. Therefore most datasets (98%) have a score of 2 for this indicator. The decision tree for M can be found in figure E.6 in appendix E.

4.4 External review

Agri-footprint 1.0 was externally reviewed on ILCD requirements by the Centre for Design and Society, RMIT University, Melbourne, Australia. The external reviewers checked the consistency and transparency of the methodology applied and completeness and transparency of data documentation.

Agri-footprint 2.0 is reviewed by RIVM (Dutch National Institute for Public Health and the Environment). This critical review is performed to ensure compliance with ISO 14040 (ISO, 2006a), 14044 (ISO, 2006b) on the following points:

- the methods used for the LCIs are consistent with this International Standard,
- the methods used for the LCIs are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the, intended goal of the LCIs.

This critical review;

- is performed at the end of Agri-footprint 2.0 development,
- includes an assessment of the LCI model,
- excludes life cycle impact assessment (LCIA).

Appendix A contains the original review letter from the Centre for Design (RMIT University). Appendix B provides responses to the comments and how it is integrated into the final Agri-footprint version. Appendix C and D contain the review report by RIVM and the response to these comments respectively.

Agri-footprint 3.0 was not formally reviewed in its entirety. However, it was developed in parallel to the EC Feed data tender project (part of the Environmental Footprint pilot) that included a review. As there is quite some overlap between the underlying data and models used in the feed tender and Agri-footprint, the review also benefited Agri-footprint indirectly.

5 Limitations of Agri-footprint

There are a number of limitations that should be taken into account when using Agri-footprint. Some additional limitations apply to specific processes; these limitations are reported in the data description section of that specific dataset (in 'Agri-footprint 4.0 - Part 2 – Description of data').

Agri-footprint provides LCI data with a standard reference unit of 1 kg. It is the responsibility of the user to determine an appropriate basis for comparison (functional unit).

The impact categories of ReCiPe and ILCD were taken into account when developing Agri-footprint. Agri-footprint uses some background data that was sourced from ELCD datasets (JRC-IES, 2012). Where LCIs of other databases are used, it is possible that errors have occurred during the development of those datasets or during implementation into third party LCA-software, the correction of these errors are beyond the control of the Agri-footprint development team. Naturally, errors that were discovered in those datasets were reported to the appropriate parties.

Elementary flows have been collated to align with requirements of ReCiPe and ILCD. Other LCIA methods may assess substances which are not included in Agri-footprint.

There are methodological limitations of LCA, which are not specific for Agri-footprint, but which are relevant for all agricultural and food product life cycle inventories:

- There is no internationally accepted methodology which is suitable for use in LCAs for loss of biodiversity due to land use or direct and indirect land use change.
- Multiple methods have been developed internationally on the impact of land use change, but there is no consensus yet on which method is best. For Agri-footprint the choice was made for the PAS2050:2012-1 method (BSI, 2012).
- For water depletion and water use related to water scarcity there is no international consensus on the methodology. The water footprint was developed (Hoekstra & et al., 2011) but internationally there is discussion on whether the green, grey as well as the blue water footprint are a suitable indicator for environmental impact. Agri-footprint incorporates water use as regionalized blue water flows to allow impact assessments such as Pfister, Koehler, & Hellweg (2009) and water resource depletion (Federal Office for the Environment, 2009) as recommended by the ILCD.
- Use of statistical data for crop yields, (artificial and organic) fertilizer application rates, when there is not specific data available.
- Due to limited data availability, elementary flows related to the environmental impact due to soil erosion and soil degradation is not included in Agri-footprint.
- Data availability is also limited in relation to production and the use of pesticides (impacting on eco-toxicity), but an approach was developed to estimate the impact on ecotoxicity of agricultural cultivation.

The system boundaries which are supported by Agri-footprint are from cradle (cultivation) to factory or farm gate. The processes can be used to support LCAs from cultivation to end-of-life, but Agri-footprint does not contain processes for life cycle phases such as packaging, distribution and retail, consumer storage and preparation or waste treatment. Some specific data sets have a lower quality (

Table 5-1), mainly due to lack of primary data.

Table 5-1: Data that has a lower accuracy, precision or completeness.

