OLCA-Pest – Final Project Report

Project reference: ADEME 17-03-C0025

Project acronym: OLCA-Pest

Deliverable number: D1.5b

Deliverable name: OLCA-Pest – Final Project Report

Version: V2b (public version)

Working package number: 1

Work package lead partner: DTU

Deliverable lead partner: DTU

Delivery date: January-2020

Authors: Peter Fantke, Assumpció Antón, Claudine Basset-Mens, Thomas Nemecek, Philippe Roux, Christel Renaud-Gentié, Pierre Naviaux, Celine Gentil, Nancy Peña, Carlos Melero

Comments: Report for public dissemination
Contents

Summary ...................................................................................................................................................... 3
Main project outputs and recommendations .............................................................................................. 4
Scientific achievements ............................................................................................................................... 4
Operationalization achievements .............................................................................................................. 5
Recommendations for scientists and practitioners .................................................................................... 7
Identified needs for additional efforts ...................................................................................................... 8
List of project-related publications .......................................................................................................... 10
  Peer-reviewed articles/book chapters ........................................................................................................ 10
  Conference contributions .......................................................................................................................... 11
  Communication flyer .................................................................................................................................. 12
Summary

Current pesticide field emission modelling and toxicity characterisation approaches suffer from several shortcomings, including unclear boundaries between Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) phases, environmental compartment mismatches between LCI databases and LCIA methods, as well as missing characterisation factors, compartments in impact assessment, and impact pathways, as well as lack of practitioner guidance. These shortcomings were discussed in an earlier pesticide consensus-building effort, which led to recommendations for harmonising emission and impact characterisation of pesticides in life cycle assessment (LCA) and product environmental footprinting. These shortcomings lead to LCA results that are incomplete and often misleading and hard to interpret and this makes it impossible to assess and compare the environmental performance profiles of different pest management systems and practices.

The OLCA-Pest project ("Operationalising Life Cycle Assessment for Pesticides", 2017-2020, co-funded by ADEME and all involved partner institutions) was implemented with nine partner institutions, in order to operationalize these recommendations from the consensus-building effort and provide clear guidance for researchers and practitioners alike. Expertise and capacity was brought together in the OLCA-Pest project to realize the vision of overcoming currently existing limitations and challenges when addressing pesticides in LCA. This included the connection of researchers and LCA practitioners from academia, industry, and regulation in the OLCA-Pest consortium, and best-possible alignment of the project’s work with current efforts on global pesticide consensus for estimating pesticide emissions for LCA and on the Agribalyse project series. Project results and models were furthermore tested in a set of realistic LCA case studies, to demonstrate the applicability of OLCA-Pest methods in human and ecotoxicity assessments.

Main project outcomes are a series of scientific and operationalization achievements, which feed directly into practices of LCA practitioners and agronomists. Scientific achievements range from developing new elements for improving pesticide field emission modelling, via improving and extending the data source for assessing pesticides in LCA, to introducing new pathways for assessing exposure and effects to agricultural pesticides. Operationalization achievements range from new data, tools and guidance for LCA practitioners and agronomists, with main focus on pesticide emission modelling and (eco-)toxicity characterization. Models, data and guidelines were tested in a series of case studies on temperate and tropical crops. Based on these achievements, a set of recommendations was proposed for LCA method developers and practitioners. These recommendations range from the choice of emission fractions in LCA case studies, via the implementation of new exposure pathways and emission compartments, to the consistent combination of LCI and LCIA models and factors, and interpretation of characterization results.

The work conducted under the OLCA-Pest project constitutes a major step forward in the improvement of the scientific foundation for assessing emissions and toxicity impacts of agricultural pesticides in LCA, and provides guidance, additional data and operational tools, and practical support for assessing emissions and toxicity impacts of agricultural pesticides in LCA. To address remaining limitations associated with pesticide emission and impact modelling, a list of future research needs was identified, as input for defining forthcoming research collaborations and funding schemes.
Main project outputs and recommendations

Current pesticide field emission modelling and toxicity characterisation approaches suffer from several shortcomings, including unclear boundaries between Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) phases, environmental compartment mismatches between LCI databases and LCIA methods, as well as missing characterisation factors, compartments in impact assessment, impact pathways, as well as lack of practitioner guidance.

