Savoir faire

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Life Cycle Assessment of agri-food systems

An operational guide dedicated to developing and emerging economies

éditions Quæ

Part 2

Agri-food LCA in developing and emerging contexts

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State of the art of agri-food LCA

Despite two decades of continuous methodological, data and tool development and improvement, the practice of LCA still faces several challenges. These challenges can be classified according to the main associated limiting factors, namely: methodological bottlenecks, data and tool availability, and financial shortages. Given the iterative LCA approach, these challenges are all highly interdependent.

Methodological LCA challenges are numerous. Common ones include the choice of functional units (FUs), the delineation of system boundaries (e.g. inclusion of capital goods, end-of-life scenarios), cut-off criteria, allocation strategy, and the selection of impact categories. The LCIA methodology is generally based on linear simple models that do not properly account for complex site-specific mechanisms. The selection of impact categories thus requires a good understanding of underlying impact characterization methods and their limits regarding the system to be assessed as well as recent scientific developments.

These issues are exacerbated in agri-food LCA because results are known to be highly sensitive to methodological choices. For instance:

- For LCA of crops and livestock, the most common physical property used as FU is mass (e.g. a fixed amount of product), yet it does not capture quality attributes of agri-food products, such as their nutritional value.
- The impact of land use is also still poorly accounted for in LCA, which means trade-offs between production and land-use impacts are poorly assessed. This issue is exemplified when comparing conventional and organic cropping systems (Meier *et al.* 2015; Biermann and Geist 2019; Knudsen *et al.* 2019). The combined use of mass (e.g. 1 kg of product, protein or other substance of interest) and area units (e.g. 1 ha of agricultural land) can result in a more comprehensive assessment of contrasted systems (van der Werf *et al.* 2009; Salou *et al.* 2016).
- Another key element when studying agricultural systems is that the crop rotation must be considered for more realistic modelling of long-term amendment impacts. Current practice often includes at least the preceeding and successive crops (including intermediate crops) to the system's boundaries (van Zeijts *et al.* 1999; Koch and Salou 2016). Recent research has proposed approaches for including the full rotation and crop interactions into agricultural LCA. See for

instance Brankatschk and Finkbeiner (2015) for a review of historical approaches and Goglio *et al.* (2017) for a full-rotation method.

• The allocation of impacts among agricultural co-products (e.g. grain and straw) definitely affects results, as shown when comparing AGRIBALYSE and ecoinvent processes for straw; AGRIBALYSE v1.3 (Koch and Salou 2016) assigns zero impacts from cereal production, while ecoinvent 3.5 (Nemecek *et al.* 2011a, b) assigns part of the agricultural impacts.

Applying LCA to agri-food systems entails further challenges due to the intrinsically variable nature of systems (Notarnicola *et al.* 2017) that are impacted not only by technological drivers, like industrial systems, but also by natural mechanisms. For instance, fisheries exploit fish stocks whose state and evolution are affected by fisheries and natural weather patterns (e.g. the El Niño Southern Oscillation (Bertrand *et al.* 2020)) and biological drivers (e.g. inter-decadal abundance regime shifts) (Thatje *et al.* 2008; Ayón *et al.* 2011). Agriculture and aquaculture depend on biophysical and geo-bio-chemical mechanisms, as well as on pedoclimatic conditions. Food processing requirements (e.g. energy, chemicals, water) are largely driven by the biophysical characteristics of the raw materials, which are highly variable. Moreover, agri-food systems are generally quite sensitive to management, which can differ greatly and lead to extremely variable performances. The LCA modelling of agri-food systems, and especially the inventories, requires careful considerations of the diversity within studied systems and the numerous biophysically driven aspects.

