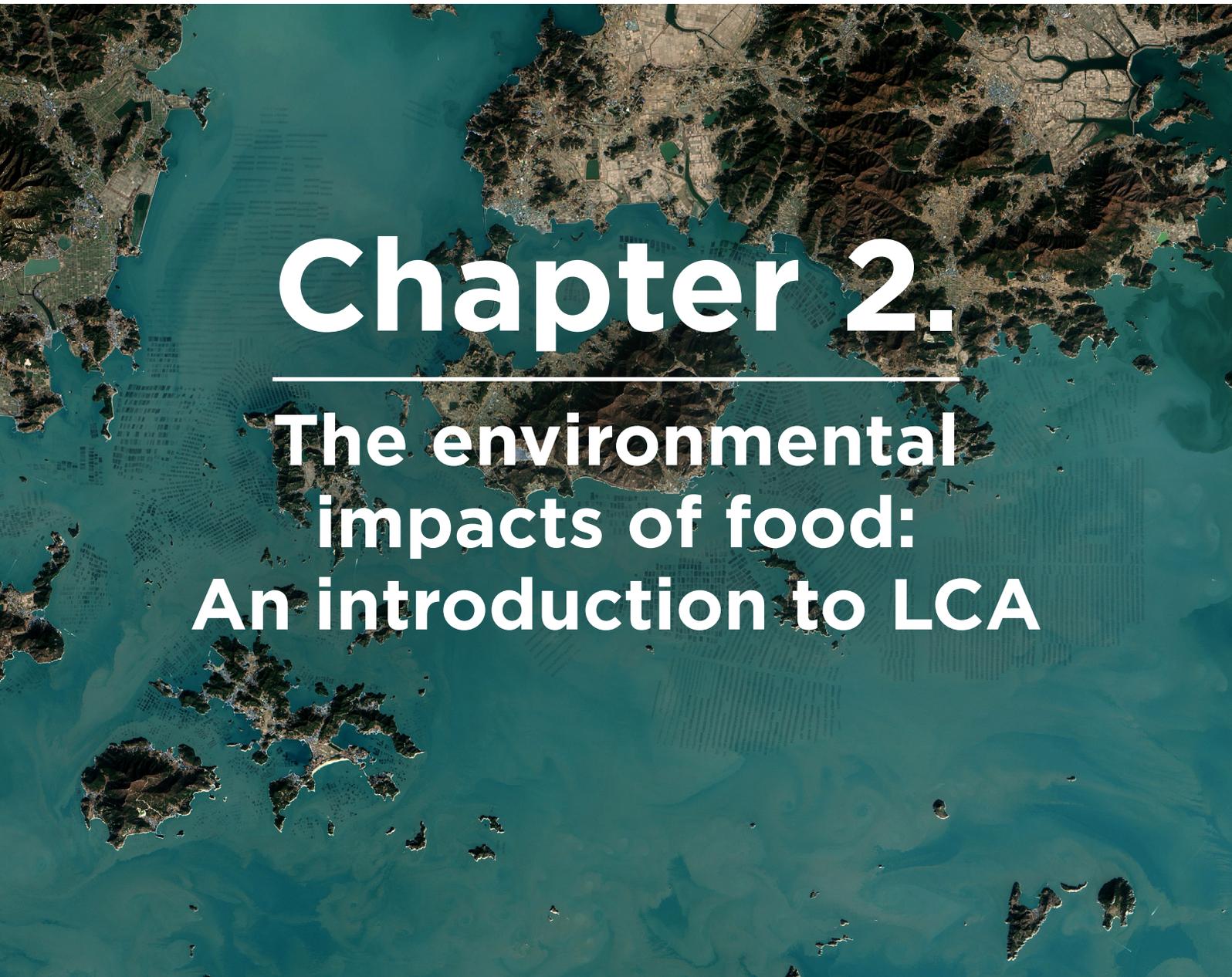




# FCRN foodsource

A free and evolving resource to empower informed discussion on sustainable food systems



## Chapter 2.

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### The environmental impacts of food: An introduction to LCA

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# Why should you read this chapter?

Food systems use large amounts of natural resources and have significant environmental impacts; so what can we do to make them more sustainable?

To answer this question, we need to understand which types of food, methods of production, ways of processing, packaging, transporting, and consuming foods have greater impacts than others. In other words, we need data to understand the current situation, and to have a way to evaluate how environmental impacts would change (for better or worse) if things were arranged differently.

Life cycle assessment (LCA) helps us to do this. It is a method used for quantifying the various environmental impacts and resources used, throughout the entire lifecycle of a product or service. LCA has been foundational in helping us understand which parts of food systems have the greatest impacts, and how they could become more sustainable. Knowing something about the LCA approach makes it possible to critically evaluate the claims made by many research studies and broader media reporting, and allows for a deeper understanding of the information presented in other Foodsource chapters.

This chapter provides an accessible primer on the life cycle assessment (LCA) methodology. It addresses the following:

- What is life cycle assessment?
- How can an LCA approach can be applied to measure the impact of a food product or related process?
- What are the complexities and uncertainties involved in performing LCA for food products and in interpreting their results?
- What are the benefits and limitations of the LCA approach, including its role in assessing sustainability?

