

# SCORELCA

STUDY NO. 2022-02

## LAND USE IN LCA: INDICATORS AND CONSIDERATION OF LAND RESOURCES

SUMMARY

November 2023

### Scientific managers

Bernard DE CAEVEL - RDC Environment  
Johan LHOTELLIER - RDC Environment  
Josquin VANDEPUTTE - RDC Environment



The SCORE LCA association is a study and research structure dedicated to work on Life Cycle Assessment (LCA) and environmental quantification. Its aim is to promote and organize collaboration between companies, institutions, and scientists, to encourage the shared and recognized development, at European and international levels, of the Life Cycle Assessment method and its practical application.

- ✓ This work was supported by ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie). [www.ademe.fr](http://www.ademe.fr)
- ✓ The views and recommendations expressed in this document are those of the authors and, unless otherwise stated, do not necessarily reflect the opinion of the entire SCORE LCA membership.
- ✓ The information and conclusions presented in this document are based on scientific and technical data and on the regulatory and standards framework in force at the time the documents were published.

**CONTENTS** (paginated)

1	Introduction.....	4
1.1	Study objectives.....	4
1.2	Scope of study.....	4
2	Clarification of theoretical concepts.....	5
3	Part A - State of the art of land use indicators in LCA.....	6
3.1	Inventory of methods and models.....	6
3.2	Analysis of inventory data.....	6
3.3	Cross-analysis of characterization models and life cycle inventories.....	9
3.4	Indirect land use change.....	9
4	Part B - Applying the LANCA model.....	10
4.1	Case studies.....	10
4.2	Recommendations.....	11
5	Part C - Taking land resources into account.....	11
5.1	Zero Net Artificialization regulations.....	11
5.2	Sharing impacts between several users of the same floor.....	11
5.3	Consideration of soil carbon storage/removal.....	12
5.4	Occupation strategies to limit land degradation.....	12
5.5	Difference between LCA and non-LCA models.....	13
6	General decision-making flowchart.....	13
7	Conclusions.....	13

# 1 Introduction

Land use is a major environmental issue, as it has an impact on:

- **Biodiversity** above and below ground, through modification of species' direct environment and fragmentation of spaces that limit the renewal of populations.
- **Climate change** through the storage/unstorage of carbon contained in above-ground biomass (deforestation by combustion) and carbon contained in soils.
- **Ecosystem services** provided by land, such as agricultural and forestry production, water purification or the limitation of physical risks (landslides, flooding) through land's contribution to the water cycle.

Today's LCA tools only consider certain impacts of land use on the environment and are often complex for practitioners to use. Results therefore vary significantly depending on whether the selected method measures the impact on biodiversity, or the amount of soil organic matter lost, and on the data inventory selected. In addition, the interpretation of impacts measured by the different methods is often difficult for LCA practitioners.

## 1.1 Study objectives

The six objectives of this study are to :

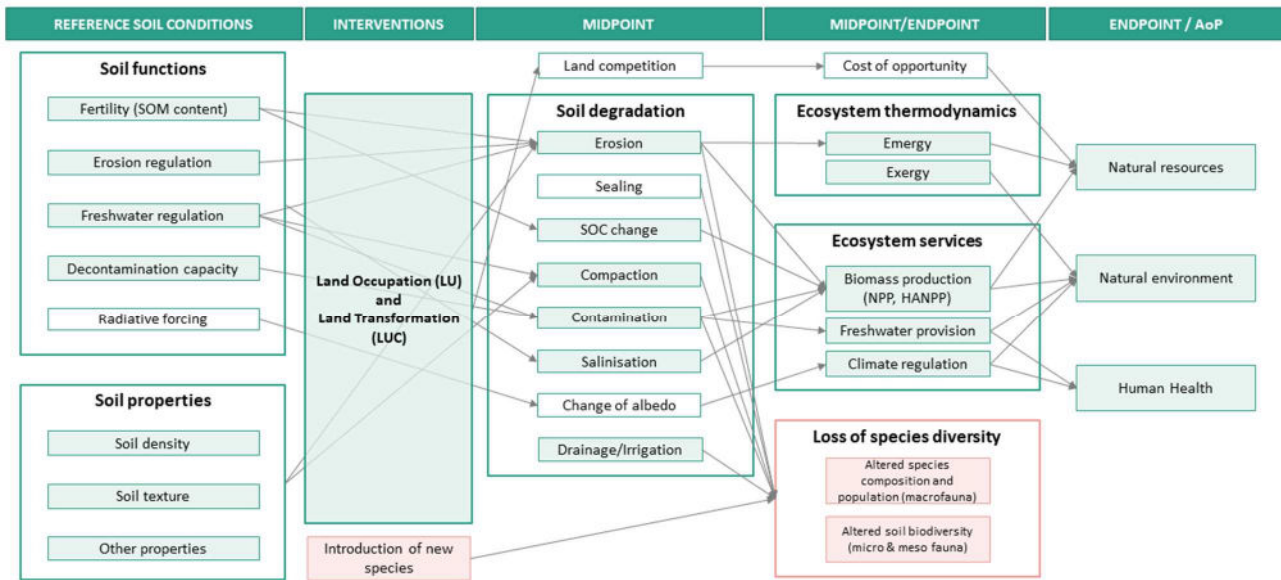
- Clarify **theoretical concepts** related to land use in LCA.
- Establish a state of the art of **indicators** for taking land use into account in LCA.
- Carry out a **critical analysis** after a selection of these indicators, evaluate their applicability and current use.
- Conduct **two case studies** using the new LANCA method recommended by the European Commission.
- Consider the **management of land resources by companies** and the methods for taking them into account in LCA.
- Formulate **recommendations** in the form of a practical guide on the choice, use and interpretation of indicators, and on the allocation of the impact of different land uses.