Process	Used in	Comment
Asbestos	*Joint production of sodium hydroxide and chlorine gas*	*No specific data available, Crushed stone 16/32, open pit mining, production mix, at plant, undried RER S.*
Mercury	*Joint production of sodium hydroxide and chlorine gas*	*No specific data available, Special high grade zinc, primary production, production mix, at plant GLO S used as proxy.*
Solvents	*Used in production of CAN*	*No specific data available, proxies used.*
Hexane	*Used in refining of vegetable oils*	*No specific data available, naphtha used as base product plus energy for additional refining.*
Lime fertilizer	*Used in crop cultivation*	*No specific data available, Crushed stone 16/32, open pit mining, production mix, at plant, undried RER S used as proxy.*
Dolomite	*Used in production of CAN*	*No specific data available, Crushed stone 16/32, open pit mining, production mix, at plant, undried RER S used as proxy.*
Bulk packaging	*Transport of crops or intermediate products during processing*	*Not included due to lack of data. Will be addressed in future upgrades.*

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Appendix A. Review letter from the Centre for Design and Society

The external review of Agri-footprint 1.0 was performed on the draft documentation and Agri-footprint. Appendix B provides the responses.

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25 March 2014

Re: Agri-Footprint methodology and database review

Dear Bart,

Thank-you for the opportunity in allowing the Centre for Design and Society to review the Agri-Footprint methodology (Part 1 and Part 2) documents and the draft (2014-03-11) SimaPro database.

Broadly, the methodology is considered to align with ILCD requirements. Including:

- Transparency in intended application, limitations, reasons, target and type of audience, prelude to comparisons and commissioner
- Consistency in application of methods, assumptions and data
- Transparency in allocation approaches
- Transparency in approaches to foreground and background data selection and missing data
- Transparency in approach to direct land use change (land transformation)
- Unbiased, uses SI units where possible

There are a number of methodology items which are considered disputable, debatable or which require more detailed reporting. These items are:

- The approach to the generation of proxy electricity grids for regions without LCI data, which adopts LCI data from the closest-matching grid based on greenhouse gas emission impacts. This is considered as being not appropriate for a number of reasons, including:
  - Greenhouse gas emission impacts are sensitive to time horizon; LCI's which are close on a 100 year time horizon might be different on shorter or longer time horizons
  - Other environmental flows, such as those contributing to ionizing radiation (from nuclear emissions), do not necessarily track greenhouse emissions. In essence, the electricity grids for two countries can have very similar greenhouse gas emisions, but very different ionizing potential. The differences are driven by the production mix, e.g. black coal, hydro, nuclear etc.

- Transparency regarding LCI data for Irish beef production. Emission tables, assumptions etc. are required to improve transparency
- Transparency regarding the choice of modelling of pesticides.
- Mass balances for auxiliary materials, e.g. bleaching earth. Presumably differences in process outputs and inputs can be attributed to emissions or exchanges, but it appears these have not been modelled.
- Air emissions of CO_2 from the production of ammonia. If all of the CO_2 is used as a feedstock (e.g. in urea), then it is not an emission. Characterising ammonia GHG impacts would thus give misleading result. Suggest cut-off approach
- It is unclear how phosphorous-related emissions (e.g. phosphate from synthetic P-fertiilizers) are dealt with. These flows are capture under ReCiPe and it is suggested that these need to be included in the inventory.

It is recommended that Blonk Consultants reassess the applicability of these aspects and take corrective measures, as required.

There are a number of items which will improve transparency and reproducibility, namely:

- A description on whether or not farming systems are single- or mixed-enterprise farms
- A description of how unit processes were developed for regions which adopt other regions' data (regionalisation)
- List and distinction of and between foreground and background unit processes used and a description of naming conventions in the SimaPro database
- Improved transparency in calculations relating to enteric fermentation
- Tabulated data quality assessment for foreground processes
- A discussion on the applicability of default IPCC emission factors for nitrogen-based emissions.
- Conversion of some reported electricity inputs from euro to kWh / MJ
- Data sources regarding assumptions for LTO operations for aircraft

I have a number of suggestions which may improve useability of the methodology documents:

- System boundaries for each product type
- A list of environmental flows required for the target impact assessment method (ReCiPe)

RMIT UNIVERSITY
School/Department/Area

With respect to the SimaPro database, the methodology described has been consistently applied to the data.

Comments to the methodology documents have been added to using track changes. I am happy to work through my comments via Skype, if required.

