

How to choose the functional unit for agricultural LCA? A stakeholder-centered conceptual framework

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ABSTRACT

A key methodological challenge in using Life Cycle Assessment (LCA) for agricultural decision support is the definition of the system's function and functional unit (FU). In complex, multifunctional agricultural systems, this choice is often ambiguous and can significantly alter study outcomes, complicating the comparability and interpretation of results and posing a challenge for decision-making. To situate this problem, we first present a focused review of 34 recent LCA studies, which confirms the diversity of current practices and underscores the need for a more structured selection approach. In response to this identified gap, this paper develops a conceptual framework for selecting appropriate FUs. The framework includes a taxonomy that classifies agricultural functions according to key stakeholder perspectives: the consumer (product function), the producer (income function), and society (land management function). Building on this classification and the challenges highlighted by the literature review, we introduce five evaluative criteria: completeness, proportionality, specificity, stability, and accessibility. These criteria are designed to guide researchers and practitioners in selecting and justifying FUs that align with specific decision contexts. By shifting the focus from a single "correct" FU to a context-appropriate one, our framework provides a robust and transparent methodology to enhance the relevance and utility of LCA in supporting sustainable agriculture.

1. Introduction

Life Cycle Assessment (LCA) is a standardized and widely recognized method for quantifying the environmental impacts of products and systems (Thoma et al., 2022; Dijkman et al., 2018; Fan et al., 2022). For environmental assessment in agriculture, it is officially recommended by institutions like the EU Commission (Commission, 2021) and frequently used to compare production systems to support decision-making (Sala et al., 2023). Such *comparative LCAs* aim to provide a fair assessment by applying the same methodology to all considered options, whether they are existing systems or prospective future scenarios. While many methodological choices (such as system boundaries or allocation methods) affect an LCA's outcome (Laurent et al., 2020), the definition of the system's function and its quantification as a functional unit (FU) is arguably the most pivotal and challenging choice (Salou et al., 2017). A seemingly objective comparison can yield substantially different recommendations by changing the FU (Ross et al., 2017). For example, in comparisons of organic and conventional farming, organic systems often show lower environmental impacts per hectare (a land management FU) but higher impacts per kilogram of product (a product FU) due to differences in yield. This makes the FU a powerful,

value-laden parameter that bridges the technical assessment with the real-world decision context (Pérez et al., 2024). Yet, its selection is often a source of confusion and debate, posing a challenge for the credibility and adoption of LCA in agricultural decision support (Notarnicola et al., 2017).

1.1. Function and functional unit

The function (or "performance characteristic" (International Organization for Standardization, 2006)) defines what the system is for. It can be understood as the reason why one runs (and thus excepts environmental impacts from) the system in the first place. The functional unit (FU) is a way to quantify this function and is primarily used as a quantitative reference for the environmental impacts. All environmental impacts are reported relative to the FU. According to the ILCD Handbook, a key guidance document, the FU should be defined in terms of "what", "how much", "how well", and "for how long" a function is delivered, ensuring that comparisons are made on a fair and equivalent basis (Joint Research Centre - Institute for Environment and Sustainability and European Commission, 2010). It is important to

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distinguish the FU from the reference flow, which is the amount of product output required to fulfill the function (e.g., 1.05 kg of apples at farm gate to fulfill the function of “1 kg of apples delivered to consumer,” accounting for 5% loss). While technically distinct, in many attributional LCAs at the farm gate, the FU (e.g., “1 kg of harvested wheat”) and the reference flow are functionally identical.