## Key points

- All food follows a pathway through time and space – or life cycle – from agricultural production through to eventual consumption or waste disposal.
- At each stage in the life cycle, resources are used (e.g. land) and outputs are created, some desirable (e.g. food), others not so (e.g. greenhouse gases).
- These inputs and outputs, in turn, impact upon things we care about such as biodiversity, human health, resource depletion, and climate change.
- LCA is an internationally standardised method for quantifying inputs and outputs related to a given amount of product or service, and for assessing their impacts.
- The value of the LCA method is in understanding the impacts of the whole-system. This avoids the risk of improving one stage in the supply chain or impact of concern, while simply shifting the problem to another stage in the supply chain or onto a different concern.
- Using LCA, we can ask questions about which ways of producing, distributing, consuming and disposing of foods, have the lowest environmental impacts.
- Because LCA is about analysing systems, the method requires careful design choices about what elements to include or exclude in an analysis, and how any impacts are attributed to products and services.
- The many variables, data sources and design choices in LCA, introduce inherent uncertainty in LCA results, which is especially high for agricultural products.
- Because LCAs are designed to answer specific research questions and come with inherent uncertainty, interpretation and comparison of their results must be done with care.
- While LCA is an extremely useful tool for analysing food system sustainability, its results must be put in a wider context to evaluate the overall sustainability of a product or process.

# 2.1 Lifecycle assessment (LCA): quantifies environmental impacts from cradle to grave of a product

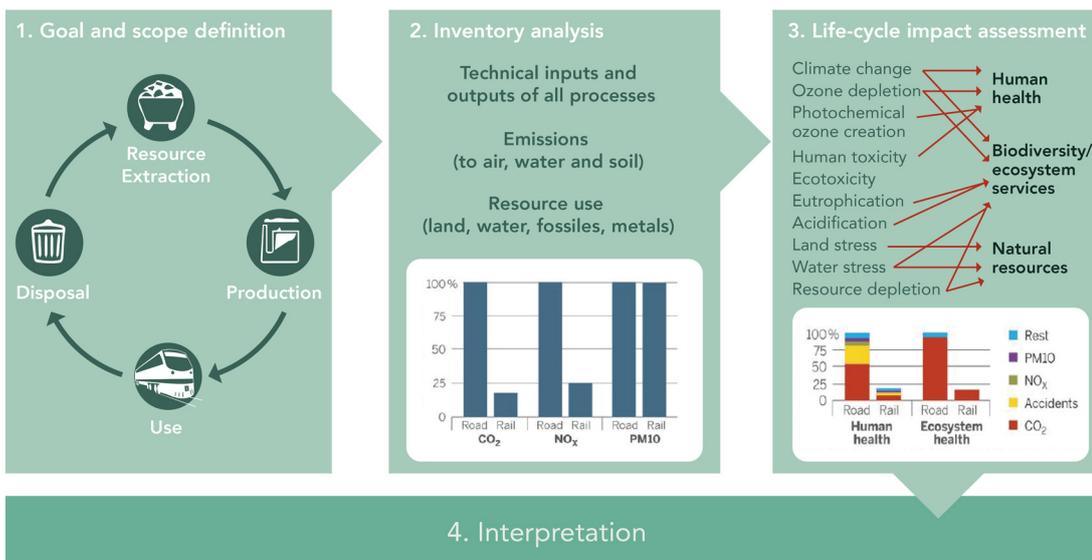
## 2.1.1 Overview of LCA aims and process

LCA studies, following the methodology framework set by ISO14040, involve 4 phases:

- goal/scope definition;
- inventory analysis;
- impact assessment; and
- interpretation.

Each phase is described in more detail in subsequent slides, but an overview follows here.

### LCA: a structured way of quantifying the environmental impact and resource use



**Figure 1: The four phases of lifecycle assessment.**

Source: Adapted from Hellweg & Milà i Canals (2014).

In Phase 1, the functional unit (the product, service or system upon which the LCA is based) is defined. This could, for example, be 1kg of pork. The system boundaries are then decided; these define what is measured and what is not, and may start with the production of the raw materials required on a farm and end with purchase of 1kg of pork at a supermarket.

In Phase 2, an inventory is made of all the inputs and outputs (e.g. resource use and emissions) accumulated in order to produce one functional unit's worth of product, at each stage within the system boundaries.

In Phase 3, emissions and resource use are grouped together into specific environmental themes or impact categories, such as climate change, eutrophication, and acidification. These are referred to as mid-point indicators. Further modelling of how these impacts will affect human health, ecosystem quality and natural resource use (end-point indicators) can also be performed. Mid- and end-point indicators are discussed later in this chapter.

In Phase 4, sensitivity and uncertainty analysis are performed to determine the robustness of the results to changes in assumptions and variables used in the calculations. Conclusions and recommendations are made. An example might be the recommendation of one manufacturing technique over another, or the identification of life cycle hotspots (locations in a product’s lifecycle where the most impacts occur) for the functional unit being studied.

One challenge within LCA, if the purpose is to compare different foods, is whether different studies use the same system boundaries, measure inputs and outputs in a consistent manner, and in how these results are interpreted. Increasing standardisation of methodologies, such as PAS 2050 (designed for carbon footprint analyses), is designed to reduce inconsistencies and allow comparison between research. This is important, especially within the food system, because of the many different production techniques and variables involved (see later in this chapter for more on this).

## 2.1.2 Phase 1: Goal and scope definition

### Phase 1: Goal and scope definition



Figure 2: Phase 1 of life cycle assessment – goal and scope definition.

Source: Adapted from Hellweg & Milà i Canals (2014).

When measuring the environmental impact of a product, service or system, we must initially define the scope of the assessment. Life cycle assessment ideally considers all stages involved in the production of a product or service (sometimes termed “from cradle to grave”, or “field to fork”).