Suitable models are needed to estimate emissions from agriculture and aquaculture. These emissions mainly consist of direct field emissions of nutrients (e.g. leaching of nitrates and phosphorus (P) and nitrogen (N) losses from agriculture; N, methane (CH_4) and P emissions from fish production systems, etc.) and pesticides, whose experimental measurement is highly resource-intensive and mostly unfeasible for time-limited or remote LCA studies. Among these models, multiple alternative approaches were developed for agricultural emissions, whereas fewer are available for aquaculture emissions (e.g. Cho and Kaushik 1990; Wang *et al.* 2012). Agriculture-oriented emission models are often aggregated into sets and described in agricultural inventory databases guidelines, such as ecoinvent (Nemecek and Schnetzer 2012), World Food LCA database (Nemecek *et al.* 2015) or AGRIBALYSE (Koch and Salou 2016). These models are “simple” ones, based on empirical equations. Other models created for non-LCA purposes are also being used for LCA. These models range from relatively simple ones, such as Indigo-N (Bockstaller and Girardin 2010; Bockstaller *et al.* 2021), to complex dynamic soil-plant/agro-ecosystem models, such as STICS (Brisson *et al.* 2003), with higher data requirements and a steep learning curve (Figure 5.1). LCA practitioners tend to use the simplest emission factors and empirical equations, such as those proposed by the Intergovernmental Panel on Climate Change (IPCC), FAO, etc. (Bouwman *et al.* 2002a, b; Roy *et al.* 2003; De Klein *et al.* 2006; Hergoualc’h *et al.* 2019).

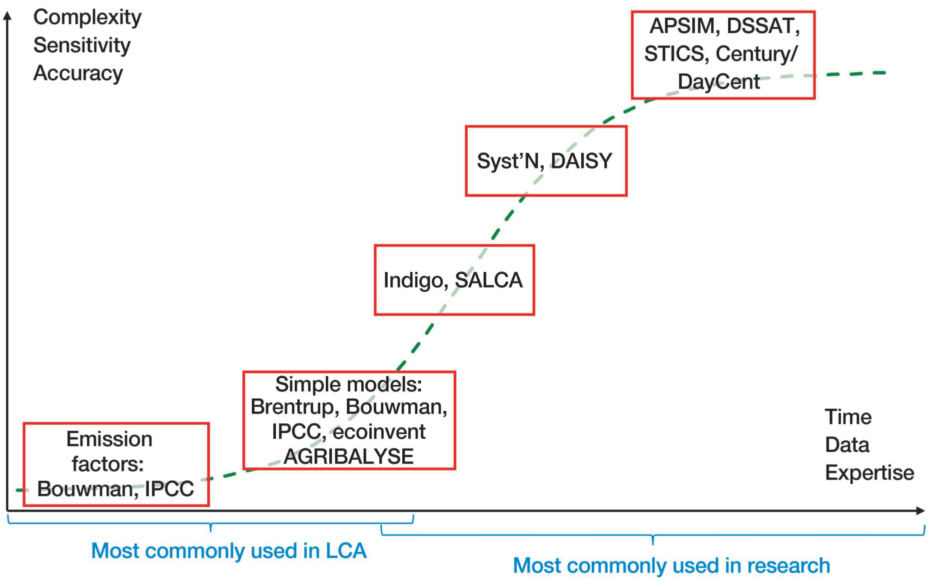

Figure 5.1. Complexity continuum of models computing direct field emissions. Source: adapted from Avadí *et al*. (2022).

Regarding the estimation of field emissions of pesticides, 100% of the applied dose is still meant to be emitted into the soil in most cases, including within the most commonly used LCI databases such as ecoinvent and WFLDB. However, as part of an international consensus-building initiative led by the Danish Technical University, new recommendations and a web-based and updated version of the PestLCI model (Birkved and Hauschild 2006; Dijkman *et al.* 2012; Fantke 2019) have been recently developed, and should enable estimating the distribution of pesticide emissions into the different environmental compartments depending on application conditions (practice, soil, climate). Additionally, the dynamiCROP model (Fantke and Jolliet 2016) can be used to estimate the fraction taken up by the harvested part of the crop and subsequent exposition and impacts on consumers. Using the PestLCI consensus webtool, Gentil-Sergent *et al.* (2021) recently provided pesticide primary emission fractions for a panel of pesticide application scenarios in tropical conditions, taking account of specific crop growth stages, foliar interception and drift curves.