## 1.2 Scope of study

In LCA, the distinction between the quantity of land used (in units of surface area) and the way in which the land is used is crucial. There are two types of land use:

1. **Land occupation**, representing the amount of surface occupied over a given period
2. **Land transformation**, representing the quantity of land transformed from one type to another

To visualize the multiple consequences of these types of land use, an in-depth **cause-and-effect chain** for this study is presented in Figure 1. This illustrates the complexity of land use management issues, and the fact that some issues are not yet considered in the literature (represented by unfilled boxes).



Inspired from Sala et al. (2019) and Souza et al. (2015)  
The filled-in boxes are covered by the models in the literature.

Figure 1 - Chain of cause and effect for land use, inspired by Sala et al. (2019)<sup>1</sup> and Souza et al. (2015)<sup>2</sup>

## 2 Clarification of theoretical concepts

The first part (Chapter 2) of this study clarifies the theoretical concepts related to land use in the logical order of the cause-effect chain presented in Figure 1. Different **soil functionalities** (properties, services, and functions) and the correlations between them are defined (section 2.1). In short, human use of land modifies its properties, which in turn affects its functions, with consequent impacts on the services it provides. By way of illustration, land use can make it denser (property), and therefore less permeable (function), which degrades its capacity to recharge groundwater (service).

Next, after explaining the **LCA terminology** used (section 2.2) and, in particular, the difference between a characterization method (e.g. EF3.0) and a characterization model (e.g. LANCA), as well as between an impact category (e.g. land use) and an indicator (e.g. erosion resistance), the methodological integration of land use in LCA is explored in greater depth.

Once the elementary flows of occupation and transformation have been defined, the **modelling of land use in LCA**, as presented in Figure 2 is explained (section 2.3). In short, we measure the quality of a soil function that varies over time according to the phases of land transformation, occupation, and relaxation. The impact of land use is measured by the area of the trapezoid formed by the three phases. A reference quality ( $Q_{ref}$ ) must therefore be defined for the soil in question, which depends on geographical characteristics and influences the relaxation time ( $t_{rel}$ ) from the transformed state to its initial natural state.

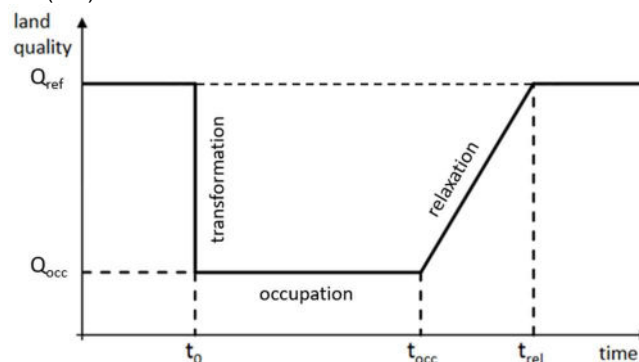


Figure 2 Impact levels in LCA (Koellner, de Baan, et al. 2013)<sup>3</sup>

<sup>1</sup> Sala, Serenella, Lorenzo Benini, Valentina Castellani, and Beatriz Vidal. *Suggestions for the update of the Environmental Footprint Life Cycle Impact Assessment - Impacts due to resource use, water use, land use, and particulate matter*. Joint Research Centre of the European Commission, Publications Office of the European Union, 2019.

<sup>2</sup> Souza, Danielle M., Ricardo FM Teixeira, and Ole P. Ostermann. "Assessing biodiversity loss due to land use with Life Cycle Assessment: are we there yet?." *Global change biology* 21.1 (2015): 32-47.

