MEANS

MEANS-InOut

Software for ecodesign of agricultural systems

INRA SCIENCE & IMPACT

cirad LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie

AGRI BALYSE

MEANS

INRA established the national platform MEANS (MulticritEria AssessmeNt of Sustainability) to provide a complete and modular set of computer tools for multi-criteria assessment of agricultural and agri-food systems. ADEME has supported the platform since 2014, and CIRAD has co-developed it since 2018. Among the tools provided, MEANS-InOut software (developed internally by the MEANS team) is dedicated to Life Cycle Assessment (LCA).
For more information, visit:
https://www.inra.fr/means_eng

Ecodesign is the consideration of environmental characteristics in the design of a product throughout its lifecycle (source: European Commission). In other words, it is a search for high environmental, economic, and even social performance of goods and services.

For agri-food products, ecodesign implies using the best environmental practices for all steps in the production of a food (agricultural production, processing, etc.) while meeting the economic expectations and balances of the market. The approach requires describing and quantifying environmental performance, which can be done using the Life Cycle Assessment (LCA) approach. A video from ADEME (the French Environment & Energy Management Agency) shows this type of approach (in French).

This document describes how the MEANS-InOut program can contribute to an ecodesign approach by estimating environmental impacts of agricultural products and identifying possible mitigation options.

Introduction to Life Cycle Assessment (LCA)

LCA is an assessment method, following international standards (ISO 14040 and 14044), used to perform quantitative multicriteria environmental assessment of a product or service. It provides an overall view of environmental impacts of a product and identifies their origins.

It is widely used internationally for all economic sectors, thus allowing environmental impacts to be estimated for all production processes regardless of the specific steps and trades involved.

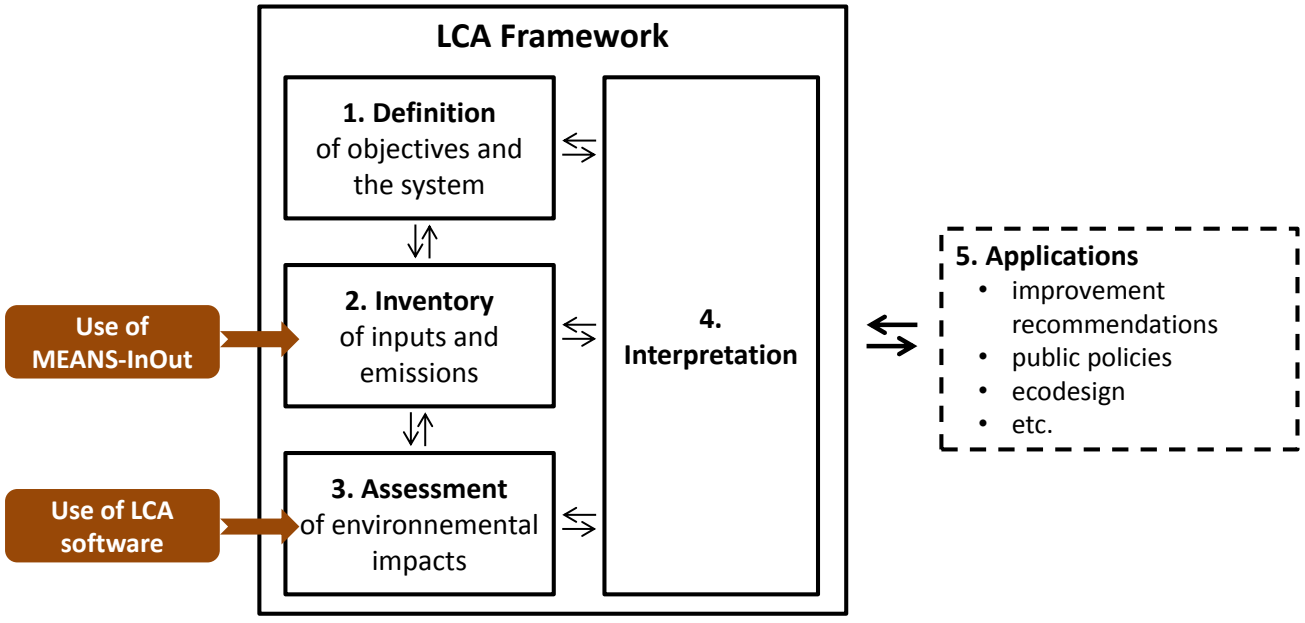
LCA adapted for agricultural products can be described in four steps:

1. Define the objectives and the system: description of the study, its objectives, and its domain of application

2. Inventory inputs and emissions in a "Life Cycle Inventory" (LCI): description of the set of agricultural field operations and calculation of resource consumption and pollutant emissions to the environment (energy, NO_3, CO_2, etc.)