Especially in the domain of agriculture, the function definition is challenging. Agricultural systems are inherently multifunctional. According to Nemecek et al. (2005), there are four functions (or groups of functions): On the one hand, the original purpose of agriculture is to produce various agricultural goods such as food, feed, fuel, fiber, etc. (productive function), often quantified by FUs like “1 kg of grain” or “1 MJ of bioenergy”. On the other hand, agriculture is supposed to fulfill a range of societal functions beyond mere production, including preservation of soil fertility and maintenance of valued cultural landscapes. Nemecek et al. (2005) combine these aspects in a “land management function”, which can be quantified as “1 hectare of land managed for 1 year”. Not least, agriculture functions as a source of income for farmers and agricultural workers (financial function), which could be represented by “1€ of net profit”. The fourth function (ecological function) is not a candidate for the FU, as it represents the results of the LCA itself (e.g., impacts on biodiversity or carbon sequestration), not the system’s purpose (Nemecek et al., 2005). If the production of a good or service is identified as the (primary) function of a production system, presence of multiple co-products can be dealt with using *allocation*. This way, the overall environmental burden is distributed over the co-products following an allocation method.

1.2. Comparative LCA and decision support

LCA studies are conducted for a variety of purposes, most notably the communication of environmental impacts to stakeholders (e.g. in Environmental Product Declarations (Del Borghi, 2013)), and the comparison of production systems for the sake of supporting decisions (Schaubroeck, 2023). For the latter, *comparative LCAs* are commonly used, in which the lifecycle impacts of two or more systems (or just their differences) are assessed, often to recommend one over the other. Independently made LCAs often lack comparability (Roßmann et al., 2021) due to subtle differences in methodological choices, such as scope, functional unit, allocation, background data (Kalverkamp and Karbe, 2019), or impact assessment method. Thus, comparative LCAs explicitly aim for fair comparisons by applying the exact same methods to all considered systems. In the context of agricultural management and policy decisions, LCA can be used prospectively to model environmental impacts in future scenarios (Lulovicova and Bouissou, 2024).

Amid the growing complexity of modern agriculture, the effective translation of scientific insights into actionable decisions is crucial for ensuring sustainable and efficient food production. A diverse array of decision support mechanisms has emerged to bridge the gap between scientific knowledge and agricultural practice. These range from extension services providing tailored advice to individual farmers to the deployment of sophisticated prediction models for weather (Luu et al., 2024), crop yields (Liman Harou et al., 2021; Javed and Murad, 2024), and pest risk (Kopton et al., 2025). Furthermore, scientific evidence underpins critical policy decisions that shape agriculture (Bonnen, 1987), as well as the development and adoption of new technologies that can influence productivity and environmental performance (Hoenen et al., 2018). Especially in the developing context, expert-informed quantitative models to support individual decisions have been increasingly adopted (Luedeling and Shepherd, 2016). In all these contexts, including environmental considerations into the decision-making process has always been challenging. In the early days of organic farming, spiritual and esoteric aspects were regarded higher than quantifiable environmental impacts (Paull, 2019). But even today, other indicators (such as “naturalness” (Verhoog et al., 2007)) are often used as proxies

for environmental impact in decision making processes (Purnhagen et al., 2021). LCA can contribute significantly to a more detailed and objective consideration of environmental concerns in decision-making processes (Borghino et al., 2021). However, to effectively use LCA results for decision support, it is crucial that the methodological choices fit to the decision in question, as defined in the study’s goal and scope. In particular, the perspective represented by the function definition needs to align with the perspective of the decision-maker and relevant stakeholders.

Although several studies justify the use of certain FUs in specific agricultural contexts, the literature remains fragmented, and a systematic overview of the current state of the art is still lacking. This paper directly addresses this gap by developing a framework to guide the FU selection process. Our objectives are to: (1) conduct a targeted review of current FU practices in complex, multifunctional agricultural LCAs; (2) propose a stakeholder-centered taxonomy to classify agricultural functions; and (3) develop a set of evaluative criteria to help researchers and practitioners select and justify the most appropriate FU for their specific decision context.