<sup>3</sup> Koellner, Thomas, et al. "UNEP-SETAC guideline on global land use impact." *The International Journal of Life Cycle Assessment*, 2013: 18:1188-1202.

## 3 Part A - State of the art of land use indicators in LCA

### 3.1 Inventory of methods and models

The state of the art of methods and models for taking land use into account in LCA has been based on literature, with the aim of exhaustiveness in identification (chapter 3.1).

A total of eighteen characterization methods (including EF3.0) have been identified as considering the impacts of land use. These methods use characterization factors (CF) derived from characterization models, themselves published in the form of scientific articles. More than fifty scientific articles are identified, analyzed, and classified according to their applicability or not in LCA and according to their focus on impacts on biodiversity or on ecosystem services.

From this inventory, five models are selected for in-depth analysis based on the following prioritization hierarchy (chapter 3.2):

1. Models focused on ecosystem services and applied by the main LCA tools.
2. Biodiversity-focused models applied by the main LCA tools.
3. Models focused on ecosystem services and not applied by the main LCA tools.
4. Other models.

The **five models selected** based on these selection criteria are as follows:

1. SOC (Brandão et al., 2013)<sup>4</sup>
2. LANCA (De Laurentiis et al., 2019)<sup>5</sup>
3. ReCiPe2016 (Huijbregts et al., 2017)<sup>6</sup>
4. SAR (Chaudhary et al., 2015)<sup>7</sup>
5. IPCC2013

**In-depth analysis** of these five models (chapters 3.3 to 3.7) consists of:

- A description of the basic principles of the model.
- A description of the indicators.
- A presentation of the temporal evolution of the model and other related scientific publications.
- A presentation of the methodology used to calculate the published characterization factors.
- A conclusion on the advantages and limitations of the model.

All these elements are grouped together in Table 1. This is the basis for a **comparison** between the models (chapter 3.8), following which two models seem to stand out from the rest. On the one hand, the LANCA model stands out for its focus on ecosystem services through four different indicators. On the other hand, the SAR model focuses on biodiversity, with an assessment of endpoint damages. Given these differences, a complementary approach using both models is recommended for a more comprehensive characterization of land use impacts.

### 3.2 Analysis of inventory data

After presenting the characterization models that publish their own characterization factors, life cycle inventory (LCI) data are analyzed in depth (section 3.9).

All inventory data has three characteristics that determine the accuracy of the results: granulometry, regionalization and the nomenclature of the associated database (DB). The elementary flows associated with a data item have a **granulometry** defined based on four characteristics:

1. Common name for land use (*e.g., forest, pasture...*)
2. Land status (*e.g., primary, or secondary forest...*)
3. Land management (*e.g., irrigated / non-irrigated crops, etc.*)
4. Intensity of land use (*e.g., intensive (nitrogen inputs), extensive (no inputs, organic)...*)

<sup>4</sup> Brandão, Miguel, and Llorenç Milà i Canals. "Global characterisation factors to assess land use impacts on biotic production." *The International Journal of Life Cycle Assessment* volume 18 (2013): 1243-1252.

<sup>5</sup> De Laurentiis, Valeria, Michela Secchi, Ulrike Bos, Rafael Horn, Alexis Laurent, and Serenella Sala. "Oil quality index: Exploring options for a comprehensive assessment of land use impacts in LCA." *Journal of Cleaner Production* 215 (2019): 63-74.

<sup>6</sup> Huijbregts, M.A.J., et al. *ReCiPe2016 v1.1: a harmonised life cycle impact assessment method at midpoint and endpoint level*. Handbook, Bilthoven, the Netherlands: National Institute for Public Health and the environment, 2017, 138-147.

<sup>7</sup> Chaudhary, Abhishek, Francesca Verones, Laura de Baan, and Stefanie Hellweg. "Quantifying Land Use Impacts on Biodiversity: Combining Species-Area Models and Vulnerability Indicators." *Environmental Science & Technology*, 2015: 49:9987-9995.

In addition, inventory data can be **regionalized** to a certain extent. Depending on the level of precision adopted by the DB, data can be differentiated at the level of ecoregions, biotic areas (or biomes), countries or continents. Finally, each DB has its own **nomenclature**, representing the data format that enables LCA software and a DB to communicate with each other.

To illustrate these three characteristics, a specific analysis is conducted on the quality of inventory data available in current DB for processes related to land use: Ecoinvent (version 3.9.1) and Agribalyse (version 3.01). The aim is to analyze the nomenclature, granulometry and regionalization available in these DBs, and to conclude with recommendations for choosing and using a DB.