Specific impact categories of great relevance for agri-food systems are still under development or their modelling lacks consensus among practitioners. These categories include land use and related considerations on modelling biogenic carbon and soil quality, water deprivation and salinization, biodiversity, and terrestrial ecotoxicity (Notarnicola *et al.* 2017).

The main challenges for agri-food LCAs are summarized in Box 5.1, Box 5.2 and Box 5.3, for agriculture, seafood, and processing, respectively.

In the specific context of seafood (i.e. fisheries and aquaculture, whether marine or not) LCA, various methodological and data limitations of LCA hinder the completeness of and comparability among studies (Avadí *et al.* 2018). These limitations have been addressed by researchers, and options are available to overcome them (Box 5.2).

Box 5.1. Challenges for agricultural LCA (A. Avadí, C. Basset-Mens, CIRAD)

Critical challenges for agricultural LCA to improve the quality and usefulness of LCA results:

- Lack of operational methods to capture the diversity of farming systems in field sampling procedures.
- Lack of consensual approaches to deal with agriculture multifunctionality (including various issues related to allocation among rotational crops, within multi-cropping systems, etc.).
- Lack of universally valid direct and indirect field emission models, for all agriculturally relevant emissions, under contrasted pedoclimatic conditions.
- Lack of suitable terrestrial ecotoxicity models.
- Lack of suitable models to account for agricultural impacts on soil quality, including biodiversity and salinization.

Box 5.2. Challenges for seafood LCA (A. Avadí, CIRAD)

Critical challenges for seafood (fisheries and aquaculture) LCA, to improve quality and usefulness of LCA results:

- Inclusion of fisheries management concerns and related impact categories (e.g. discards, by-catch, seafloor damage, biotic resource use, biomass removal impacts on the ecosystem and species).
- Data availability and data management: capture data, fuel-use data, aquafeed data, uncertainty data.
- Lack of CFs for waste emissions into the ocean, such as bilge water, lubricating oils and certain toxic molecules used in antifouling paints.
- The relation between LCA and seafood certifications. Seafood LCA guidelines were found to have either failed to include all relevant concerns or have yet to be widely applied by the industry (i.e. a consolidated set of practices is not widely applied by practitioners).

Box 5.3. Challenges for food processing LCA (T. Tran, CIRAD)

Critical challenges for food processing LCA to improve the quality and usefulness of results:

- Allocation of energy, water and chemical expenditures among interconnected and/or partially overlapping industrial processes within a factory producing multiple products.
- Limited background data for packaging materials. Such data are often required to model tin and aluminium cans, glass and plastic containers, woven plastic fabric/bags, etc. in the foreground.
- Flows of both input materials or energy, and by-products are often not monitored, especially waste water and solid by-products with no residual economic value; hence the difficulties for quantitative estimation of these flows. This is particularly true and critical for artisanal food processing chains that can be very diversified and based on “local recipes”.
- Trade secrets can make factory managers reluctant to share data on their operations. Sometimes, concerns may be addressed by anonymizing or averaging data.
- In the case of small-scale factories, how do practitioners estimate the number of factories to survey to reach a representative sample?

For proposed solutions to overcome these challenges, see Chapter 9 "Building life cycle inventories" and Avadí and Vázquez-Rowe (2019a, b). These challenges are further analysed in the following sections in relation to developing contexts.

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Specific challenges for agri-food LCA in developing and emerging contexts

All the general challenges described for the LCA of agri-food systems are even more critical in developing and emerging contexts. Three main constraints cover most critical challenges:

- a great diversity of production systems with little reliable data;
- highly specific natural contexts with little data, knowledge and tools for informing the inventory and impact assessment phases (especially for tropical systems);
- stakeholders' varying awareness and capacities in relation to the environment and environmental assessment.