2. The state of practice: A targeted review of functional unit application

2.1. Review methodology

To ground our conceptual framework in current scientific practice and to demonstrate the need for a more structured approach, we performed a targeted literature analysis. This analysis was not intended as an exhaustive systematic review, but rather as a focused effort to map out how FUs are currently being used in LCAs of complex and multifunctional agricultural systems. The methodology was guided by the PRISMA framework (Page et al., 2021) to ensure transparency. In September 2023, we conducted a structured search in the Web of Science database. In order to map out FU challenges and innovations, we specifically focused on multifunctional agricultural systems incorporating various land-use practices such as crop rotation, intercropping, mixed cropping, agroforestry, and agrivoltaics. We focused on these systems because they present the most complex and ambiguous challenges for FU definition, often involving multiple products, services, and stakeholder interests, thus providing the richest ground for analyzing current practices. While we acknowledge that a vast body of literature exists on LCA in conventional monoculture systems, in those system the alignment of decision context and FU is often more straightforward, typically centering around a single product function. By concentrating on multifunctional systems, we aimed to capture the full spectrum of methodological approaches and challenges associated with FU selection in agricultural LCA. The specific search string designed to capture relevant studies on LCA in such multifunctional agricultural systems used was:

“life cycle assessment” OR “lifecycle assessment” OR “LCA”) AND (“multifunctional” AND “agricultur”) OR “crop rotation” OR “intercropping” OR “mixed cropping” OR “agroforest*”) OR “agrivoltaic*”*

This search yielded 291 results. For the acronym “LCA” we ensured that it referred to “life cycle assessment” by checking the context in the title and abstract. We restricted the search to peer-reviewed journal articles, conference proceedings, and book chapters published in English. We included studies that applied LCA methodologies to multifunctional agricultural systems, assessed the environmental impacts of at least one of the specified agricultural practices, and provided transparent methodological details and results. Conversely, we excluded studies that focused solely on conventional monoculture systems without multifunctional components, lacked sufficient methodological transparency for reproducibility, or were review papers without original LCA findings. Furthermore, we excluded social LCA and consequential LCA studies, since both methodologies do not use FUs in the sense of classic attributional LCA (for social LCA see e.g. Manik

(2021) assume that both systems considered in their study produce exactly the same combination of products, thus providing a rare example of a multi-component FU (“412,596 MWh and 7200 rabbits”). As they compare integrated production with separate production of their two products, they can satisfy this assumption by scaling the separate production components accordingly. Wiloso et al. (2015) used a multifunctional mass-based FU, namely “crude palm oil + palm kernel oil + palm kernel cake”. In some cases, the issue of multiple production functions was solved using allocation. Arzoumanidis et al. (2019) used economic allocation to account for both honey production and pollination service. González-García et al. (2023) and Morandini et al. (2020) used economic allocation to separate grain from straw and other crops in the crop rotation.

2.4. Other functions

In ten studies, the land management function was included via area-based FUs in addition to the production function. Ding et al. (2023) use area · time as an FU for the LCA part of their study, but embed it in a multiobjective optimization. The objective function of this optimization problem was composed of two environmental impact categories from the lifecycle impact assessment plus four product objectives. This way, the production function was not included as a quantitative reference (calculating the eco-efficiency), but as a separate goal. This approach acknowledges the area constraints of the Belgian region considered in the study, while for scalable production systems, LCA has also been integrated into multi-objective optimization with product-based FUs (Kopton et al., 2023).

3. A stakeholder-based taxonomy of functions

Our quantitative and qualitative review findings (Sections 2.2–2.4) demonstrate the significant diversity in how FUs are applied in multifunctional agricultural LCAs. Studies variously employ mass, energy, monetary value, or area, often combining them or using allocation to solve for multiple products. This methodological variety is not arbitrary; it highlights a fundamental challenge rooted in the fact that agricultural systems are inherently multifunctional, serving different purposes for different groups of people. While other industrial sectors like clothing are also multifunctional (providing protection, fashion, group identity, etc.), agriculture is uniquely complex due to its intrinsic link to land use. This creates a direct tension between the productive, financial, and societal function, the last of which is often legally mandated (e.g., via farm subsidies).