3. Estimate environmental impacts: transform the LCI into impact indicators (e.g., climate change, eutrophication) that can be analysed and interpreted. Since LCA can calculate many impact indicators, this document focuses on those most relevant for agricultural sectors.

4. Interpret the results



The four steps of Life Cycle Assessment (LCA) according to ISO standards 14040 and 14044
Note: Applications (step 5) are not part of the LCA standards

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MEANS-InOut
software for environmental assessment of agricultural products

Agricultural production is a crucial step in the environmental performance of food products. It is estimated to contribute 50-90% of most environmental impacts (climate change, acidification, land occupation, etc.) of food production[1]. Compared to industrial activities, agriculture has specific characteristics and a wide diversity of production methods that require tools adapted to assess it.

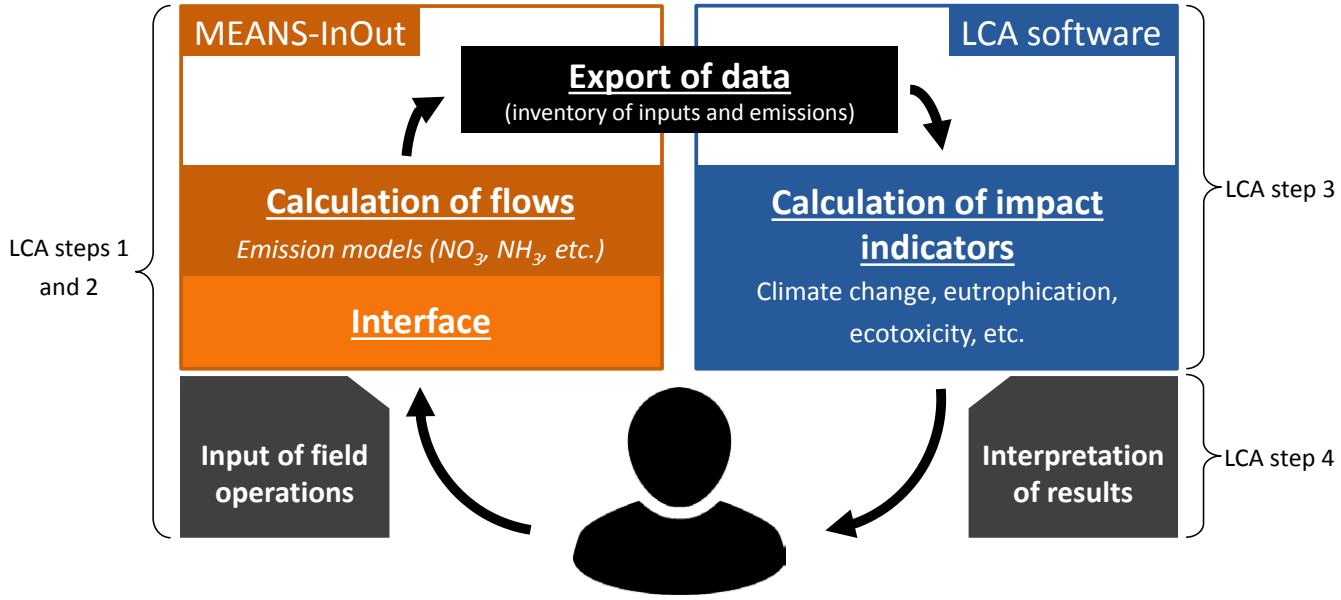
MEANS-InOut is a software program that is used to perform environmental assessments of agricultural products. MEANS-InOut uses the methodological framework of Life Cycle Assessment (LCA), following the AGRIBALYSE method, which was co-developed by experts from agricultural sectors. It thus relies on robust and recognised methods to quantify the environmental performance of agricultural products.