Diversity of agri-food systems due to specific natural conditions and combined socio-economic constraints

As described in Chapter 1 (section "Most developing and emerging countries are located in the tropical zone"), highly diversified agri-food systems still co-exist in tropical developing and emerging countries. Their levels of complexity and performance may be subdivided in three mainstream groups, although not exclusively and with great variability levels across and within groups:

- traditional production systems based on small family farms, often partially for household consumption and "organic" by default;
- input-intensive production systems based on large farms and often dedicated to export;
- urban and peri-urban production systems to feed ever-expanding cities, operating in highly constrained conditions with a generally excessive and inappropriate use of chemical and organic inputs.

In terms of LCA modelling, tropical contexts generate specific issues. Most existing direct emission models used in LCA were calibrated for field conditions of crops growing in temperate environments (practices, soil characteristics, temperature, rainfall, etc.). Hence, their validity domain pertains to the conditions for which they were initially calibrated. It is notably true for the Swiss model suite SALCA

(Swiss Agricultural LCA) used in ecoinvent, which encompasses the modelling of all primary field emissions, e.g. nitrogen, phosphorus and trace element emissions, while relying on field data collected in Switzerland only. Other commonly used empirical models for nitrogen and carbon compounds are the IPCC guidelines (IPCC 2006, Volume 4, Chapter 11). These guidelines are regularly updated to account for state of the art. For instance, in the latest version (IPCC 2019), models from Stehfest and Bouwman (2006) or Cardinael *et al.* (2018) were updated. But the coverage of tropical conditions in the background datasets is still limited (Bouwman *et al.* 2002c). Existing direct field emission models were not designed – or calibrated – to properly consider specific tropical conditions nor developing and emerging contexts, i.e. the pedoclimatic conditions or the substantial variability in practices (e.g. the high diversity of field inputs, agroforestry systems, etc.) (Table 6.1, more details in Appendix B p. 122). This issue was also recently demonstrated for pesticide emission models by Gentil *et al.* (2019) and for N emission models by Avadí *et al.* (2022). Other process-based models exist, such as APSIM (Holzworth *et al.* 2018), STICS (Brisson *et al.* 2003) and combinations of models (Constantin *et al.* 2015; Lammoglia *et al.* 2017), that make it possible to calibrate the models to very specific site conditions. However, calibrating process-based models requires specific expertise and extensive datasets. Moreover, such models are not available for all cropping systems, nor can all process-based models model the field emissions in a mechanistic way.

The same limitations apply to impact assessment models which are either too generic or valid only for temperate conditions. For instance, Gentil *et al.* (2019) highlighted in their review the lack of validity of ecotoxicity data for tropical species that show a specific sensitivity to the exposure to pollutants. Avadí *et al.* (2022) demonstrated that direct field nitrogen emissions modelling is to date not well adapted to tropical conditions, organic fertilization, or short-cycle crops such as market vegetables.

Data gaps on the systems to be characterized

Agri-food systems in developing and emerging countries are somewhat represented in LCA literature, especially field crop commodities exported worldwide, but on a limited scope compared with more industrialized agri-food systems. Aquaculture in developing and emerging countries focuses, for instance, on different species than those raised in developed ones, and different types of systems are used. The aquaculture systems and species in developing and emerging contexts, despite representing the bulk of global production (FAO 2016, 2018a, 2020a), are much less represented in LCA literature than systems and species exploited in industrialized countries. A similar situation applies to fisheries, where the vast majority of fisheries modelled with LCA are found in industrialized countries or operated by international firms (Avadí *et al.* 2018).

Table 6.1. Comparison of simple direct emission models for nitrogen (N) losses and their applicability to contrasted agricultural conditions.