To structure this complexity, we propose a taxonomy that classifies these functions according to the primary stakeholder perspective they represent (see Fig. 2). This taxonomy was developed through a synthesis of the practical examples identified in our targeted literature review (Section 2) and broader theoretical considerations from LCA practice. Our review of 34 studies provided the empirical basis, revealing the range of FUs currently employed (e.g., mass, area, economic value). We then structured this empirical evidence by mapping these FUs to the different purposes and stakeholder interests they serve, drawing from established concepts in agricultural and LCA science. This approach allows us to classify the diverse functions based on the stakeholder groups whose primary interests they reflect.

We identify three core stakeholder archetypes whose perspectives give rise to three distinct categories of functions: the consumer, the producer, and society at large (see Fig. 2). While these roles can overlap in reality, distinguishing their primary interests helps to clarify the purpose of an LCA and justify the choice of an FU.

From the perspective of the consumer, the principal function of agriculture is the production of goods such as food, feed, fiber, or fuel. This *product function* is the most traditionally recognized purpose of farming. The most straightforward FU from this perspective is the mass or volume of the final product (e.g., 1 kg of apples or 1 liter of

milk). However, simple mass often fails to capture crucial differences in product quality or composition. Consequently, more specific FUs are sometimes used, such as the total energy content of biofuels, the mass of specific nutrients like protein, or composite nutritional indicators. For products where quality is paramount, such as different grades of fruit, an economic value (e.g., 1€ of revenue) can be used as a proxy to integrate both quantity and quality into a single metric, as demonstrated in studies by Cerutti et al. (2013) and Hokazono and Hayashi (2015).

For the producer acting as an economic agent, the primary function of the agricultural enterprise is to generate income. While related to the product function, the *income function* is distinct because it is concerned with economic viability, not just physical output. From this viewpoint, the most relevant function is the financial profitability of the operation. This is best represented by FUs based on net economic returns, such as gross profit or gross margin, which accounts for production costs. These functional units are demonstrated in studies like Nemecek et al. (2015) and Lago-Oliveira et al. (2023). Using the total revenue or monetary value of the product (as in the consumer perspective) is not strictly a reflection of the producer perspective since it does not account for the costs incurred by the producer to create it. While sharing certain challenges and benefits, “financial” or “monetary” FUs can thus be used to quantify two different functions, namely the value of the products (product function) and the economic profitability of the farm (income function).

Beyond providing products and income, society expects agriculture to fulfill a range of other services related to its use of land. The *land management function* captures the societal interest in maintaining valued cultural landscapes, preserving soil fertility, and providing ecosystem services. This perspective is particularly relevant in policy-making and regional planning, such as in the EU’s Common Agricultural Policy, which explicitly pays farmers for the provision of such public goods. The function of managing land is most commonly quantified using an area-based FU combined with a time dimension (e.g., “per hectare and year”). This approach allows for the assessment of environmental impacts relative to the land area occupied, making it suitable for evaluating land-use efficiency and the provision of area-dependent public goods.

3.1. Land sparing/land sharing

In addition to the representation of different stakeholder groups, the choice of an FU reflects a fundamental tension in agricultural policy that maps directly onto the long-standing land sparing versus land sharing debate (Fischer et al., 2014). The land sparing model aligns with the consumer and producer perspectives, which prioritize the product function and income function, respectively. This viewpoint argues for maximizing output through agricultural intensification on the smallest possible land footprint, thereby “sparing” other land for nature conservation. Consequently, comparative LCA studies using product-based FUs (e.g., impact per kilogram of grain or per dollar of profit) inherently favor intensive systems that are highly efficient in converting inputs into a specific output. For example, Smith et al. (2019) show for England and Wales that producing the same amount of products in a more extensive way would drastically increase land use and carbon footprint. Conversely, the land sharing model resonates with the societal perspective, emphasizing the land management function. This approach advocates for more extensive farming systems that integrate food production with the provision of other ecosystem services, like biodiversity conservation, within the same agricultural landscape. When an LCA employs an area-based FU (e.g., impact per hectare per year), it naturally values systems with lower environmental pressure on the land they occupy, thus favoring extensification.