The AGRIBALYSE program, led by ADEME in partnership with agricultural research institutes and agricultural technical institutes, developed a homogeneous and transparent database of environmental impacts of the main French agricultural products. Since 2018, the MEANS-InOut software program has been used to update the AGRIBALYSE database.

MEANS-InOut simplifies LCA by generating LCIs of inputs and emissions for agricultural products (i.e., step 2 of LCA), using the following functions:

- **an input interface**, helping users describe the field operations of their agricultural products
- **automated calculation of all pollutant flows with suitable models**
- **automated export of data** to LCA software, in which the flows will be transformed into impact indicators (step 3 of LCA).

[1] Notarnicola, B., R. Salomone, L. Petti, P.A. Renzulli, R. Roma, and A.K. Cerutti. 2015. *Life Cycle Assessment in the Agri-Food Sector - Case Studies, Methodological Issues and Best Practices.*



Environmental assessment with MEANS-InOut
Users input their data using the program's interface. The data input are used to calculate flows of pollutants (based on associated models). Finally, results are exported to LCA software (e.g., SimaPro), which users can use to calculate and analyse impacts.

Note : LCA software must be used with MEANS-InOut to perform environmental assessment. The SimaPro program is strongly recommended, but analysis is possible using another program capable of reading the ecoSpold1 format, which is used to export MEANS-InOut data.

The two programs (MEANS-InOut and LCA software) work together to estimate a system's impacts. MEANS-InOut calculates pollutant emissions (e.g., NO_3, NH_3) and input consumption (e.g., diesel, water), while the LCA software uses these values to calculate impact indicators (e.g., eutrophication).

For example, for the use of a tractor:

- MEANS-InOut estimates its fuel consumption as a function of the type of operations performed,
- LCA software estimates the environmental costs of consuming the fuel, as well as those of building and maintaining the tractor.

In sum, MEANS-InOut organises the collection, updating, and correction of data; ensures robust modelling of emissions; decreases the need for expert input, and decreases the risk of errors. Combined use of MEANS-InOut and LCA software thus considerably eases the application of LCA to agricultural products.

Ecodesign with **MEANS-InOut**

Estimate environmental impacts of plant products

Which plant products can one study? At what scale?

MEANS-InOut can be used to assess French field crops (including certain crop associations), grasslands, major vegetable and market crops, perennial crops (orchards, vineyards), as well as several tropical crops (cocoa, coffee, oil palm, etc.).

Analysis is performed at the field scale. For a given field, one can study one single crop (or crop association) over the duration of its production. For example, a maize crop is studied from harvest of the previous crop until harvest of the maize. Likewise, an apple orchard is studied over several years of full production.

One can also study a crop succession, such as wheat-sunflower-broad bean, which improves assessment of each crop in it.

In all cases, analysis extends up to the “field gate” (i.e., harvest).

Operations downstream from harvest (transport, processing, etc.) can be included in the LCA software.

What can one vary in the field operations?

MEANS-InOut can vary system performances (yields, etc.), mechanical operations (soil preparation, seeding, fertiliser and pesticide applications, harvest, etc.), the type and doses of agricultural inputs (fertilisers, pesticides, irrigation), and management of crop residues and cover crops.

MEANS-InOut provides users with a large database of inputs (fertilisers, pesticides, etc.) and agricultural operations. Each input and operation is associated with environmental impacts, estimated by experts. This spares users from having to estimate resource use and emissions of agricultural operations and inputs. It is possible to create a new operation or input by contacting the MEANS team.

Does assessment consider the soil and climate context?

The soil and climate context is used to calculate flows of ammonia, nitrate, and phosphorus, as well as water consumption. Also, its influence is considered indirectly in the technical performance of a system (modifying the yield, the number of operations to perform, etc.).

New models added to MEANS-InOut during its development tend to be less generic and increasingly sensitive to the regional or soil and climate context.