Model / model set	**Applicability to different pedoclimatic conditions**	**Applicability to different crops**	**Applicability to organic fertilization**	**Remarks**	**Main reference**
IPCC guidelines for national GHG inventories	Global	Tier 1: Default emission factors for flooded rice fields; temperate, tropical and boreal crop and grassland soils	Tier 1: Default emission factors for animal effluents and crop residues	Direct and indirect N_2O emissions from crop production, livestock and agricultural soils. Emission factors and regression equations based on literature estimates. Other emissions considered: CO_2 and CH_4.	(IPCC 2019)
EMEP/EEA emission inventory guidebook	Global	Default emission factors for permanent and arable land crops, rice fields, market gardening, grassland and fallows	Default emission factors for animal effluents	Direct NH_3 and NO emissions from crop production, livestock and agricultural soils. Emission factors and regression equations based on literature estimates. Other emissions considered: NMVOC and PM.	(EMEP/CORINAIR 2006; EMEP/EEA 2009, 2013, 2016, 2019)
Indigo-N v2	France, Europe (i.e. temperate)	Field crops and prairies	Default emission factors for certain organic fertilizers	Direct NH_3, N_2O and NO_3 emissions from crop production. Emission factors and empiric equations.	(Bockstaller and Girardin 2010)
Indigo-N v3	Global	Field crops, vegetables, prairies	Consideration of the modes of action of organic fertilizers	Emission factors combined with correction factors for gaseous emissions; novel formalism for nitrate emissions (based on drainage balance periods).	(Bockstaller *et al.* 2021)
SALCA-NO3	Europe (i.e. temperate)	Field crops, vegetables, prairies	Default emission factors for animal effluents	Direct NO_3 emissions from crop production and manure management.	(Richner *et al.* 2014)
Ecoinvent v3	Switzerland, Europe, in principle global	Field crops	Default emission factors for manure and sugarcane vinasse	Direct NH_3, N_2O, NO_3 and NOx emissions from crop production and manure management. Integrates SALCA-Nitrate, SQCB-NO3 (Faist Emmenegger *et al.* 2009), AGRAMMON (https://agrammon.ch/en/) and IPCC.	(Nemecek and Schnetzer 2012)
World Food LCA Database v3	Global (main exporting countries)	Field crops and prairies	N/A	Very similar to ecoinvent v3.	(Nemecek *et al.* 2015, 2020)

N_2O: nitrous oxide; NH_3: ammonia; NOx: nitrogen oxides; NMVOC: Non-methane volatile organic compounds; PM: Particulate matter; SQCB: Sustainability quick check for biofuels.

Moreover, in developing and emerging contexts, public databases are not as systematic as in industrialized countries. Therefore, data on agricultural activities and production systems are not exhaustively available, or not available at all[4]. Depending on the country, the administrative resources at governmental level, the political stability and the decentralization level, databases may be more or less complete, reliable or accessible. The reasons are multiple, but a common limiting factor is the level and regularity of public funding for data collection. When funds are intermittent, production data may be estimated instead of measured (based on expected or theoretical yields, which are usually overly optimistic), or collected at different subnational levels with varying levels of detail and accuracy (Box 6.1). Furthermore, required data is often not publicly available, but it may be accessible upon request (in person, and accompanied by a suitable reference/introduction) at specific government offices. It is almost always impossible to have access to complete and reliable agricultural databases without acting in situ and having the right local contacts.

Visits within the country to institutional offices, farmers' associations and field operators (those in charge of production and processing), are critical to identify where data is available and how representative it is according to LCA data quality criteria (technologically, temporally and geographically).

Box 6.1. Availability and quality of statistical data in developing and emerging countries (A. Avadí, CIRAD)

In developing and emerging countries as different as Ecuador (agriculture), Peru (wild caught anchovy), Zambia (farmed tilapia), Côte d'Ivoire and Benin (vegetable market gardening), it has been observed that:

- Subnational statistics were very detailed in some cases and very basic in others.
- The national central statistics office combined data differing in quality and age, and database documentation was sometimes incomplete.
- Government officers declared lacking the funding for detailed and regular data collection.
- Some data were not combined or published.
- Due to political reasons, some data stopped being published or were even removed from public websites.