Some authors (such as van der Werf et al. (2020)) and advocacy groups (IFOAM, 2021) even directly advocate for deliberately choosing LCA methods that produce favorable results for organic farming

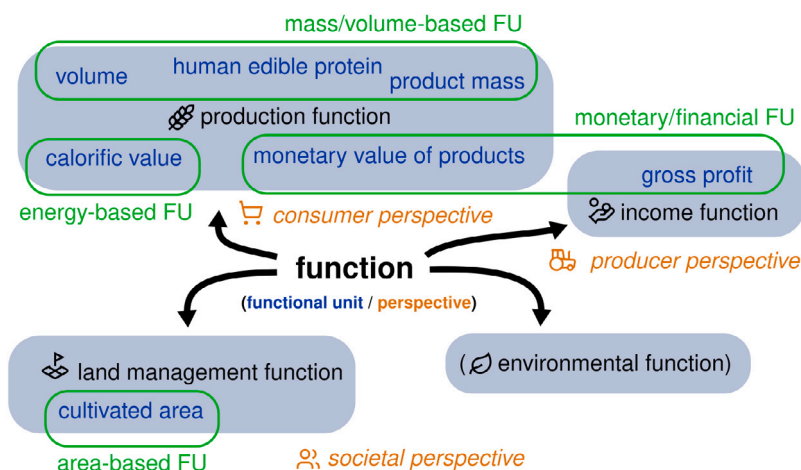


Fig. 2. Taxonomy of functions (black), functional units (blue) and the respective perspectives (orange) for agricultural systems. FUs can be based on different types of units, which are outlined in green.

to promote their adoption. This highlights how FU selection can be embedded in broader political goals, moving it from a purely technical choice to a strategic one. All in all, the selection of an FU can prefigure an LCA’s outcome within this debate, underscoring that the choice is a value-laden decision rather than a purely objective one.

4. Criteria for evaluating functional units

To address the challenges identified in theory (Sections 1 and 3) and practice (Section 2), a structured approach is needed. Based on our analysis, we developed five criteria to guide the selection of an FU. These criteria are synthesized from recurring methodological themes in the LCA literature and the practical challenges observed in our review. Some of these criteria were explicitly addressed in the methods sections of individual reviewed LCA studies, while we inferred others that were implicitly used to make certain FU choices. To our knowledge, criteria like these have not been systematically compiled into a coherent framework specifically for agricultural LCA.

The goal is not to find a single, universally “correct” FU, but to select one that is most appropriate for a specific decision context, as defined in the study’s goal and scope. We propose five criteria for evaluating and justifying the choice of an FU: *completeness*, *proportionality*, *specificity*, *stability*, and *accessibility* (see Table 1). These criteria are designed to make the selection process more transparent and to align the technical aspects of the LCA with the real-world needs of decision-makers.

As a first criterion we propose *Completeness*. We consider an FU or set of FUs *complete* if the perspectives of all key stakeholders relevant to the study’s goal are included. An incomplete FU risks ignoring a critical aspect of the system’s performance. For example, an assessment for regional policy-making that uses only a mass-based FU (the consumer perspective) would be incomplete because it ignores the societal perspective on land management. On the other hand, when making a management decision for an agricultural production system, using only an area-based FU would disregard the perspective of the consumer and the producer. If an LCA’s goal is explicitly limited to a single stakeholder (e.g., a consumer-facing product declaration), a single FU representing that perspective may be “complete” relative to that goal. The criterion becomes crucial when a mismatch exists between the stated goal and the broader decision-making context. As an example of an FU that was explicitly designed for completeness, Wiloso et al. (2015) used a multifunction FU (“crude palm oil + palm kernel oil + palm kernel cake”) for the assessment of an oil palm system.