The Glasgow consensus workshop in 2013 started a consensus building process with three scientific workshops and a stakeholder workshop, with findings published open access in the International Journal of Life Cycle Assessment (http://doi.org/10.1007/s11367-015-0871-1). In order to operationalise the recommendations resulting from this consensus building effort for harmonising the emission quantification and impact characterisation of pesticides in life cycle assessment (LCA) and product environmental footprinting, the OLCA-Pest project (“Operationalising Life Cycle Assessment for Pesticides”, 2017-2020, funded by ADEME) was implemented with nine partner institutions.

The present summary report informs about the main outcomes of the OLCA-Pest project and the consequences for LCI databases, LCIA assessment and LCA practice related to assessing pesticides in LCA.

Scientific achievements

The OLCA-Pest project resulted into several scientific achievements, which feed directly into practices from two types of users, namely agrifood LCA practitioners and agronomists (Figure 1).

Figure 1. Scope for using OLCA-Pest scientific achievements by two types of users.
During the 3.5 years duration of the OLCA-Pest project, the team of researchers and LCA practitioners worked on advancing the scientific foundation for assessing pesticides in LCA across various aspects. These aspects range from developing new elements for improving pesticide field emission modelling, via improving and extending the data source for assessing pesticides in LCA, to introducing new pathways for assessing exposure and effects to agricultural pesticides. The project achievements, in part, correlate with certain methodological developments for tropical conditions from the InnovACV project funded by ADEME Martinique (https://ur-hortsys.cirad.fr/en/projets-de-recherche/projet-innovacv).

The main scientific achievements of the OLCA-Pest project are listed in the following:

- **Coupling emission and impact models**: Connecting in a matrix algebra framework the PestLCI Consensus initial emission distribution fraction results to inputs for the dynamiCROP plant uptake model
- **Pesticide residue impact factors**: Calculating human toxicity impacts associated with exposure to pesticide residues in food crops based on the adapted dynamiCROP plant uptake model
- **Improvement of drift modeling**: Spatial integration of drift deposition functions over the distance from the edge of the treated field to reflect cumulative drift deposition fractions lost to off-field surface areas
- **New drift deposition functions**: Definition of additional drift deposition functions and consideration of crop characteristics for crops produced under tropical conditions, and the assessment of model choices and the role of spatial differentiation for ecotoxicity assessment of pesticides
- **Introducing groundcover management**: Definition of a complete mathematical mass balance for incorporating groundcover management into PestLCI Consensus emission modelling, as relevant e.g. for vineyards or tropical crops
- **New data sources and factors**: Introduction of a data source hierarchy and effect data conversion definition to consider a wider range of physicochemical substance data and effect test result metrics as input for pesticide emission and toxicity effect modelling, as well as of pesticide application scenarios for consistent definition of drift functions and air emissions
- **Additional pathways and models**: Development of mathematical proof-of-concept models for assessing impacts from exposure to pesticides on bees and potentially other pollinating insect species, for assessing impacts from pesticide emissions from agricultural fields on human residential bystanders, and for identifying safer and more sustainable alternatives to harmful pesticides based on a chemical substitution framework

With these scientific advancements, the work conducted under the OLCA-Pest project, in part supported by other projects, such as InnovACV, constitutes a major step forward in the improvement of the scientific foundation for assessing emissions and toxicity impacts of agricultural pesticides in LCA.

**Operationalization achievements**

In addition to scientific advances, the OLCA-Pest project also resulted into several operationalization achievements for assessing pesticides in LCA. These operationalization achievements range from
new data, tools and guidance for LCA practitioners and agronomists, with main focus on pesticide emission modelling and (eco-)toxicity characterization (Figure 2).