This is especially crucial since the lack of systematic databases may also hide a huge diversity in production systems which complicates data collection. In many developing and emerging contexts, specific and variable soil and climate conditions combined with diverse socio-economic contexts have led to an extreme diversification of production systems. In developing and emerging countries, this was probably exacerbated in many situations by the lack of means to massively

4. There are notable exceptions, such as that of Ecuador, where very detailed agricultural data at the farm and parcel level are publicly available and anually updated by the Ministry of Agriculture: https://www.ecuadorencifras.gob.ec/estadisticas-agropecuarias-2/

invest in inputs and machinery, paving the way to more original and diversified management practices.

Another situation, affecting certain developing and emerging economies, is the doctoring of production statistics. With fisheries, for instance, certain countries including China and Myanmar are believed to under- or over-report catches (Pauly and Zeller 2017).

Moreover, informal trade is not included in official statistical systems. The informal economy is known to be dynamic and easily adapt to market variations (Benjamin *et al.* 2014). According to the World Bank, the informal economy represents the majority of economic activity and employment in least developed countries. In (lower and upper) middle income countries, even if the existence of an informal economy is known, determining its size and assessing it is difficult. National experts often consider that micro and small informal businesses belong to a small sector that evolves or disappears when demand decreases. However, in some examples such as Colombian milk, despite more than half of it still being produced by informal farmers, this product represents around 25% of the agricultural gross domestic product (GDP) (Vega 2018). This reality affects LCA studies, since specific sectors are only partially represented if only official statistical data are considered. The operations of these informal producers might also be different due to small investment capacity.

The World Bank has developed a database on informality, estimating the proportion of the informal economy per country (http://www.enterprisesurveys.org/data/exploreTopics/Informality). This resource should nonetheless be used with caution, just as an estimation, as the agricultural sector features specific issues regarding informality (e.g. informality in the rural sector, family businesses).

Varying awareness and capacities of stakeholders

In contexts were security and food security can be high priorities, stakeholders and the population rarely have the same level of awareness about environmental issues. Although life cycle thinking has spread throughout the world since its early development in the 1980s, there is still a gap among world regions in terms of LCA capacity building and applications. Particularly in developing countries, in areas where capacity building resources are limited, few stakeholders are aware of the methods and even fewer are able to apply LCA. To tackle this issue and enable the global use of credible life cycle knowledge by private and public decision-makers, the UN Environment Life Cycle Initiative has been implementing a roadmap with quantified targets towards 2022. Among those targets, providing capacity building worldwide and a solution to access all interoperable LCA databases are milestones being pursued through collaboration platforms in Africa, Asia, and Latin America. Under the Life Cycle Initiative, ecoinvent leads a project[5] that aims to establish national LCI databases in several developing and emerging countries.

The varying awareness regarding LCA objectives and challenges may be exacerbated in countries where life cycle thinking is not widespread, and LCA not extensively applied. A diverse range of stakeholders may be involved in an LCA study, and can be classified according to four groups (sometimes overlapping): commissioners and decision-makers, stakeholders directly involved in the agri-food system, facilitators who may or may not be directly involved in the agri-food system, and experts carrying out the LCA of the agri-food system. Both LCA knowledge and interest in LCA results may vary considerably across these stakeholder groups, although they are tightly connected for LCA application. Likewise, knowledge and expectations can vary greatly among stakeholders within each of these groups. The greatest challenge for a commissioned LCA study thus lies in managing multiple expectations, which may be conflicting (Box 6.2).