Proportionality as a second criterion describes whether the FU represents all included functions according to their relative importance

with respect to the decision. As such, *Proportionality* can be seen as an extension to *Completeness*, but focuses on the relative weighting of the included functions rather than their mere presence. An FU lacking *proportionality* may treat different functions as equally important, even when they are not. For example, for the consumer’s perspective on wheat farming, using a mass-based FU of “1 kg total biomass” to cover both grains and straw would be *disproportionate*, since consumers value the edible grains far higher than the residual straw. Economic FUs can improve proportionality by capturing quality differences, as demonstrated by Cerutti et al. (2013) in their use of economic value to account for different apple grades. A non-economic example would be using a composite nutritional index (Chen et al., 2021), which is more proportional to the “food function” than simple mass.

As a third criterion, we suggest *Specificity*. We consider an FU lacking *specificity* if there are unrelated other decision options that outperform the considered ones when using this FU. With *unspecific* FUs, the results are very sensitive to the selection of decision options. In contrast, *specific* FUs allow for more open decision questions. As an example, using only unspecific profits as an FU for assessing different agroforestry options would invite the comparison to completely different ways of generating profits (e.g., manufacturing) which could have lower environmental impacts per dollar than any kind of agroforestry or even any kind of farming. The more specific FU “1 kg cocoa” would allow for the more open decision framing “what is the most sustainable way to produce cocoa?”. Another example for an *unspecific* FU would be “per hectare and year” for a decision about different crop varieties, since this FU would invite comparisons to non-agricultural land uses (e.g., reforestation) that could have lower impacts per hectare than any crop production. For this reason, Zaher et al. (2013) explicitly limit the decision options to various levels of tillage for the same production systems. A lack of specificity in the environmental assessment of banking portfolios could lead to banks excluding the impact-heavy agricultural sector altogether, instead of funding a transition towards more environmentally sustainable farming practices.

A fourth criterion *Stability* describes how sensitive the LCA results are to disturbances from outside the considered production system. For example, area-based FUs can be considered *stable* as they are insensitive to the growing or market conditions in a certain year. Mass-based FUs can lead to the effect of the environmental footprint depending on the yield and therefore weather conditions of a given season. This can make LCA results (and thus decision recommendations) more dynamic. Using monetary FUs makes the results contingent on the economic context, which depends even more sensitively on time and geographical location. If, e.g., the price of wheat is high in a given season, the impact per dollar is low. While this volatility can be managed (e.g., using

Table 1
Overview of the five criteria for evaluating functional units.

| Criterion | Question it answers | Favorable example | Unfavorable example |
|-----------------|---|--|---|
| Completeness | Are all stakeholder perspectives relevant to the goal included? | Using both “per kg” and “per ha” for a policy decision | Using only “per ha” to assess a new crop variety for farmers (omits product function) |
| Proportionality | Does the FU reflect the relative value of the included outputs? | Using nutritional index for different food crops. | Using “kg of total biomass” for wheat (values 1 kg grain = 1 kg straw) |
| Specificity | Is the function precise enough to avoid irrelevant comparisons? | “1 kg of cocoa” | “1€ of profit” (invites comparison to non-agricultural sectors) |
| Stability | Are results robust against external (e.g., market, weather) fluctuations? | “per hectare” (insensitive to yield/price) | “per € of revenue” (highly sensitive to market prices) |
| Accessibility | Is the result easy for the target audience to understand? | “per kg of apples” | “per unit of aggregated nutritional yield” (complex for consumers) |

multi-year averages), it represents a methodological burden and can be unhelpful if the goal is to assess a system’s structural impacts, not its performance in a specific year. Hokazono and Hayashi (2015) acknowledged the instability of their FU by observing that using a monetary FU instead of a mass-based FU changed the recommendation for organic paddy systems due to price premiums, making the results dependent on a specific economic context.

As a fifth criterion, we propose *Accessibility* to express how easily the LCA results can be communicated to and considered by stakeholders and decision-makers. If, e.g., the targeted decision-makers are consumers in a supermarket, complex FUs like “total nitrogen content” (Bernas et al., 2021) or even “412,596 MWh and 7200 rabbits” (Pascaris et al., 2021) could confuse the decision-makers and thus hinder the consideration of environmental impacts into the decision-making process. Dianawati et al. (2023) use “kg of dark chocolate bar” as an FU, which would be highly accessible even for consumers unfamiliar with LCA methodology.