A total of thirteen inventory data from Ecoinvent for various sectors (agriculture, mining, construction, etc.) and four data from Agribalyse are examined in depth. The analysis focuses on the elementary flows of data occupation and transformation. In particular, the difference between elementary transformation flows "to" and "from" is explained, as are the so-called "unspecified" flows.

The **recommendations** arising from this analysis of inventory data quality are as follows:

- The issues highlighted by the database used must be known by the LCA practitioner.
- Description and regionalization must correspond as closely as possible to what is to be modeled.
- The granulometry of the process must be sufficiently detailed and the associated value must differ from other similar processes while remaining within the same order of magnitude.
- If the elementary flows "to" and "from" cancel each other out (*i.e.*, of the same granulometry and associated with the same values), it must be mentioned that the transformation impacts associated with the process are not considered.
- The presence of "unspecified" elementary flows in a process should be mentioned as a limitation of the model.

**Table 1 - Summary of the five in-depth models**

	<b>1. SOC</b>	<b>2. LANCA</b>	<b>3. ReCiPe2016</b>	<b>4. SAR</b>	<b>5. IPCC2013</b>
<b>Indicator(s) evaluated</b>	Soil organic carbon (kg C.years)	Erosion resistance Mechanical groundwater filtering capacity Groundwater recharge capacity Biotic (biological) production potential	Relative species richness	Number of species lost	Carbon from land transformation Methane from land transformation
<b>Method scope</b>	Occupation Transformation	Occupation Transformation	Occupation Transformation Relaxation	Occupation Transformation	Transformation
<b>Impact level</b>	Midpoint	Midpoint	Midpoint Endpoint	Endpoint	Midpoint
<b>CF particle size distribution</b>	Level 1-3 (Type and management of land use)	Level 1-4 (114 different FC)	Level 1 (5 types of use) 6 species groups	Level 1 (6 types of use) 4 species groups	NA
<b>CF regionalization</b>	Climatic regions (10) Mondial	Ecological zones (20) National Mondial	No	Ecoregions (804) National	NA
<b>Reference situation</b>	PNV <sup>8</sup> by biome Previous anthropogenic use	PNV <sup>8</sup> by ecological zone, then by country (5 stages)	Grassland vegetation or forest vegetation	Grassland vegetation or forest vegetation	NA
<b>Relaxation time</b>	20 years ( <i>from any surface to any PNV<sup>8</sup></i> )	85 years ( <i>from artificial surfaces</i> ) 20 years ( <i>from other types of surfaces</i> )	73.5 years ( <i>to a forest</i> ) 7.5 years ( <i>towards grassland vegetation</i> )	73.5 years ( <i>to a forest</i> ) 7.5 years ( <i>towards grassland vegetation</i> )	NA

<sup>8</sup> PNV = Potential Natural Vegetation. Represents the estimated state of the land in the absence of any human intervention, also known as the reference (semi-)natural state. In general, each ecoregion/biome (natural mix of forests, meadows, lakes, rivers, etc.) is linked to a (semi-)natural state, defined by the model used.

### 3.3 Cross-analysis of characterization models and life cycle inventories

Each elemental flux and each characterization factor have their own specific granulometry and regionalization. There is no dependency between one and the other. In other words, it is not because a model has an exceptionally fine granulometry and/or regionalization that it produces fully accurate results.

The accuracy of the results associated with land use impacts depends on three actors, as shown in Figure 3 (section 3.10). Firstly, the **producers of the characterization model** publish CF with a certain granularity and regionalization. These include the LANCA or SAR model developers introduced earlier. Secondly, the **producers of the inventory data** publish Life Cycle Inventories (LCI) with a certain granularity and regionalization independent of that of the CF. Thirdly, **LCA software publishers** implement the CF from the characterization models according to the software's specifications (notably with the nomenclature) and couple them with data from the database selected by the practitioner to calculate, *in fine*, the impacts linked to the land use of an activity.

The accuracy of the results therefore depends on the quality of this correspondence between the implementation of CF in the software and the granulometry and regionalization of the inventory data. The least precise actor limits the final accuracy of the calculated impacts.