### Eutrophication

Eutrophication refers to the buildup of nutrients in a body of water (e.g. nitrogen and phosphorus) to a level in excess of what would occur naturally and to which aquatic ecosystems are adapted. This can result in detrimental impacts on many aquatic plants and animals, as well as the rapid growth of some plants and algae.

### Acidification

Acidification refers to changes to the chemistry of a body of water that make it more acidic over time (i.e. increased hydrogen ion availability). This change in acidity can then affect many other reactions that take place in water, including those important for ecosystem functioning.

For example, the LCA scope for a loaf of bread could include producing raw materials for farming, production on the farm, harvesting and processing the crop, manufacturing the bread, delivery and storage at retail, impacts from consumption (including toasting), and transport and waste impacts all along the product's life cycle.

Some LCA studies deliberately limit their scope in order to focus on the impacts of a particular stage. An example might be an assessment of different production techniques for certain crops, in order to understand how different farming techniques might affect environmental outcomes.

In practice, as supply chains are often very complex, some inputs that are known to have a very small contribution to the overall environmental impact are sometimes ignored, and it is often a matter of judgement where these boundaries are set.

We also need to define what output it is whose impacts we are measuring – e.g. one kg of product, or 100 calories of product, or 1ha of farmed land and so forth. This is called the functional unit. The impacts – e.g. the quantity of carbon dioxide equivalent CO<sub>2</sub> equivalent emissions emitted in delivering this functional unit are expressed as a ratio – e.g. 0.5kg CO<sub>2</sub> eq./kg product. The output can also be converted and expressed as CO<sub>2</sub> eq. per average or recommended portion.

### Choice of functional unit can influence results

The functional unit is the unit that is being studied. It can be an individual product (e.g. 1kg of pork or the packaging of 1 litre of soda) or a service – e.g. (to take a non-food example) delivery of a week's supply of washed cloth nappies.

LCAs for food products normally use weight of finished food products as the functional unit (e.g. 1 kg of pork), but also use units of area (for example, the environmental impact of wheat production in terms of hectares used) or nutritional units (for example, the environmental impact of producing 100g of protein from a food product). The choice of functional unit could influence comparison between foods. For example, egg usually has a lower carbon footprint than poultry meat if the functional unit is 1 kg of product (egg or poultry meat) but if the functional unit is 1 kg of protein instead, the carbon footprint is more similar between the two as eggs only contain 12% of protein compared to 20% in meat.

The choice of the functional unit should reflect the purpose of the LCA-study. For example, if the purpose is to compare the production of pork using different animal feed inputs, a relevant functional unit could be 1 kg of pork meat at the farm gate. For another study comparing different ways of securing protein in our diet (e.g. via meat, fish, dairy, legumes etc.), a functional unit of 1 kg of protein might be better. However, as food purchases are seldom made on the basis of the nutrient content of food, a functional unit of 1 kg is often very relevant.

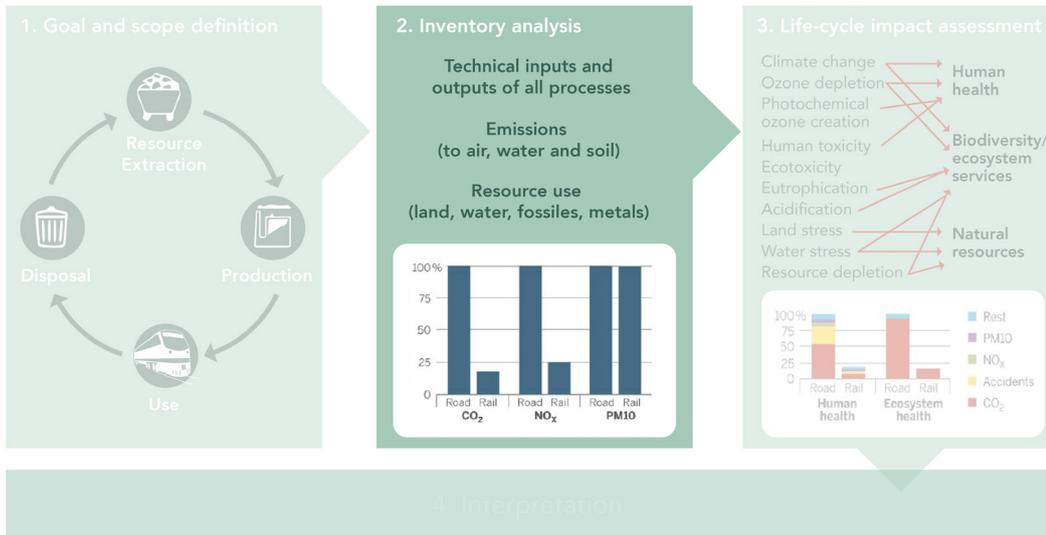
The relative impacts of different products can change, depending on which functional unit is used.

### Carbon dioxide equivalent

Carbon dioxide equivalent (CO<sub>2</sub> eq) is a measure used to compare and combine the warming effect of emissions from different greenhouse gases, using single measure of impact. This is done on the basis of a conversion factor known as the Global Warming Potential (GWP), which is the ratio of the total energy trapped by a unit of greenhouse gas (e.g. a tonne of methane) over a specific period of time (normally 100 years), to that trapped by carbon dioxide over the same time period.