Box 6.2. When key players of the agri-food system boycott the LCA study (C. Basset-Mens, CIRAD)

As part of an LCA study for fresh French beans produced in Kenya for the EU market and commissioned by the European Union's Directorate-General for International Cooperation and Development (DG-DEVCO, now the department for International Partnerships), certain key industry stakeholders had refused to meet the LCA and local experts or collaborate in data collection. The reason given was that EU was not legitimate nor welcome to come and control the fresh French bean value chain after fifty years of high regulatory and sanitary constraints leading to major perceived difficulties by the value chain operators and farmers. Often, such tensions can be relieved by face-to-face efforts to explain the work and diplomacy supported by local experts. However in this particular case, despite all the talent and effort of the local expert to convince them, these stakeholders did not accept to be part of the study, which had implications on the representativeness of the data collected for the study and its final results.

On one hand, LCA practitioners are usually well aware of the data needs of the LCI, the existing LCIA methods, and the overall potential and limits of LCA when interpreting the results. On the other hand, some commissioners may be

5. Development of National LCA Database Roadmaps and further development of the Technical Helpdesk for National LCA Databases (https://www.lifecycleinitiative.org/call-for-proposals-development-of-national-lca-database-roadmaps/).

too demanding or overly optimistic in terms of conclusions and applicability of LCA results. In particular, means in terms of funds, work force or time allocated by the commissioners may not be appropriate to carry out the LCA in satisfactory conditions. Stakeholders directly involved in the agri-food system or the facilitators may play a key role in enabling access to data. It is thus critical to know what their roles and expectations are to anticipate how these factors may affect data quality (see Chapter 8 section "Critical analysis of the demand, constraints and avoidance strategies").

7
Established and emerging initiatives

Several initiatives have emerged to overcome LCA challenges in developing and emerging contexts. In Asia, Africa and Latin America, networks of major producers of primary resources (i.e. commodities such as minerals, cotton or soya) are being structured by local (e.g. national environmental organizations such as Fundación Chile (https://fch.cl/en/)) and external (e.g. international development organizations such as UN Environment) stakeholders (Quispe *et al.* 2016).

Worldwide, several initiatives and networks are emerging to support the life cycle thinking approach (local, regional and global). We have attempted to identify the known existing LCA networks based on available sources (scientific and grey literature, online research and LCA forum discussion list). Bjørn *et al.* (2013) identified around a hundred initiatives among which 29 were considered as networks. The authors mapped and characterized these networks according to their structure and activities. Global initiatives and communities also record regional, national and other LCA networks, for instance (https://www.lifecycleinitiative.org/networks/life-cycle-networks/) and the Forum for Sustainability (https://fslci.org/regional-networks/).

As of April 2021, we found nine international and regional initiatives and 32 national networks or platforms (Table 7.1). At least eight websites were no longer available or appear inactive while other initiatives were just emerging. The detailed list of networks is available in Appendix C (p. 126). The stability and permanence of those national networks seems to be inconstant. In further work, it would be interesting to understand the main challenges they faced and to update the list at least annually.

Scientific publications are correlated to the formation of LCA networks and their continental distribution. A vast majority of networks are located in Europe and the United States, but some operate in Africa, the Middle East and Central Asia. In those regions, non-governmental organizations (NGOs) are more represented in these networks than in developed countries. In developing and emerging contexts, major actors in LCA networks are academia and industry, with a varying presence of government authorities and NGOs. LCA networks are context dependent. Out of six networks in developing and emerging economies, few work with LCA software and communicate through websites, but when compared with networks based in developed economies, they host more conferences and open seminars, thus raising awareness (e.g. the biannual CILCA conference, organized by the pan-Latin American Red Iberoamericana de Ciclo de Vida (https://redi-beroamericanadeciclodevida.wordpress.com/).

Table 7.1. Networks, platforms and initiatives identified by regions and sub-regions.