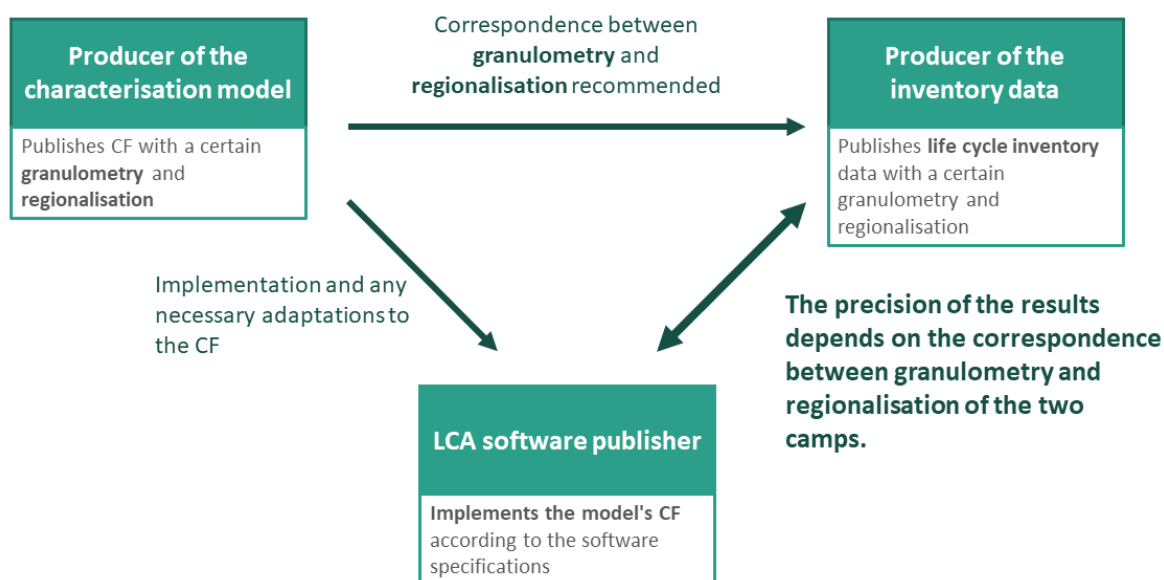


Figure 3 - The different players involved in determining the accuracy of final LCA results

Finally, the limited accuracy of results is illustrated through an in-depth comparison between characterization models (*i.e.*, SOC, LANCA, ReCiPe2016 and SAR) and databases (*i.e.*, Ecoinvent and Agribalyse).

### 3.4 Indirect land use change

Land use characterization models used in LCA focus on the impacts of one type of land use on another (e.g., the impact of land artificialization on infiltration capacity or biotic production capacity). This is known as "direct land use change" (dLUC), and covers impacts on biodiversity and/or ecosystem services that are restricted to the land used.

However, the allocation of land for a certain use can also have indirect impacts on other lands, in other countries and/or over a period that is different from the time of land use. This introduces the concept of **indirect land use change (iLUC)**.

These indirect impacts can be measured by iLUC characterization models publishing factors for diverse types of land use based on the economic phenomena associated with land use. In summary, this study recommends that indirect effects associated with land use should always be considered, particularly in the agricultural and forestry sectors (section 3.11). Economic models are available to calculate these impacts, but results vary widely depending on the assumptions made by the model.

## 4 Part B - Applying the LANCA model

Of all the models presented in the previous sections, the LANCA model - developed by (De Laurentiis, et al. 2019)<sup>5</sup> - is the only one recommended by the European Commission for calculating the environmental impacts of land use.

Part B answers the following questions (Chapter 4):

- How to apply the LANCA model?
- How to interpret results expressed in Points?
- What are the strengths and limitations of the LANCA model?
- What are the recommendations for using the LANCA model?

### 4.1 Case studies

To answer the above questions, the LANCA model is applied to **two case studies**:

1. Biofuel production from rapeseed (section 4.1).
2. Logging for wood energy (section 4.2).

These case studies do not consist of a complete LCA, but of an analysis of elementary flows and results characterized by LANCA to answer the questions listed above. The analysis approach is as follows:

1. Definition of the functional unit.
2. Defining the boundaries of the system under study.
3. Choice of input inventory data.
4. Analysis of elementary data flows associated with land use.
5. Analysis of impacts calculated by the LANCA model.
6. Decomposition of the LANCA aggregate score and four sub-indicators.
7. Comparison of results with other similar processes.

The **decomposition of the SQI** (Soil Quality Index) is particularly detailed in this study, as the interpretation of the SQI, expressed in Points, is difficult for LCA practitioners. It is more meaningful to see which indicator(s) contribute most to the single score for the same type of land use. So, to illustrate the contributions to the four indicators considered in the SQI, a waterfall diagram is shown in Figure 4. These four indicators are added together to form the final SQI. Indicators with a favorable and unfavorable impact on the environment are shown in green and red, respectively. The total SQI is shown in grey. We can conclude that the process in question is particularly unfavorable for erosion resistance, but favorable for groundwater recharge capacity. This decomposition therefore qualifies the conclusions regarding the impact characterized by the LANCA model.