## 2.1.3 Phase 2: Assessing inputs and outputs

### Phase 2: Inputs and outputs for all stages are included



**Figure 3: Phase 2 of life cycle assessment - inventory analysis.**

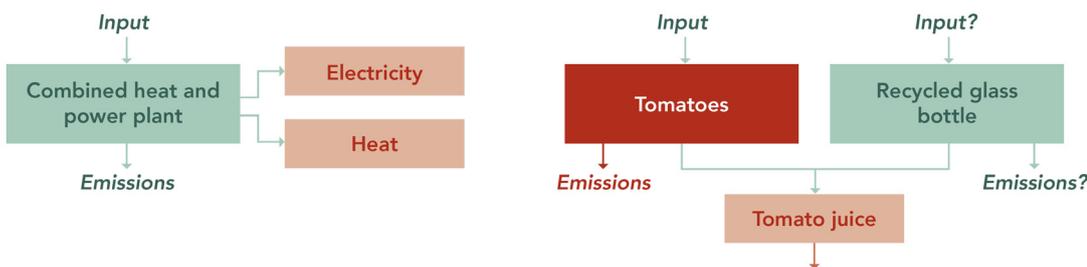
Source: Adapted from Hellweg & Milà i Canals (2014).

Data are collected for inputs and outputs at each stage within the scope of the LCA. Inputs might be energy, land and water use; outputs are the products and waste leaving the system at each stage.

Emissions are estimated for each of these, for example CO<sub>2</sub> emissions for the energy use to produce the chosen functional unit. The data used for this purpose may be source data specific to the focus of the LCA, such as the measured energy used in a factory process. Alternatively the data may be more generic and drawn from existing databases, which contain average impacts arising from certain types of common process. Clearly, the more specific the data the more accurate the results. Whatever the source of the data, the data need to be scaled to give the amount per functional unit that is the focus of the LCA.

#### Production systems often:

- Produce more than one product
- Contain the use of recycled material



**Figure 4: Allocation of inputs and emissions between products.**

Source: FCN. (2016).

## Allocating emissions and inputs between products is important but can be difficult

If a factory manufactures three different products, one of which is the functional unit of an LCA study, then the energy use in that factory needs to be allocated appropriately to the functional unit being studied (maybe 1/3 of energy use), rather than the total energy used by the factory as a whole. Sometimes allocation is a complex process. For example, a dairy system produces not just milk but also meat (male calves, dairy cows no longer lactating). Some of the overall herd emissions need to be allocated to this meat production – but on what basis? In terms of their relative economic value? In terms of the calories or protein they supply as compared with the protein or calories supplied by the milk? Different studies adopt different approaches.

All of the data included contributes to the final LCA results. Emissions and resource use at all stages that lie within the defined scope of the LCA need to be included because they all contribute to the environmental impact of the product or service in question.

## How do we deal with the problem of allocating emissions to products?

### 1. **Avoid allocation altogether**

If possible it is preferable to avoid having to divide emissions between co-products by, for example, expanding the system boundaries to include all products produced in the system – for example by including both the milk and the meat produced in a dairy system in the functional unit. However, if the purpose of the study is to compare milk with some other beverage, emissions needs to be split between the milk and the meat.

### 2. **Substitution**

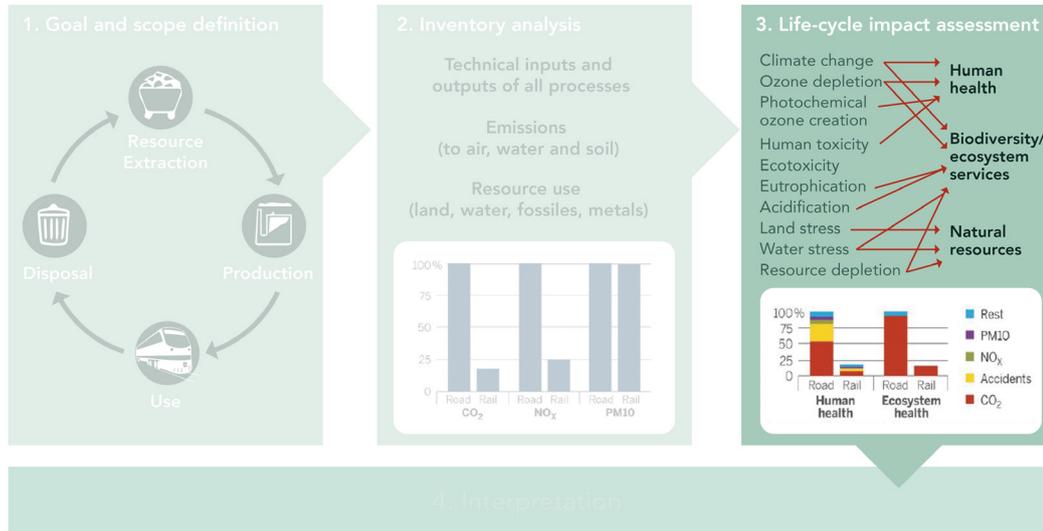
One way of handling this is to consider alternatives to the co-products on the global market based on the reasoning that when a co-product of a production system enters the market the production of some other product with the same function can be 'avoided'. For example, the beef produced in the dairy system would avoid production of other beef meat e.g. from a suckler cow system or meat from pork or poultry. The emissions from the production of milk is then calculated as the total emissions from the dairy system minus the emissions from the production of the alternative 'avoided' product, in this case the beef.