Yours sincerely,

Dr. Enda Crossin
Program Director – Life Cycle Assessment
Centre for Design
RMIT University
enda.crossin@rmit.edu.au

Appendix B. Response to the comments in the review letter

Appendix A contains the original review letter from the Centre for Design (RMIT University). This appendix provides responses to the comments and how it is integrated into the final Agri-footprint version. The responses are indicated by '*Agri-footprint team:*'

Review letter from the Centre for Design (RMIT University):

There are a number of methodology items which are considered disputable, debatable or which require more detailed reporting. These items are:

The approach to the generation of proxy electricity grids for regions without LCI data, which adopts LCI data from the closest-matching grid based on greenhouse gas emission impacts. This is considered as being not appropriate for a number of reasons, including:

- Greenhouse gas emission impacts are sensitive to time horizon; LCI's which are close on a 100 year time horizon might be different on shorter or longer time horizons
- Other environmental flows, such as those contributing to ionizing radiation (from nuclear emissions), do not necessarily track greenhouse emissions. In essence, the electricity grids for two countries can have very similar greenhouse gas emissions, but very different ionizing potential. The differences are driven by the production mix, e.g. black coal, hydro, nuclear etc.
- *Agri-footprint team: Good comment. New inventories for non-EU countries were developed. See section 'Extension of ELCD data' for more explanation.*

- Transparency regarding LCI data for Irish beef production. Emission tables, assumptions etc. are required to improve transparency
  Agri-footprint team: The section in the data description report in which the Irish beef system is described is extended.

- Transparency regarding the choice of modelling of pesticides.
  Agri-footprint team: A new table is included in section 'Pesticide application' of the data description report in which the substance replacements and the reason for replacement are given.

- Mass balances for auxiliary materials, e.g. bleaching earth. Presumably differences in process outputs and inputs can be attributed to emissions or exchanges, but it appears these have not been modelled.
  Agri-footprint team: A scaling error happened and return flows were not modelled. The error is solved and the return flows are now explained in the text.

- Air emissions of CO_2 from the production of ammonia. If all of the CO_2 is used as a feedstock (e.g. in urea), then it is not an emission. Characterising ammonia GHG impacts would thus give misleading result. Suggest cut-off approach
  Agri-footprint team: It is not known if all CO_2 is used. It is now better explained in section of the data description report: All CO_2 from the feedstock is captured in absorbers and utilized in Urea making, if applicable. However, ammonia could also be used in other processes where the CO_2 cannot be used, in that case it needs to be vented. Therefore, an input of CO_2 from nature is included in Urea making, to mass balance the CO_2 (no net emissions) and ensure that CO_2 emission is accounted for in all other cases.

- It is unclear how phosphorous-related emissions (e.g. phosphate from synthetic P-fertilizers) are dealt with. These flows are capture under ReCiPe and it is suggested that these need to be included in the inventory.
  Agri-footprint team: A new section is included in the data description report in which the phosphorous-related emissions are described.

There are a number of items which will improve transparency and reproducibility, namely:

- A description on whether or not farming systems are single- or mixed-enterprise farms
  Agri-footprint team: All farms are single enterprise farms. This statement is included at several places in the documentation.

- A description of how unit processes were developed for regions which adopt other regions' data (regionalisation)
  Agri-footprint team: This is explained in section 4.1.1 of the methodology report.

- List and distinction of and between foreground and background unit processes used and a description of naming conventions in the SimaPro database
  Agri-footprint team: All background processes from other sources are now listed in the section 'Extension of ELCD data' of the data description report.

- Improved transparency in calculations relating to enteric fermentation
  Agri-footprint team: A new paragraph is included in the dairy farming section of the data description report.

- Tabulated data quality assessment for foreground processes
  Agri-footprint team: This will be performed in the next version of Agri-footprint due to time constraints.

- A discussion on the applicability of default IPCC emission factors for nitrogen-based emissions.
  Agri-footprint team: A paragraph is included in the data description report in which the IPCC Tier 2 approach is underpinned and discussed.

- Conversion of some reported electricity inputs from euro to kWh / MJ.
  Agri-footprint team: Conversions are now mentioned in the tables of the data description report.

- Data sources regarding assumptions for LTO operations for aircraft.
  Agri-footprint team: The data source is 'European Environment Agency (2006) Emission Inventory Guidebook' and is included in the air transport section of the data description report.

I have a number of suggestions which may improve usability of the methodology documents:

- System boundaries for each product type
  Agri-footprint team: System boundaries for each product type are included in section 3.5.

- A list of environmental flows required for the target impact assessment method (ReCiPe)
  Agri-footprint team: After consultation with RMIT it was decided that the added value was limited. So this is not included in the reports.