**Figure 4 - Waterfall diagram of the four resized indicators, where ER represents erosion resistance, MF the mechanical groundwater filtering capacity, GW the groundwater recharge capacity, and BP the biotic (biological) production potential.**

## 4.2 Recommendations

Based on the two case studies and the analysis of the strengths and limitations of the LANCA model, recommendations are made (section 4.3):

1. Choose a database appropriate to the sector (agricultural, mining, etc.).
2. Learn about the elementary flows of inventory data and the assumptions made by the data developer (amortized impacts, type of land use, etc.).
3. Apply the LANCA model to the selected process and obtain the SQL results.
4. Break down the results into four indicators expressed in Points for greater clarity.
5. Compare results with other similar processes (not necessarily the same elementary flows or the same geographical area).
6. Complete the assessment by considering any indirect impacts linked to land use, assessed using an appropriate model.
7. Complete the assessment by considering the impacts of land use on biodiversity, using the SAR model for example.
8. Conclude on the impact of the activity studied.

## 5 Part C - Taking land resources into account

Part C focuses on the management of land resources by companies (chapter 5). The aim is to move beyond the theoretical framework of land use and address the various issues that companies may face. Some of these issues have already been introduced in previous sections. The aim is to answer these practical questions:

1. How can LCA databases contribute to the effective implementation of the "Zéro Artificialisation Nette" (ZAN) regulation?
2. In LCA, how can we share the impacts of land use between several users?
3. How is the storage/unstorage of carbon (temporary or otherwise) in soils considered?
4. To what extent are the benefits of certain land use strategies - making it possible to limit the degradation of land functions - highlighted by existing LCA methods?
5. How do non-LCA models measuring the impact of land use, such as GLOBIO, differ from the LCA models presented?

### 5.1 Zero Net Artificialization regulations

The "**Zéro Artificialisation Nette**" (ZAN), regulation, Zero Net Artificialization in English, included in the Climate and Resilience Act n°2021-1104 of August 22, 2021, in France, aims to achieve:

- Zero percent net artificial land cover by 2050.
- A 50% reduction in artificial development by 2030.

To analyze how LCA databases can contribute to the effective implementation of the ZAN regulation, ZAN's definition of "artificialized land" is first made explicit and the satellite databases used by the regulation are introduced (section 5.1).

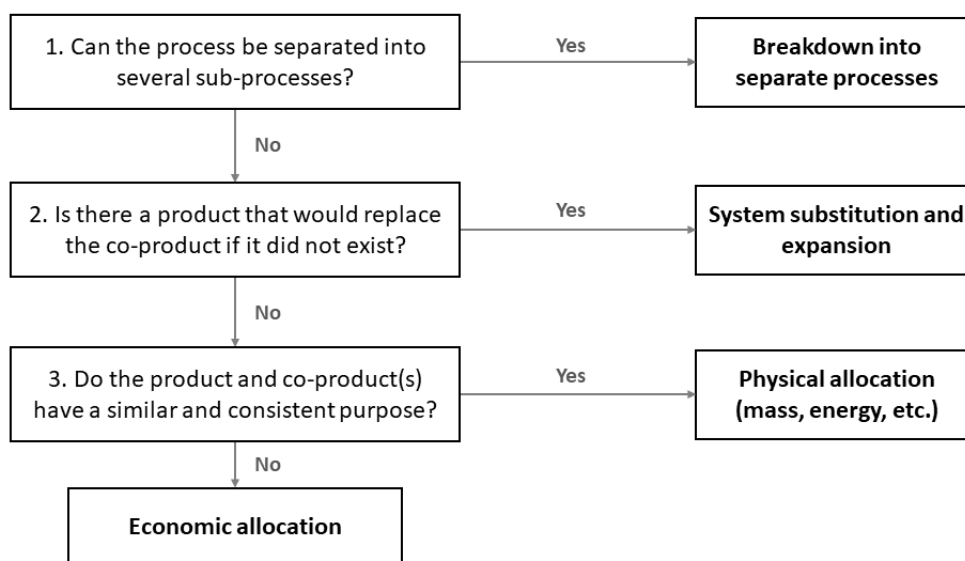
After analysis, this study concludes that LCA cannot help companies and politicians to measure land artificialization in France over time. Although LCA databases make it easy to distinguish between (non-)artificialized surfaces thanks to their granulometry, their minimum mesh size is far too large (at least on a national scale) to measure artificialization on a communal scale, as required by the ZAN.

However, this study suggests the development of weighting factors between types of land use considered by the ZAN from LCA data. This would enable a more coherent census in terms of environmental impacts, and the establishment of a final consensus on the definition of artificialized surface by the various satellite DB. LCA data would then be used by public policymakers for a more reasoned implementation of the ZAN, and not by companies who are asked to identify land use types.