### 3. **Allocate based on physical relationships (e.g. mass or energy) or economic relationships**

Another simple way of doing this is to allocate by mass or economic value. For example, if an economic allocation method is used, then the relative economic value of the co-products is used as the basis for allocating impacts – e.g. the relative value on the market of milk and meat. The precise impacts will vary as the market prices fluctuate.

## 2.1.4 Phase 3: Assessment of impacts and allocation to indicators

### Phase 3: Impacts are assessed and allocated to indicators



**Figure 5: Phase 3 of life cycle assessment – impact assessment.**

Source: Adapted from Hellweg & Milà i Canals (2014).

The total emissions and resource use from all life cycle stages are grouped into environmental themes or categories (mid-point indicators) according to the impact they cause, and are converted to common impact units. Examples of impact categories are climate change, eutrophication potential, water use and land use. Effects that these impacts can have on humans and ecosystems may also be modelled. Results are then presented using what are called end-point indicators; these refer to broader issues of concern such as human health, biodiversity/ecosystem services. The end-point indicators are fewer in number than the mid-point indicators and therefore might be easier to interpret. However, the modelling of end-point effects is associated with great uncertainties.

The results can be shown for each different impact category, or presented in relation to particular stages in the product’s life. Thus, the water use for producing 1kg of bread can be shown for the whole life cycle and for each stage within that (such as farming, manufacture, etc.).

### LCA does not just measure greenhouse gas emissions

LCA can be used to measure many different environmental impacts, one of which is the global warming potential or greenhouse gas emissions (GHG). Other impacts include:

- Ozone layer depletion;
- Acidification;

### Ecosystem services

The tangible and intangible benefits that are provided by ecosystems to humans, which both enable human life and that contribute to its quality. Ecosystem services include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.

### Global warming potential

The ratio of the total heat energy trapped by a unit of greenhouse gas (e.g. a tonne of methane) over a specific period of time (normally 100 years), to that trapped by an equal amount of carbon dioxide over the same time period. The global warming potential (GWP) of carbon dioxide, is therefore, always one. GWP is used to compare the warming effect of different gases on a common basis. It varies according to both the type of gas and the length of time considered.

### GHGs

GHGs is an abbreviation for greenhouse gases. These include gases such as carbon dioxide, methane, and nitrous oxide, which are released as a result of human activity, and which trap heat within the earth’s atmosphere, leading to global warming.

- Eutrophication;
- Photochemical smog;
- Ecotoxicity;
- Land use; and
- Water use.

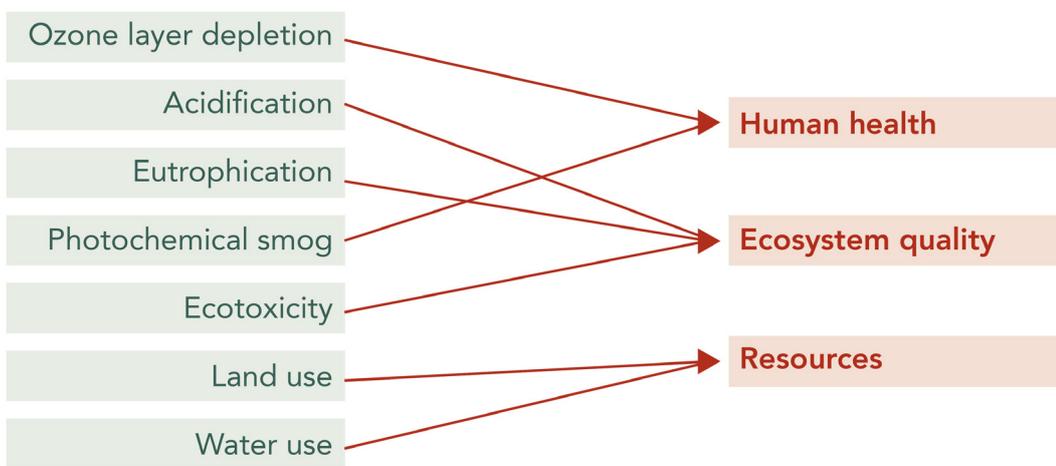
*Holistic assessment avoids burden shifting, whereby improving one metric might adversely affect another.*

Measuring more than one factor in this way means we are able to see wider environmental impacts, and can avoid unintended negative consequences from reductions in one specific impact (sometimes called “burden shifting”).

For example, if an intervention is designed to reduce global warming impact, but as a consequence this increases land-use requirements, then it is important to know this.

These impacts can be further allocated to general impact categories (related to actual physical impacts) concerning human health, ecosystem quality, climate change and resource use.

**Environmental impacts can be presented as Mid- & end-point indicators**



**Figure 6: Lifecycle assessment – mid- & end-point indicators.**

Source: FCRN. (2016).

Mid-point indicators represent impacts as specific environmental themes.

End-point indicators are categories of impact contributed to by (often multiple) mid-point indicators, representing impacts on broader issues of concern such as human health and ecosystem quality. For example, depletion of the ozone layer and increases in photochemical smog (presented as mid-point indicators) can both contribute negatively to human health; high land-use and water requirements place a burden on resources.

**Ozone layer depletion**

A decline in the level of ozone gas (O3) present in the earth’s stratosphere, owing to its breakdown into oxygen (O2). This breakdown can be affected by natural processes, but is known to have been accelerated by the release of man-made chemicals, such as refrigerant gases. The ozone layer acts to reduce the amount of light at ultra-violet wavelengths reaching the earth’s surface; wavelengths that can have harmful impacts on humans, including skin cancer.