During the 3.5 years duration of the OLCA-Pest project, the team of researchers and LCA practitioners worked on providing practical guidance and operationalizing the assessment of pesticides in LCA across various aspects. These aspects range from a web-based pesticide emission model, via default emission fractions and new characterization factors, to methodological guidance for assessing pesticides in LCA.

The main operationalization achievements of the OLCA-Pest project are listed in the following:

- **LCI consensus model**: Implementation of an improved PestLCI Consensus web-based modeling tool (https://pestlciweb.man.dtu.dk), which includes a simple user interface, allows single pesticide and multi-pesticide (batch) runs, has an adapted drift deposition module, and provides results for initial (primary) and secondary emission distributions
- **Default emission fractions**: A set of pre-calculated, recommended default pesticide emission fractions for initial (primary) emission distribution for a set of pre-defined crop type-pesticide target class combinations (e.g. insecticides applied to fruit trees)
- **LCI-LCIA model coupling**: Operational procedure for linking emission compartments of pesticide emission fraction results to emission compartments of LCIA models for consistently coupling LCI results with LCIA characterization results for pesticides applied to agricultural fields
- **New crop compartment**: Introduction of a new emission compartment "crop" with 13 sub-compartments based on pre-defined crop classes that are part of a set of pre-defined scenarios

Figure 2. Main operationalization achievements resulting from the OLCA-Pest project.
for assessing pesticides in LCA according to pesticide target class, crop type and application method

- **New input data and characterization factors**: Introduction of additional, internally consistent pesticide physicochemical property data for several hundred pesticides, and additional characterization factors that were calculated following USEtox guidelines for more than hundred pesticides currently not available in LCIA models, but proposed for inclusion into the formal USEtox scientific consensus model

- **Methodological guidance**: Book chapter providing state-of-the-art overview for assessing pesticides in LCA (http://doi.org/10.19103/AS.2018.0044.08), and full documentation and manual for operating the new PestLCI Consensus web-based model

- **Case studies**: the methods, tools, emission and characterization results were tested in five real-world LCA case studies, including assessing the environmental performance of production of vineyards, wheat, rape seed, potato, sugar beet, carrot, and tomato under tropical conditions

With these operationalization advancements, the work conducted under the OLCA-Pest project provides guidance, additional data and operational tools, and practical support for assessing emissions and toxicity impacts of agricultural pesticides in LCA.

**Recommendations for scientists and practitioners**

Based on the several scientific advances as well as based on the implementation and testing of emission and impact assessment data, models and results in practical LCA case studies, we propose a set of recommendations for LCA method developers and practitioners. These recommendations range from the choice of emission fractions in LCA case studies, via the implementation of new exposure pathways and emission compartments, to the consistent combination of LCI and LCIA models and factors, and interpretation of characterization results. In the following, we list the main recommendations that derive from the OLCA-Pest project:

1. **Default emission fractions for LCA**: Use default initial emission fractions as background system pesticide emission estimates in LCA studies.

2. **Web-based emission model**: Apply PestLCI Consensus web-tool for estimating foreground system pesticide emissions in LCA studies or to adjust emission estimates to specific situations for background applications.

3. **Exposure to pesticide residues in crops**: Include pesticide residues in food crops as additional exposure pathway contributing to human toxicity impacts. These factors can be aggregated with characterization factors from USEtox for other exposure pathways.

4. **LCI-LCIA model coupling**: Follow our proposed approach for coupling emission and impact assessment results and models (PestLCI Consensus, USEtox, dynamiCROP) for a consistent combination of LCI and LCIA results for pesticides.

5. **LCI emission compartments**: Implement additional emission compartments in LCI databases to cover human exposure associated with agricultural pesticide residues in field crops harvested for human consumption.