### 5.2 Sharing impacts between several users of the same floor

When the use of land generates two or more products to be purchased or used, the environmental impacts associated with the use of this land must be divided between these various products. For example, a chicken farm with photovoltaic (PV) panels on the roof produces eggs, meat, and electricity. In LCA, the question then arises as to which (co-)product to allocate what proportion of the impacts linked to the use of the same land.

To this end, this study recommends following the ADEME **flowchart** presented in Figure 5 to establish a common, cross-sector approach that avoids double-counting or the disappearance of impacts (section 5.2). If several decision rules apply (two different rules, two applicable physical criteria, etc.), it is strongly recommended that a sensitivity analysis be conducted to demonstrate the consequences of using one rule rather than another.



**Figure 5 - Decision flowchart for sharing impacts between (co-)products resulting from the use of the same land, inspired by (ADEME 2014)<sup>9</sup>.**

### 5.3 Consideration of soil carbon storage/removal

Taking account of soil carbon storage/removal in LCA models is a prominent issue, as soils can play a key role in regulating the carbon cycle by storing atmospheric carbon via plants and soil micro-organisms.

At present, many LCA models do not consider the carbon storage/removal associated with land use. This study recommends applying the SOC model, developed in depth in this study, to account for this impact (section 5.3).

### 5.4 Occupation strategies to limit land degradation

There are many different land use strategies available to limit the degradation of one or more soil functions. However, a land-use strategy may be beneficial for some soil functions, but detrimental for others. It is therefore important to consider all soil functions and the interactions between them, to weigh up the pros and cons of an occupation strategy in terms of environmental impact. It is therefore necessary to adopt an integrated, systemic approach to assessing the impacts of a land-use strategy on a list of soil functions that aims to be exhaustive.

To this end, a practical guide in five steps enabling LCA practitioners to assess the benefits associated with an occupancy strategy aimed at limiting the degradation of soil functions is established (section 5.4):

1. Determine an occupation strategy to limit degradation of the soil functions to be assessed.
2. Identify soil functions that could be affected by the selected occupation strategy
3. Using LCA models to quantify the impact of occupation strategy on identified soil functions
4. For soil functions that cannot be assessed using LCA models, qualitatively determine the impact of the occupation strategy on these functions.
5. Synthesize the results of the quantitative assessments (weighting them based on a metric) alongside the qualitative assessments to conclude on the overall impact of the occupation strategy on soil functions.

<sup>9</sup> ADEME. *ADEME's position on multifunctionality management rules in the agriculture and primary processing sectors*. Note, Angers: ADEME, 2014.

## 5.5 Difference between LCA and non-LCA models

Among the non-LCA models for measuring the impacts of land use, **GLOBIO** is a model for assessing the impact of human activities on biodiversity on a global scale, using the MSA (Mean Species Abundance) indicator. The model differs from the other LCA models presented in this study in that it measures the impacts of six human pressures - including land use - on biodiversity on a regional and global scale. Although the model has the advantage of being simple to use and of publishing regional impacts that can be easily interpreted by the average person, it does not offer the same precision or rigor in its results, as it focuses solely on direct impacts on biodiversity and does not address ecosystem services. This study therefore recommends not limiting oneself to the results presented by GLOBIO but using it to get an initial idea of the impact of land use in a defined geographical area (section 5.5).

## 6 General decision-making flowchart

Based on the various themes addressed in this study, the **flow chart** presented in Figure 6 (Chapter 6) provides guidance for LCA practitioners wishing to measure the impacts of land use in their LCA.

To sum up, it is suggested that the practitioner, after defining the functional unit and the system boundaries, begins by selecting the inventory data judiciously through the choice of database, an analysis of elementary flows and allocations between co-products.

The impacts of land use are then calculated in 4 stages: using the LANCA model to assess impacts on ecosystem services (as in the 2 case studies), using the SAR model for impacts on biodiversity, any indirect land use impacts and other impacts such as carbon storage/removal using the SOC model or climate change using the IPCC 2013 model.

The final assessment of the impact of the activity's land use *is* based on a discussion of the results of these four additional points.

## 7 Conclusions

This study offers an in-depth perspective on land use modelling in LCA, with the aim of providing LCA practitioners with a better understanding of the issues involved in land resource management.

Part A clarifies the theoretical concepts and application of soil functionality in LCA. It includes a comprehensive inventory of models and methods assessing the impact of land use, with a selection of five detailed models, among which the LANCA and SAR models particularly stand out. An in-depth analysis of the inventory data highlights the crucial importance of data quality on the accuracy of results.