**Ecotoxicity**

Ecotoxicity refers to the toxicology of pollutants in the environment. The study of ecotoxicology includes consideration of the interaction of pollutants both with abiotic aspects of the environment - soil, air and water; and how they interact with living systems, at the level of cell, organ, and organism to communities and ecosystems.

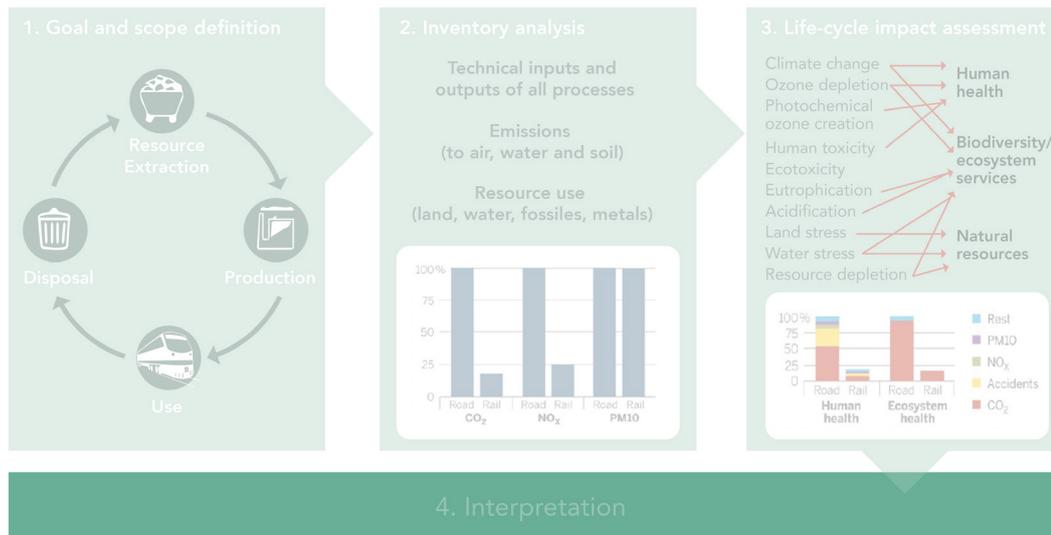
**Photochemical smog**

Photochemical smog is observed as a haze in the atmosphere, typically near to cities. It is created through the action of sunlight on pollutants (nitrogen oxides and volatile organic compounds) emitted by automobiles and other industrial sources, which creates other pollutants harmful to health, such as ozone.

Modelling end-point indicators thus allows LCA studies to communicate the real impacts on the environment from producing a product or service, in a less abstract way. However, not all LCA studies specifically take this extra step due to the difficulties in modelling end-point effects and the increased uncertainties associated with this step.

## 2.1.5 Phase 4: Interpretation of results

### The final phase is the interpretation of the results



**Figure 7: Phase 4 of life cycle assessment - interpretation of results.**

Source: Adapted from Hellweg & Milà i Canals (2014).

This can include drawing conclusions about the environmental impact of the product being studied, and identifying hotspots both in relation to life cycle stages (such as the stages that have the highest environmental impacts), impact categorisations (which environmental impacts are most of concern as a result of producing this product), or both (which stages contribute the most to the key environmental impacts).

Results are also analysed and tested to see how robust they are using sensitivity analysis and/or uncertainty analysis (i.e. use of different input data, comparison with model data, choice of system boundaries, functional units, allocation principles, etc.).

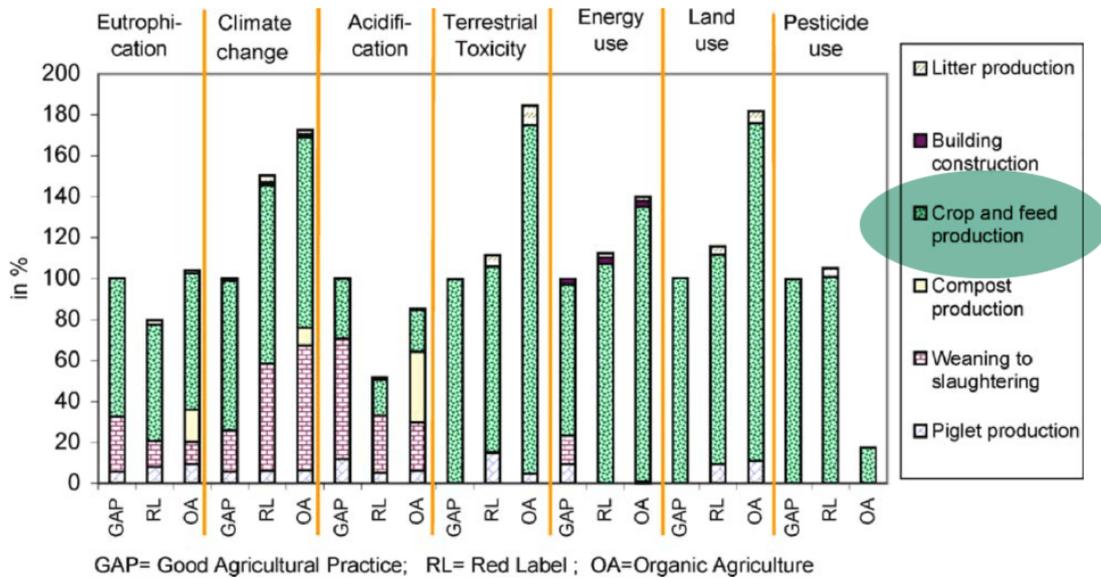
Environmental hotspots can be defined (i.e. life cycle stages with high impact) and conclusions are drawn about the overall impact of the functional unit being assessed.