7. Frequently Asked Questions (FAQs): synthesis report of answers from OLCA-Pest partners concerning the consideration of evaluation of pesticides in Life Cycle Assessment (LCA) for non-specialists, LCA practitioners and LCA experts

Identified needs for additional efforts

The work conducted under the OLCA-Pest project already constitutes a great step forward for assessing emissions and toxicity impacts in life cycle assessment (LCA). The results from this effort will be useful for the two types of users: agrifood LCA practitioners and agronomists. However, despite the research and operationalization advances from this project, there are still research questions to be resolved to further improving the consideration of pesticides in LCA.

In this context, many of the remaining limitations associated with pesticide emission and impact modelling are not specifically related to the development within LCA, but are instead related to the general limits of knowledge. This includes, for example, the possible influence of chemicals in plant protection formulations other than the actual pesticide active ingredients on the effectiveness, the environmental fate and the toxicity potency of pesticides. However, the composition of formulations is usually a trade secret and not known to LCA practitioners or agronomists. Hence, related aspects cannot be considered in LCA or elsewhere. This and other aspects can partly be addressed through further research. Hence, a list of main future research needs identified from the OLCA-Pest project work, is provided in the following. This list may constitute a valuable starting point for defining forthcoming research collaborations and funding schemes for further improving the assessment of pesticides in LCA:

- **Secondary emission distributions** should be further researched, where various environmental processes are improved and a consistent mass balance is established.
- **Drift deposition fractions** should be derived from parameterized deposition scenarios (instead of being derived from fixed-scenario drift experiments) to allow for scaling drift deposition fractions as function of field size and shape as well as to consider a much wider range of application methods.
- **Various pest control and crop management practices** should be integrated into current emission modelling, including methods to evaluate seed coating, bag impregnation, groundcover management, and mix-cropping systems.
- **Pollinator, and other ecosystem impacts** require the advancement of initial models to characterize exposure and effects of pesticides on pollinating insects, soil organisms, predatory birds, groundwater, and sediment-dwelling organisms need to be newly developed or existing approaches extended and operationalized for a consistent integration into existing LCIA ecotoxicity characterization.
- **Worker and bystander impacts** require the development or improvement of initial models for characterizing exposure and effects of pesticides on human workers and bystanders.
- **Metal-based pesticides** and pesticides containing metal ions require the development or adaptation of approaches to be included in emission models.
- **Inorganic pesticides** (metal- and non-metal inorganic substances) require the development of additional emission and characterization results. Current models are unable to account for the
complex reaction kinetics and dynamics of inorganic pesticides and hence need to better account for chemical reaction processes in the different environmental media.

- **Biological pesticides** require completely different approaches for characterizing emission, fate, exposure and effect mechanisms. Only based on additional efforts to account for the emission and impact characteristics of each of these biopesticides groups it will be possible to ultimately evaluate and compare alternative and chemical pesticide-based farming practices.

- **Metabolites** need to be consistently characterized, since various chemical and biological pesticides undergo complex transformation processes. This requires additional data efforts to understand the metabolic fractions, media and finally physicochemical property and effect data for all metabolites, of which the latter is currently the main limiting aspect.

- **Upscaling** from field via farm to regional levels are finally needed to compare not only individual pesticides and certain practices, but also consider differences in local and regional conditions.
List of project-related publications

In the following, a list of scientific output from the OLCA-Pest project published during the project implementation period is presented.

Peer-reviewed articles/book chapters


Conference contributions


5. **Naviaux P., Renaud-Gentié C., Roux P.,** 2019. Workshop A : Consideration of pesticides in LCAs, AGRIBALYSE Closing seminar, Angers (France), January 2019 (oral presentation)


Communication flyer

An educational communication flyer, aimed at a wider audience (agrifood stakeholders and non-LCA experts as well as advanced practitioners and experts) is available for download on the project’s official website (http://www.sustainability.man.dtu.dk/english/research/qsa/research/research-projects/olca-pest). The communication flyer is entitled "A step forward in accounting for pesticides effects in LCA: OLCA-Pest project summary & Frequently Asked Questions (FAQs)".