Part B analyzes the practical application of the LANCA model through two case studies, highlighting its usefulness while underlining the need for specific improvements. The complexity of land-use issues is highlighted, warning against an over-simplistic interpretation of the model's results.

Finally, Part C discusses various aspects of corporate land management, including the "Net Zero Artificialization" regulation, highlighting the possibility of using LCA data to measure artificialization. However, limitations remain, particularly in the accounting of land use types by companies.

In conclusion, although the LANCA model is hailed as one of the best for characterizing land use in LCA at present, improvements are needed, and the study puts forward recommendations for careful model use and consideration of various land use strategies.

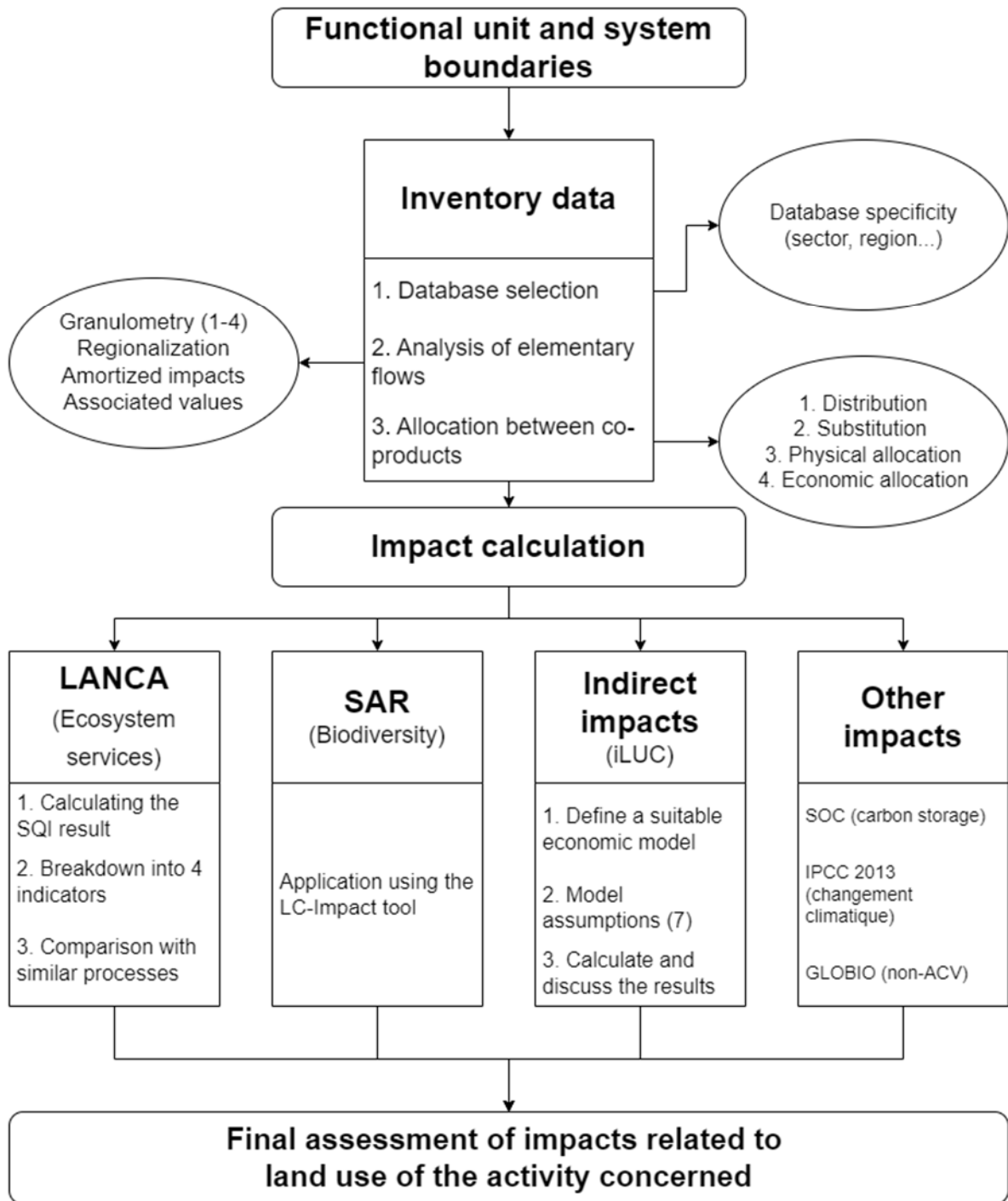


Figure 6 - Final flowchart guiding the LCA practitioner through the assessment of impacts linked to the use of an activity.