… / …



Assessment of innovative systems generally has two types of limits: lack of data and references about them, as well as limited domains of existing models, which generally represent only the most common systems. Methodological developments are often necessary to represent the specific characteristics of these original systems well.

Is it possible to assess systems that are unconventional, innovative, organic, in "rupture" with current systems, etc.?

Recent developments in MEANS-InOut (analysis of crop associations and of crops within a succession) have improved assessment of non-conventional systems.
Thus, it is possible to assess many production methods, while keeping in mind the limits of the models used. For example, climate change is estimated well, but complementary indicators are necessary to represent its effect on biodiversity or soil quality.

What is the impact of my new set of field operations on the product's nutritional quality or economic performance?

Currently, MEANS-InOut does not consider economic aspects or nutritional or health qualities of products.

In conclusion, what main environmental impacts can be estimated for plant production?

The main advantage of LCA is to provide an overview of a wide range of impacts. This ensures that users do not assess only one type of pollutant and also consider pollution transfers between impact categories. Nonetheless, at the moment, not all impacts are estimated with the same degree of precision.

It is thus important to verify that the impacts considered the most important in the study context (a function of needs and issues in each region and sector) are estimated sufficiently well by the method selected.

"Take the example of an ecodesign approach

I want to update the specifications of a Protected Designation of Origin certification to improve the environmental performance of products and the image of the region. To do so, I want to estimate potential environmental improvements of mechanisms that can be implemented: resistant varieties, crop associations, addition of legume crops to crop successions, etc. I will thus assess whether LCAs, performed with MEANS-InOut, will address my needs.

My main concerns include climate change, pressure on land, and water quantity and quality.

The use of MEANS-InOut is absolutely relevant in these contexts; the following impacts would be the most effective to estimate:

- **Climate change:** calculation of greenhouse gas emissions (CO_2, N_2O, etc.) throughout the production phase, including direct and indirect energy consumption (by machines, production and transport of inputs, etc.), and production and use of nitrogen fertilisers,

… / …



- **Water footprint:** quantity and scarcity of water used directly and indirectly for production,
- **Eutrophication and acidification:** impact of certain pollutants (nitrate, ammonia, phosphorus, etc.) in the environment. The sensitivity of the assessment will depend upon the models used (many are available) and the scale of the assessment (many results if studying an entire succession rather than a single crop),
- **Land occupation:** all land area used for production.

I am in a zone with high levels of pesticide application or erosion risk.

Models exist to estimate these impacts, but because of the high complexity of the processes involved, uncertainty in their estimates is usually high, and their sensitivity to practices is low or moderate.

- **Toxicity and ecotoxicity:** the estimated impacts usually have high uncertainty. At the moment, it is useful to combine LCA indicators with more classic indicators of practices (e.g., treatment frequency index). Developments are underway to improve estimates of toxicity and ecotoxicity related to pesticides.
- **Impacts related to soil erosion:** MEANS-InOut contains a model of soil erosion, but the model is rarely used for LCA impacts. Other impacts are likewise subject to high uncertainty, such as those associated with heavy metals.

I want to assess biodiversity-related criteria, the presence of hedgerows or grassy strips, carbon sequestration in the soil, or soil quality."

It is not possible at the moment to assess these issues with MEANS-InOut. Due to the lack of reliable and easily applicable LCA indicators, and the absence of a scientific consensus about these issues, they cannot be addressed in a satisfactory manner.

The LCA approach requires quantitative assessment of multiple impacts, but biodiversity- and soil-related issues are particularly complex and difficult to study. These subjects are current research fronts, giving hope for advances in the medium term.

These issues are just as much perspectives for the MEANS platform, and the team is open to partnerships to develop new methods. In addition, it is possible to combine LCA with indicators developed elsewhere, so as to better represent these dimensions that are little-addressed by LCA.

The ERYTAGE website is recommended to discover and choose complementary multicriteria assessments.



Ecodesign with **MEANS-InOut**

Estimate environmental impacts of animal products

Operations and activities downstream from the animal production system (milk collection, agri-food processing, etc.) can be combined later within LCA software.

To define new raw ingredients, users may contact the MEANS team.

Which animal products can one study? At what scale?