Appendix C. Review letter from RIVM – Agri-footprint 2.0

National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

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T 030 274 91 11

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info@rivm.nl

Dealt with by
Anne Hollander
DMG

T 3013
anne.hollander@rivm.nl

Date 21 September 2015
Subject Review statement Agri-Footprint 2.0

Dear,

On behalf of Blonk Consultants, RIVM performed a review of the concept Agri-Footprint 2.0, which was carried out by Michiel Zijp and Anne Hollander of the department DMG. Blonk Consultants provided RIVM the concept database as well as two background reports ('Part 1– Methodology and basic principles' and 'Part 2 – Description of data'; both draft 27 May 2015).

RIVM reviewed both the texts and data in the reports, and the database itself. This critical review was performed conform ISO 14071. Self-declarations of reviewer independence and competencies of Anne Hollander and Michiel Zijp were provided. Comments on the reports were given in track changes in the reports itself. Comments on the database were listed in the Review table.

Based on the written comments of RIVM and a discussion meeting between Blonk Consultants (Jasper Scholten and Lody Kuling) and RIVM (Michiel Zijp and Anne Hollander) in June 2015, Blonk consultants updated both background reports and the database. These final documents seem to RIVM appropriate and reasonable in relation to the, by Blonk, intended goal of the LCIs. Moreover, the methods used for the LCIs are consistent with the International Standards ISO 14040, ISO 14044.

RIVM is therefore pleased to approve the Agri-Footprint 2.0.

With kind regards,

Anne Hollander and Michiel Zijp
RIVM/DMG

Version: 1 Status: Final Page 1 of 1

Appendix D. Self-declarations Agri-footprint 2.0 reviewers

agri›footprint‹

Appendix I: Self-declaration of reviewer independence and competencies *(based on ISO 14071)*

I, the signatory, hereby declare that:

- I am not a full-time or part-time employee of the commissioner or practitioner of the LCA study (external reviewers only)
- I have not been involved in defining the scope or carrying out any of the work to conduct the LCA study at hand, i.e. I have not been part of the commissioner's or practitioner's project team(s)
- I do not have vested financial, political or other interests in the outcome of the study

My competencies relevant to the critical review at hand include knowledge of and proficiency in:

- ISO 14040 and ISO 14044
- LCA methodology and practice, particularly in the context of LCI, (including data set generation and data set review, if applicable)
- critical review practice
- the scientific disciplines relevant to the important impact categories of the study
- environmental, technical and other relevant performance aspects of the product system(s) assessed
- language used for the study

I declare that the above statements are truthful and complete. I will immediately notify all parties involved (commissioner of the critical review, practitioner of the LCA study, reviewer(s)), as applicable, if the validity of any of these statements changes during the course of the review process.

Date: 16-6-2015
Name: Anne Hollander
Signature:

Appendix I: Self-declaration of reviewer independence and competencies
(based on ISO 14071)

I, the signatory, hereby declare that:

- I am not a full-time or part-time employee of the commissioner or practitioner of the LCA study (external reviewers only)
- I have not been involved in defining the scope or carrying out any of the work to conduct the LCA study at hand, i.e. I have not been part of the commissioner's or practitioner's project team(s)
- I do not have vested financial, political or other interests in the outcome of the study

My competencies relevant to the critical review at hand include knowledge of and proficiency in:

- ISO 14040 and ISO 14044
- LCA methodology and practice, particularly in the context of LCI, (including data set generation and data set review, if applicable)
- critical review practice
- the scientific disciplines relevant to the important impact categories of the study
- environmental, technical and other relevant performance aspects of the product system(s) assessed
- language used for the study

I declare that the above statements are truthful and complete. I will immediately notify all parties involved (commissioner of the critical review, practitioner of the LCA study, reviewer(s)), as applicable, if the validity of any of these statements changes during the course of the review process.

Date: 21-9-15
Name: Michiel Zijp
Signature: [signature]