Recommendations can also be made to reduce environmental impacts, based on the hotspots identified, and may be placed in the context of wider environmental challenges. For example, the GHG of a product can be put in the context of wider climate change concerns.

### System boundaries

The subjective boundaries that define what is included within the system under analysis (and so counted) and what is external to the system (and so not counted). System boundaries have multiple dimensions, including what stages are focused on (e.g. production, distribution), what inputs and outputs are measured (e.g. land, greenhouse gases), what geographic locations are included, and more.

## LCA allows us to identify environmental hotspots



**Figure 8: A comparison of environmental impacts from different pig farming systems.**

Source: Basset-Mens & van der Werf (2005).

This example illustrates the relative impacts on eutrophication, climate change, acidification, terrestrial ecotoxicity, energy use, land use and pesticide use from different pig farming systems. It is clear that the production of feed is the hotspot in all impact categories except for acidification.

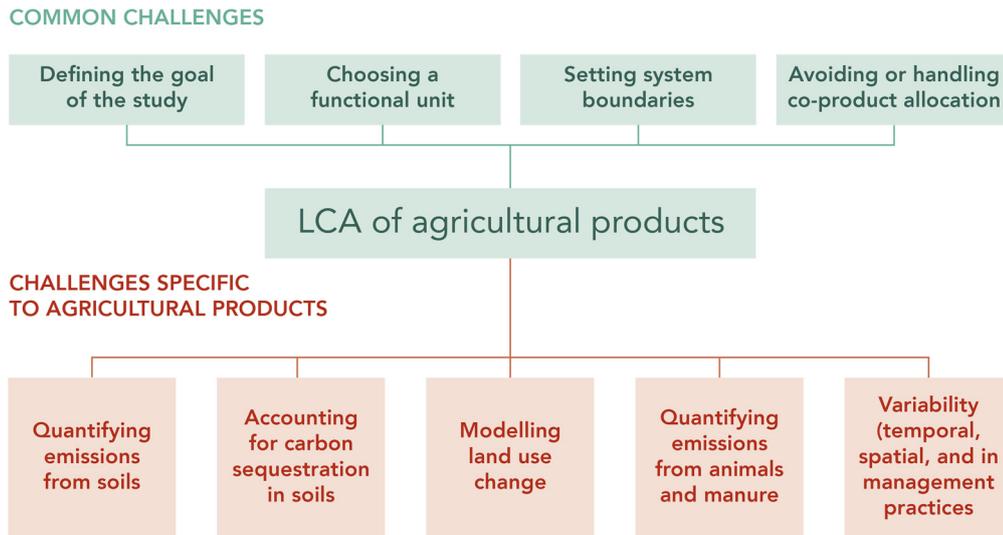
## 2.2 Lifecycle assessment of food products is a complex undertaking

All LCA research faces common challenges when defining the scope of the life cycle to be measured, what functional unit to use, how to deal with changes over time, and problems associated with allocation of shared inputs and outputs. However, the agriculture stage presents unique complexities for LCA, as defining the system boundaries is particularly difficult.

### LCA Challenges

For example, how should the emissions from deforestation of an area be allocated to the products that are grown on this land when arguably all agricultural production contributes to deforestation: even production on existing agricultural land, by preventing another crop being grown, could be seen as being indirectly responsible for 'driving' that production onto forest land?

- There may be multiple food and non-food drivers of deforestation (e.g. both cattle ranching and logging)?



**Figure 9: Challenges in lifecycle assessment of agricultural products.**

Source: FCRN and Dr Elin Rööös.

- Additionally, direct emissions are usually not easily measured; consider, for example, the difference between measuring the emissions from a factory chimney and measuring the emissions from hectares of agricultural land. Therefore, emissions usually have to be modelled rather than measured, a step which is associated with great uncertainties. Furthermore, emissions from agriculture vary widely depending on geographical location, production method, temperature, soil and rainfall patterns, and more. Generic data are therefore often used, so reducing the accuracy of the findings. To add to the complexity, soils can act as greenhouse gas sources (emissions) or sinks (absorbing emissions) and both land-use and agricultural practices can change over time.

In addition, quantifying emissions from animals (and their manure) is also difficult because of a large number of variables involved, including breed differences, quantifying methane emissions from enteric fermentation, different feeds and production systems, different impacts of different manure treatments, etc.

However, the scope of an LCA usually encompasses far more than the agricultural stages of the food supply chain, and all stages can present difficulties with respect to scope. For example, food products are processed, often refrigerated, transported and stored for different times. Food can be prepared in different ways (e.g. a carrot can be eaten raw, microwaved, boiled or roasted). The impacts associated with all these stages need to be understood and quantified.

As such, there is a considerable degree of uncertainty when measuring the environmental impacts of food.

### Enteric fermentation

Enteric fermentation is a natural part of the digestive process of ruminant animals (e.g. cattle and sheep) where microbes decompose and ferment the food present in large rumen portion of the stomach. As a byproduct of this fermentation process, some bacteria species in the stomach produce methane.

## 2.3 Carbon footprinting is based on the LCA approach but focuses only on greenhouse gas emissions

### 2.3.1 Defining terminologies

#### GHG = greenhouse gases

The IPCC provide a list of gases that contribute to global warming. The most important for food production are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), and refrigerant gases.