The MEANS-InOut program is adapted for nearly all French animal products: cattle, pigs, sheep, goats, poultry, and rabbits
Assessment is performed from the “cradle” to the “farm gate”. That is, all processes influencing impacts are considered up to the exit of the production system (production and transport of raw materials for feed, heating for buildings, animal watering, etc.).

How is animal feeding represented?

In MEANS-InOut, it is possible to define in detail the rations distributed to animals. The program relies on the AGRIBALYSE program, whose database has complete information (chemical composition and environmental impacts) about the main forages and ingredients used in animal feeding.

In the perspective of environmental improvement of animal production, animal feeding is the first item to optimise as it is usually responsible for the majority of environmental impacts of animal products.

How are animal waste, its management, and its impacts represented?

Waste management is another major mechanism in the ecodesign of animal production.
MEANS-InOut estimates amounts of pollutants and waste generated as a function of animal feeding and waste (e.g., slurry, manure) management.

… / …



Are changes in animal-production performances represented?

Environmental performance is correlated with animal-production performances. All changes in performances (feed conversion ratio, mortality rate, fecundity rate, etc.) are considered in the modelling. They are quantified based on the number of animals and the amount of feed consumed in the system, thus influencing the final results.

Is it possible to assess systems that are unconventional, innovative, organic, in "rupture" with current systems, etc.?

It is possible to assess many systems, especially innovative systems that may have environmental benefits.

However, assessing common animal-production systems is more accurate, mainly due to the availability of data in databases.

Modifications may be necessary to assess non-conventional systems, and this needs to be discussed with the MEANS team. For example, current developments aim to improve assessment of organic animal-production systems, in particular by developing a database of raw feed ingredients from organic agriculture.

Are grasslands and grass-based systems present in MEANS-InOut?

MEANS-InOut considers grassland functioning for ruminant feeding; however, methods to estimate impact of these grasslands on biodiversity and carbon sequestration in the soil are not yet available.

Can one assess the impacts of buildings and machines?

Construction and maintenance of buildings and machines contribute relatively little to the environmental impacts of the entire system; however, they are included in the description of systems.

… / …



In conclusion, what main environmental impacts can be assessed for animal production?

In sum, use of MEANS-InOut can identify the main issues of production sectors. The method is sensitive and effective at measuring impacts of animal production, especially the following impacts:

- **Climate change:** direct and indirect emissions of greenhouse gases (CO_2, CH_4, N_2O, etc.)
- **Eutrophication and acidification of the environment**
- **Water footprint:** quantity and scarcity of all water used directly and indirectly by the system
- **Energy consumption**, to assess dependence on energy sources
- **Land occupation, direct and indirect** (via feeds and forages)

It is important to recall that certain impacts or issues are not currently considered (e.g., impact on biodiversity, impacts of antibiotic use, health risks, animal welfare), due to a lack of methods to assess them in the LCA framework or a lack of scientific consensus. Nevertheless, it is possible to use other indicators developed elsewhere.

The ERYTAGE website is recommended to discover and choose complementary multicriteria assessments.

In addition, the MEANS team is open to partnerships to develop new methods and thus continue development of the tool.

Take-home message

MEANS-InOut is versatile software for performing multicriteria environmental assessment of agricultural systems that can be used to ease implementation of ecodesign approaches. Based on a rigorous and internationally known method, the software can compare scenarios and assess mechanisms for progress, while considering specific contexts.

In a later step, these results can be combined with downstream operations in the food production chain (processing, logistics, packaging, etc.) to perform comprehensive assessment of food up to the consumer.

Because LCA is a demanding method, familiarity with the MEANS-InOut program and good understanding of analysis methods are necessary to perform reliable analyses and be capable of interpreting results well. Training workshops (2.5 days) are regularly offered to users, especially non-specialists in LCA.

Availability of MEANS-InOut

Employees of INRA and CIRAD can use the MEANS-InOut program for free. For other potential users, access available for an annual fee. More information at this link.

The development team is open to partnerships and projects to develop the tool further (assess new types of production, methodological advances, etc.).

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Useful links

The MEANS platform website
The AGRIBALYSE method
For more information about the AGRIBALYSE method, used by MEANS-InOut, read its methodological report