Appendix E. Decision trees for Data Quality Assessment

Technological Representativeness

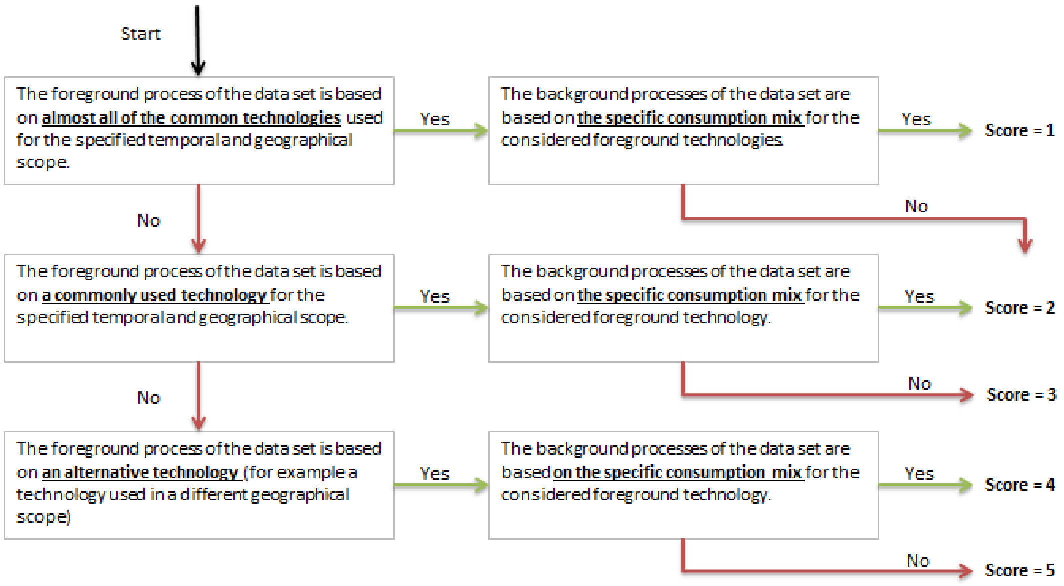


Figure E-1: Decision tree for Technological Representativeness (TeR)

Geographical Representativeness

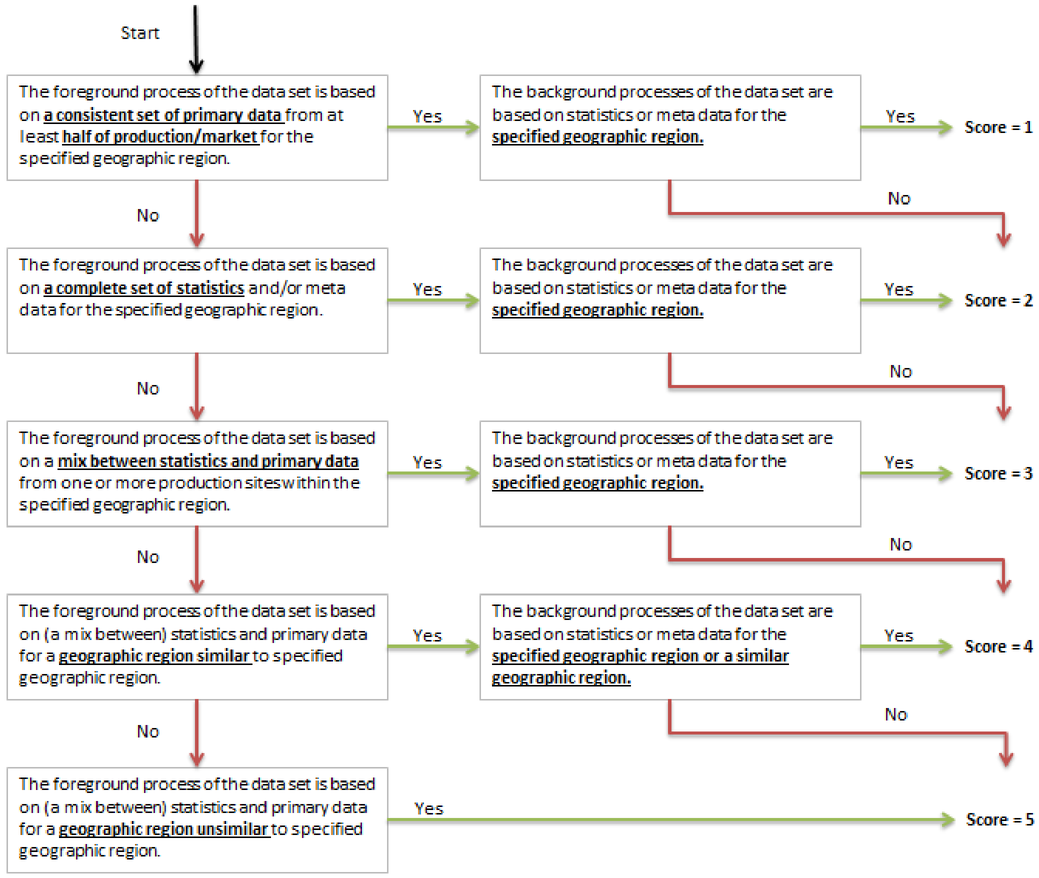


Figure E-2: Decision tree for Geographical Representativeness (GR)