Expressed in terms of 20, 100 or 500 years:

Methane = 34 x more potent than CO<sub>2</sub> (over 100 year time-period)

Nitrous oxide = 298 x more potent than CO<sub>2</sub> (over 100 year time-period)

Refrigerant gases = thousands x more potent than CO<sub>2</sub>

#### IPCC

The Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. It is administered by the United Nations with participation and decision making from 195 member states. The assessments that it produces provide the basis for government at all levels to create climate related policies.

Most discussion about GHGs outside the food and agricultural sector focuses on carbon dioxide (CO<sub>2</sub>). However, there are other greenhouse gases too, such as methane and nitrous oxide, and the food system is a particularly significant source of these.

The Kyoto Protocol includes 6 main GHGs : carbon-dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF<sub>6</sub>)

Different GHGs have different potency – that is, the strength of their contribution to radiative forcing (a measure of global warming) differs.

Measured over a time-period of 100 years, the global warming potential of methane is 34 times more potent than carbon dioxide; nitrous oxide is nearly 300 times more so.

The total global warming impact of different gases can be expressed in aggregated form, known as carbon dioxide equivalent (CO<sub>2</sub> eq.). This is also referred to as the global warming potential (GWP), and when related to a specific product or service is often known as its carbon footprint (CFP). The abbreviation GHG is widely used as shorthand for either of these. There also exist other climate change metrics such as Global Temperature Potential (GTP).

## 2.3.2 GHGs arising from the food system

The most important GHGs arising from the *food system* are methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>).

*Agricultural emissions* are dominated by methane and nitrous oxide, although land-use change for agriculture is a major source of carbon dioxide emissions.

*Post-production stages* (such as food processing, transport, storage, refrigeration) give rise to notable carbon dioxide emissions, due to more significant energy and fossil-fuel use.

The food system is different from many of the sectors and activities (such as construction, heavy industry and transport) because agricultural emissions are dominated by methane and nitrous oxide. In industrial processes carbon dioxide arising from energy use tends to dominate.

This said, agriculturally induced land use change (for example deforestation, or conversion of peatlands to crop production) leads to very significant releases of carbon dioxide.

## 2.4 The value and limitations of lifecycle assessment

### 2.4.1 Values and limitations of LCA

- LCA enables a more complete and holistic understanding of the impact of food at all stages in its production.
- It allows analysts to identify stages, or practices, that generate particularly high negative impacts, and potential solutions to be identified.
- It also reveals the trade-offs that may exist across areas of environmental concern, and that difficult decisions may need to be made.
- Inconsistency in methodological choices (e.g. of functional units and system boundaries) make comparisons across studies difficult. There is, however, increasing focus on encouraging standardisation of methodologies.
- An LCA may only give an indication of the environmental impact associated with the average or industry standard production of a product – it may not give an indication of the best case outcome of a particular food product (i.e. novel production systems with vastly reduced environmental impacts may exist for a particular product, but this may or may not be taken into account in any given LCA study).
- LCA has historically focused on environmental, not social impacts, although attempts are being made to develop a methodology for social LCAs.

- LCA is a useful but incomplete tool for measuring of sustainability.
- LCA can show impacts but it doesn't necessarily tell us 'what to do.'

## 2.4.2 LCAs have historically focussed on environmental impacts

Currently, the majority of LCA studies focus on environmental impacts and do not concern themselves with social impacts.

As such, the impacts on employment, health, well-being, community benefits, and human rights are not measured or represented (although the use of end-point indicators gestures in this direction).

Introducing social and economic issues adds complexity. For example, GHG emissions arising from a certain food producing activity may be high, but may also support many people's livelihoods, have positive or negative health consequences, or represent value to communities in other ways.

LCA methodologies and standards are beginning to evolve in an attempt to incorporate measurements of social impacts into assessment.

## 2.4.3 Can LCAs determine whether something is sustainable?

- No, because LCA does not consider the number of users or needs and the broader value or importance of any given product or activity.
- LCA quantifies impacts but does not give "sustainability" thresholds (i.e. set a limit for what is an acceptable level of impact).
- LCA cannot address broader societal questions about the impacts of consumption and consumerism in society in general.

However:

- LCA results are indispensable as an aid to making assessments about sustainability.

The LCA measurement of a product is useful when comparing different products with a similar function, but in the context of sustainability, this needs to be estimated in terms of how much of the product is used in absolute terms, what the trends are in its usage, what value it has for society, and other social and ethical aspects of its production or use.

For example, if the GHG of a certain food product is very high per kg, but consumption levels are very low, then its overall impact might be lower than a product with lower GHG per kg but which is consumed in large quantities. Similarly, if a food product has a high nutritional value then this should be considered within the perspective of society's needs for nutritious healthy diets. Certain animal production systems may have higher GHG impacts than others, but the welfare of the animals raised may be better than those reared in lower GHG-impact systems.

## 2.5 Conclusions

- LCA is the most common method used for quantifying the environmental impacts and resource use throughout the entire life cycle of a product or service.
- It comprises four stages: goal and scope definition, allocations of inputs and outputs to stages of the lifecycle, assessment of impacts, and the interpretation of results.
- LCA of agricultural products is difficult and uncertain.
- Carbon footprinting is based on the LCA approach but focuses only on greenhouse gas emissions.
- LCAs have historically focussed on environmental impacts, but are increasingly incorporating societal considerations.
- LCA is an extremely useful tool but cannot by itself indicate the sustainability of a product or process.

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