LCA network/platform type	Geographical scope	Initiatives by region/countries
International	Global	3
Continental networks	Africa	1*
	Asia	1*
	Europe	2*
	LAC	1
	North America	1
National networks or platforms by continent	Africa	1 (Uganda)**
	Asia	7 (China, India, Indonesia, Japan, Korea Malaysia Thailand)
	Europe	14 (Denmark, Estonia*, Finland, France (3), Germany*, Hungary, Italy, Poland*, Spain*, Switzerland, Turkey, UK)
	America	6 (Argentina, Brazil, Chili*, Colombia*, Ecuador, Mexico, Peru, US)
	Oceania	2 (Australia, New Zealand)

*website inactive or not fully accessible; **no website available.

Africa remains the region with the least representation in networks. The only regional network was the now inactive ALCANET initiative (Ramjeawon *et al.* 2005). Although the African networks are not very visible on the internet, they may still continue to emerge, such as the Uganda network created in 2018. Nonetheless, LCA is not a common research tool among the African research community (Box 7.1).

There are national LCI database initiatives, especially from developed and emerging countries outside Europe and North America, which could inspire developing countries to build their own. For instance, IDEA is a process-based Japanese database (http://idea-lca.com/?lang=en), AusLCI is the Australian National LCI database (http://www.auslci.com.au/), and emerging economies such as China, Brazil, Peru and Thailand are continuously building their national LCI databases. In December 2020, ecoinvent released the version 3.7.1 of its database (updated as 3.8 in 2021), which includes many seafood and agriculture (crops and livestock) inventories from developing and emerging countries. However, there is a significant time lag between the release dates of the latest version of the database, its implementation in reference LCA software (often six months to a year later), and its standard use by the practitioner community: in the first half of 2021, many scientific LCA publications are based on ecoinvent versions 3.5 or 3.6, published in 2018 and 2019, respectively. Curated lists of LCI data, both free and fee-based, are available through the Global LCA Data Access (GLAD) network (https://www.globallcadataaccess.org/) and openLCA Nexus (https://nexus.openlca.org/databases).

Box 7.1. LCA in Africa (A. Avadí, C. Basset-Mens, CIRAD)

The reasons for the lack of penetration of LCA in Africa are multiple. Among them, capacity building limitations by universities and experts as for disseminating the concepts and language of LCA play a major role, together with LCA's traditional focus on the product-service, which evolved from a context of overconsumption and which is not necessarily valid in Africa (Ramjeawon *et al.* 2005). Moreover, almost no LCA background data is available for African contexts, while in the specific field of agri-food, direct field emission models adapted to tropical conditions are lacking; this further hinders the development of LCA on the continent. In a recent review, Karkour *et al.* (2021) found around 200 papers on LCA in Africa among which agriculture appeared as the sector receiving the most attention, with 53 articles (predominantly commissioned by non-African institutions). The number of articles related to LCA have increased in recent years. However, the coverage of LCA studies among African countries is highly uneven, with South Africa (Brent *et al.* 2002), Egypt and Tunisia being where most of the research was conducted. The authors highlighted remaining challenges for LCA in Africa, such as the need to establish a specific LCI database for African countries or a targeted valid LCIA method. A recent and ongoing programme by the European Commission's department for International Partnerships is performing sustainability assessments (including LCA for the environmental dimension) of several agri-food supply chains in developing and emerging regions, including some located in Africa: the Value Chain Analysis for Development – VCA4D programme (https://europa.eu/capacity4dev/value-chain-analysis-for-development-vca4d-).

National and regional initiatives are spreading and provide a breeding ground for new LCA studies in the tropics and emerging contexts. There should be mutual interests in contributing to and benefiting from such networks and databases, notably when preparing an LCA study from an office rather than in the field or when helping to disseminate the final results. Conducting an LCA study abroad is quite challenging and local or neighbouring networks may be very useful to avoid pitfalls and better plan for the fieldwork.

Facing challenges in conducting agricultural LCA in tropical and emerging contexts requires a good understanding of local issues and available solutions. In the next chapters, we provide detailed guidelines from designing the study to communicating the final results to harness the most useful information from any agricultural LCA conducted in the tropics and/or emerging contexts.