Time-related Representativeness

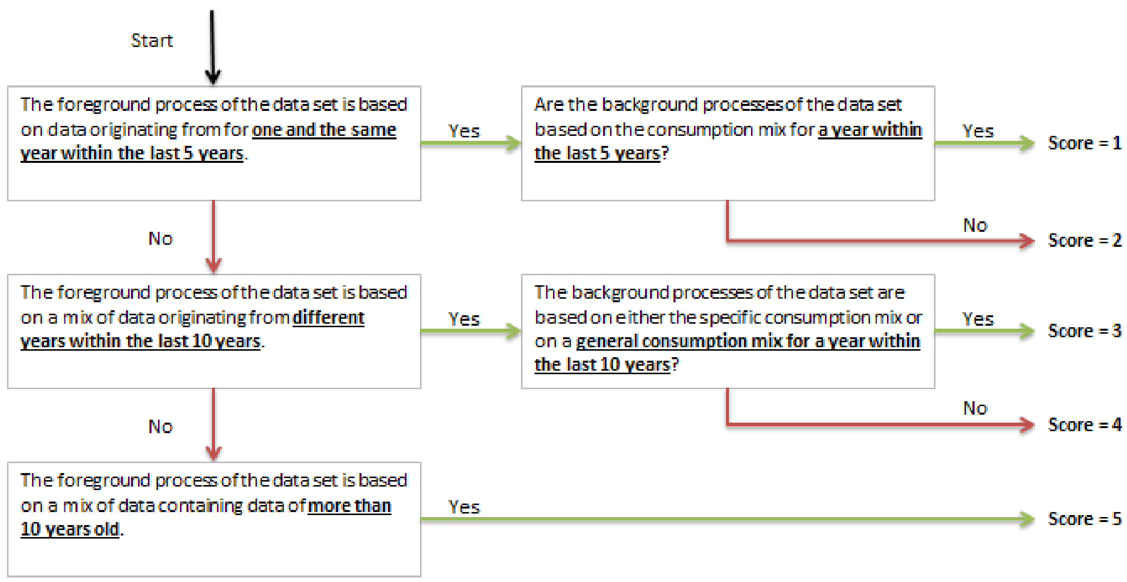
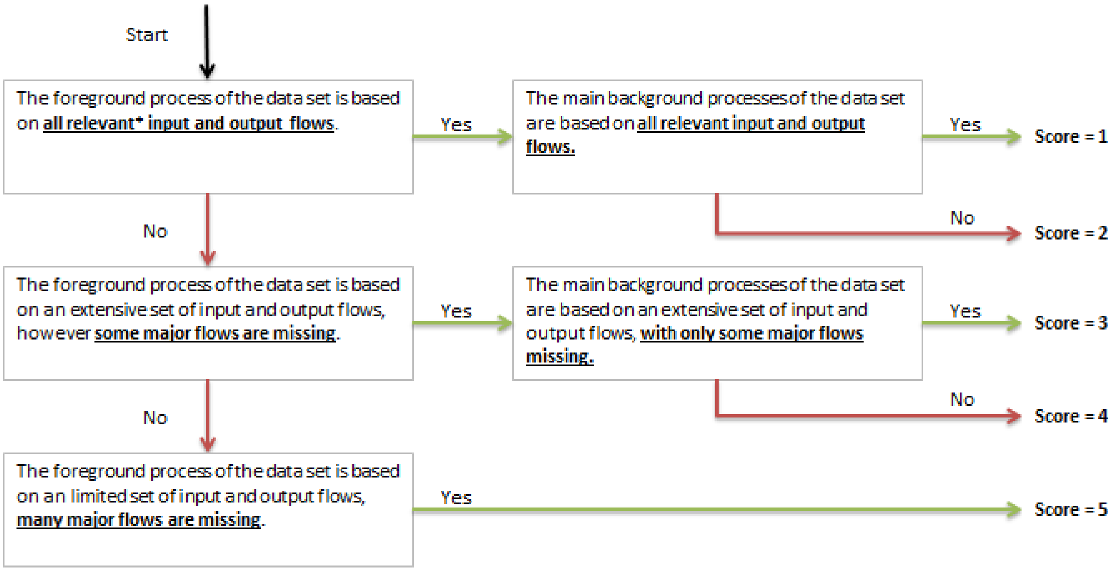