The application of these criteria is a process of navigating trade-offs. Improving an FU on one criterion may weaken it on another (e.g., a “nutritional index” is more proportional but less accessible than “per kg”). Therefore, the optimal FU (or set of FUs) is the one that strikes the most appropriate balance for a given decision context. LCA practitioners should use these criteria to transparently justify their choices, explicitly stating which aspects they chose to prioritize and why, thereby strengthening the credibility and relevance of their findings.

Handling these trade-offs becomes particularly challenging when stakeholders disagree on the relative importance of the criteria. For example, a producer (prioritizing the income function) may favor a profit FU, while a policy-maker (societal view) may favor a per hectare FU. Our framework does not resolve this conflict, but rather illuminates it. By using the criteria, an LCA practitioner can (a) acknowledge the conflict, (b) present results using multiple FUs (one for each key stakeholder), and (c) transparently justify why one FU was chosen as primary, based on the study’s specific goal. To further improve the comparability of LCA results, we suggest that standardization bodies explore the potential of the proposed criteria for harmonizing FU definitions in future regulations and guidelines.

These five proposed criteria offer a structured framework for evaluating the appropriateness of FUs in LCA-based decision support within complex agricultural systems. Each criterion addresses a distinct yet interconnected aspect of how FUs shape the relevance, robustness, and communicability of LCA results for diverse stakeholders. By applying these criteria systematically, researchers and practitioners can

better align LCA methodology with the specific informational needs of decision-makers, thus enhancing the credibility and utility of sustainability assessments in agriculture.

5. Conclusion

This paper has argued that the persistent challenge of functional unit selection in agricultural LCA stems from the inherent multifunctionality of agricultural systems and the diverse perspectives of stakeholders. Instead of seeking a single, universal solution, we have proposed a conceptual framework to guide a more transparent and context-specific selection process. Our primary contribution is a stakeholder-based classification of functions (production, income, and land management) and a set of five criteria: completeness, proportionality, specificity, stability, and accessibility. This framework moves the discussion beyond a simple technical choice to a structured, justifiable decision that explicitly considers the goals of the assessment and the needs of the decision-maker. The focused literature review serves to illustrate the problem’s relevance, showing that while many studies grapple with these choices, a systematic approach is lacking. Our framework addresses this gap. By applying the proposed criteria, researchers and practitioners can better navigate the trade-offs inherent in any FU choice.

This analysis has focused on attributional LCA, where the FU is a central methodological choice for normalization. A promising avenue for future research is to explore how this framework can be adapted to other industries (such as manufacturing or energy) to understand how stakeholder perspectives relate to function definition in those sectors. While the specific stakeholder archetypes (consumer, producer, society) are tailored to agriculture’s land-based nature, the underlying principle of linking function to stakeholder perspective is likely transferable. However, other sectors would require a bespoke taxonomy of functions and may face different challenges, such as defining the function of intangible services. Further work could also explore the framework’s applicability to consequential or social LCA.

Ultimately, the goal of comparative LCA in agriculture is to provide credible, relevant, and accessible environmental impact information to better support decisions. The credibility of LCA results depends heavily on the justification of its core methodological choices. Our conceptual framework provides the language and structure to build this justification for FUs, enhancing the role of LCA as a trusted tool for farmers, policymakers, and other stakeholders. For agricultural science to effectively guide the transition towards sustainability, it needs methodologies that are not only scientifically sound but also robustly tailored to the complex realities of decision-making. We believe this work is a significant step in that direction.

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CRedit authorship contribution statement

Johannes Kopton: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Amelie Michalke:** Writing – review & editing, Resources, Methodology, Data curation, Conceptualization. **Katja Schiffrs:** Writing – review & editing, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.cesys.2025.100389>.

Data availability

No data was used for the research described in the article.

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