Figure E-3: Decision tree for Time-related Representativeness (TiR)

Completeness



* Flows that can have a major impact +-25% on commonly used impact categories

Figure E-4: Decision tree for Completeness (C)

Parameter uncertainty

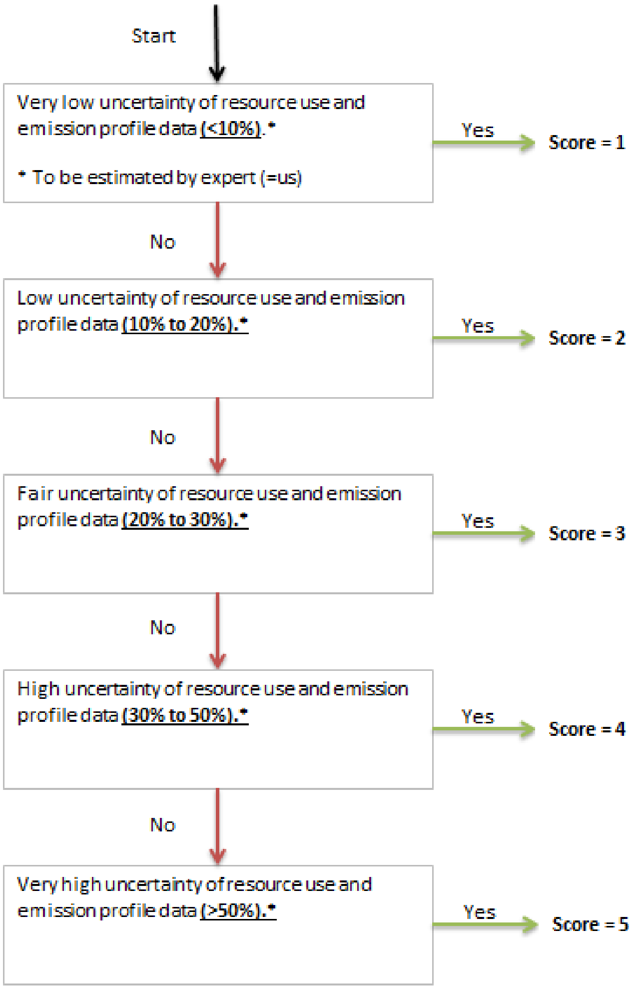


Figure E-5: Decision tree for Parameter uncertainty (P)

Methodological appropriateness and consistency

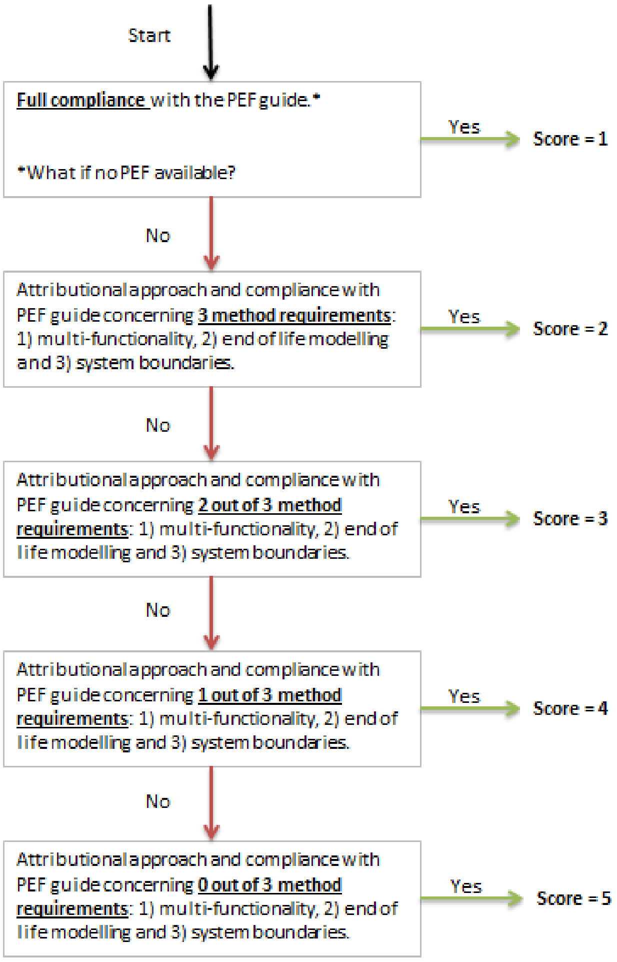
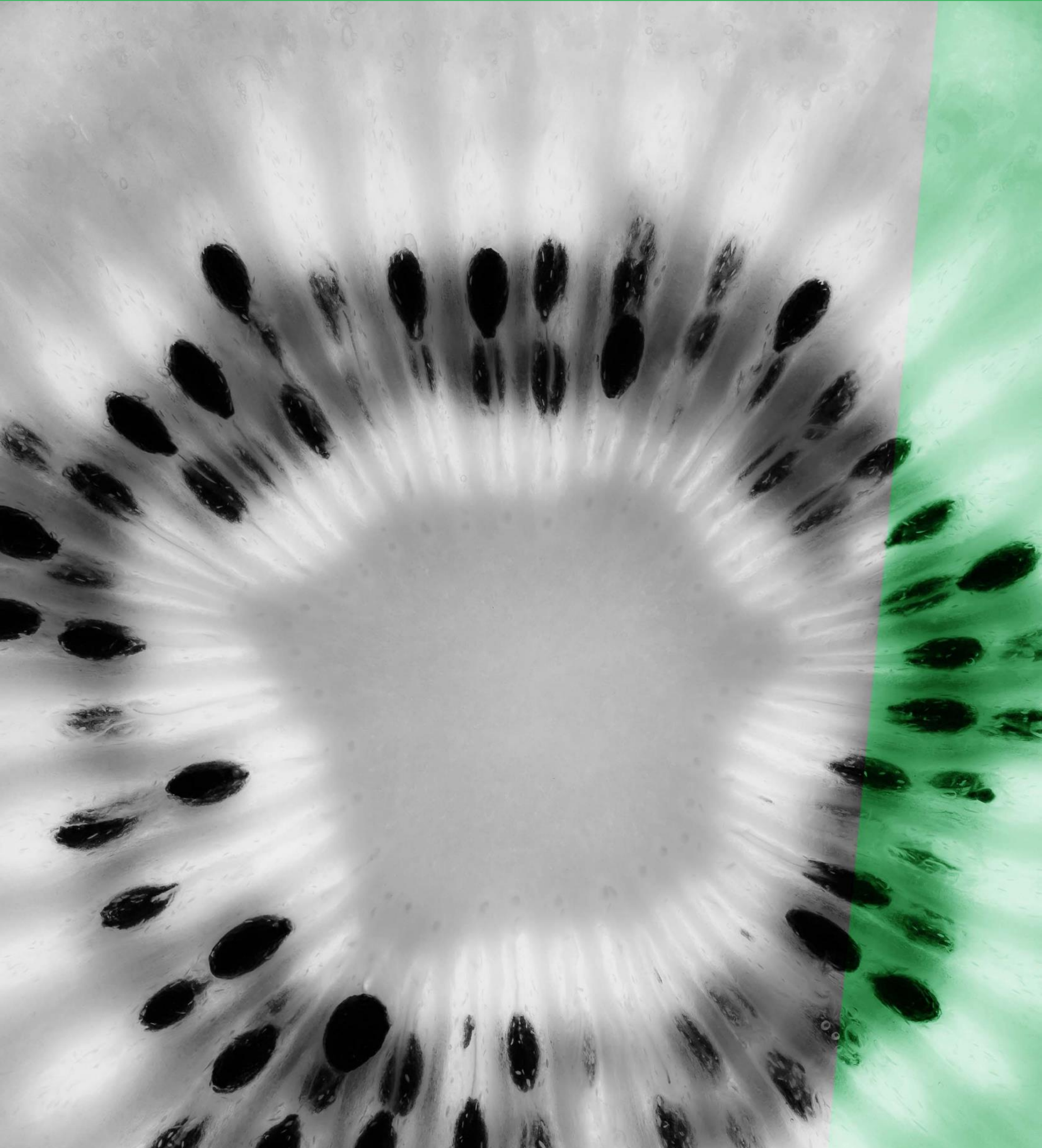


Figure E-6: Decision tree for methodological appropriateness and consistency (M)



Agri-footprint is a high quality and comprehensive life cycle inventory (LCI) database, focused on the agriculture and food sector. It covers data on agricultural products: feed, food and biomass and is used by life cycle assessment (LCA) practitioners. In total the database contains approximately 8,500 products and processes. In the last years Agri-footprint is widely accepted by the food industry, LCA community, scientific community and

Agri-Footprint

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