132. Estimating pesticide emission fractions for use in LCA: a global consensus-building effort

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ABSTRACT

A practical challenge in LCA for comparing pesticide application in different agricultural practices is the agreement on how to quantify the amount emitted, while only the amount applied to the field is known. Main goal of this paper is to present an international effort carried out to reach agreement on recommended default agricultural pesticide emission fractions to environmental media. Consensual decisions on the assessment framework are (a) primary distributions are used as inputs for LCIA, while further investigating how to assess secondary emissions, (b) framework and LCA application guidelines and documentation will be compiled, (c) the emission framework will be based on modifying PestLCI 2.0, (d) drift values will be provided by German, Dutch and other drift modelers, (e) pesticide application methods will be complemented to develop scenarios for tropical regions, (f) climate, soil and application method scenarios will be based on sensitivity analysis, (g) default emission estimates for LCA will be derived from production-weighted averages, and (h) emission fractions will be reported spatially disaggregated. Recommendations for LCA practitioners and database developers are (a) LCA studies should state whether the agricultural field belongs to technosphere or ecosphere, (b) additional information needs to be reported in LCI (e.g. pesticide mass applied), (c) emissions after primary distribution and secondary fate processes should be reported, (d) LCIA methods should allow for treating the field as part of technosphere and ecosphere, (e) fate and exposure processes should be included in LCIA (e.g. crop uptake), (f) default emission estimates should be used in absence of detailed scenario data, (g) and all assumptions should be reported. The recommended pesticide emission fractions results and recommendations are presented and disseminated to strive for broad acceptance at a dedicated stakeholder workshop back-to-back with the current LCA Food 2016 conference in Dublin.

Keywords: life cycle assessment, emission quantification, agricultural pesticides

1. Introduction

Life Cycle Assessment (LCA) helps establishing and comparing environmental performance profiles of products or services. For agricultural LCA in particular, one of the major challenges is the comparison between different farming practices, comparing for example various pesticides applied in conventional agriculture to alternative (functionally equivalent) solutions, such as organic or integrated farming practices. LCA thereby aims at identifying the "best-in-class" solution(s) among all considered practices.

What is required to quantify impacts on humans and ecosystems related to the pesticides used is the amount of pesticides emitted to the different environmental media (air, water, soil, crop residues) under different practices (Dijkman et al., 2012). However, this information is mostly not available to LCA practitioners, while typically the pesticide amount applied to the agricultural fields is known (Fantke et al., 2012).This constitutes a practical challenge in LCA for comparing the application of pesticides in different agricultural contexts and practices. Different tools and approaches exist to address the quantification of pesticides emissions in LCA, yielding inconsistent outcome, thereby hampering to consistently account for impacts related to the use of pesticides in agricultural LCA.

In response to this challenge, a global effort was initiated[1] with the objective to estimate and agree on recommended default agricultural pesticide emission fractions to environmental media. It is the

[1] http://www.qsa.man.dtu.dk/Dissemination/Pesticide-consensus

aim of the present paper to summarize the findings of this effort, to outline the followed approach, the recommendations that have been agreed upon until now, and to provide an outlook on how to set the achieved results and recommendations into practice.

2. Methods

Three expert workshops have been organized involving more than 70 specialists representing industry, government, and academia from 24 countries and 5 continents. Main objectives of the workshops were to streamline and coordinate the global effort on quantifying emission fractions for use in LCA.

The first workshop (scoping workshop) was held in 2013 in Glasgow (UK) with focus on providing guidance on the delimitation between life cycle inventory and impact assessment in LCA with respect to pesticide use in agricultural practices. Consensual recommendations were reached as result of this workshop on a consistent accounting of emissions and impact assessment. These recommendations have been fully peer-reviewed and published in Rosenbaum et al. (2015).

The second workshop (framework workshop) was held in 2014 in Basel (Switzerland) with focus on agreeing on how to consistently model the fractions of applied pesticides that enter air, water, soil, and agricultural crops as emissions under different agricultural pesticide application practices. Outcome of this workshop was a defined set of data and models that can be used and that can be consistently combined to arrive at an overall emission quantification framework that can be ultimately operationalized to quantify pesticide emission fractions to the environment for a defined set of scenarios applicable for LCA.

The third workshop (consensus workshop) was held in 2015 in Bordeaux (France) with focus on presenting and discussing intermediate results of the follow-up work after the first two workshops. In the consensus workshop, agreement was reached on (a) the modeling framework, (b) the set of default scenarios to be recommended for LCA, and (c) the format of the emission results along with associated data requirements for implementation into current LCA software.

The consensus building process until the workshop in Bordeaux in 2015 is illustrated in Figure 1.

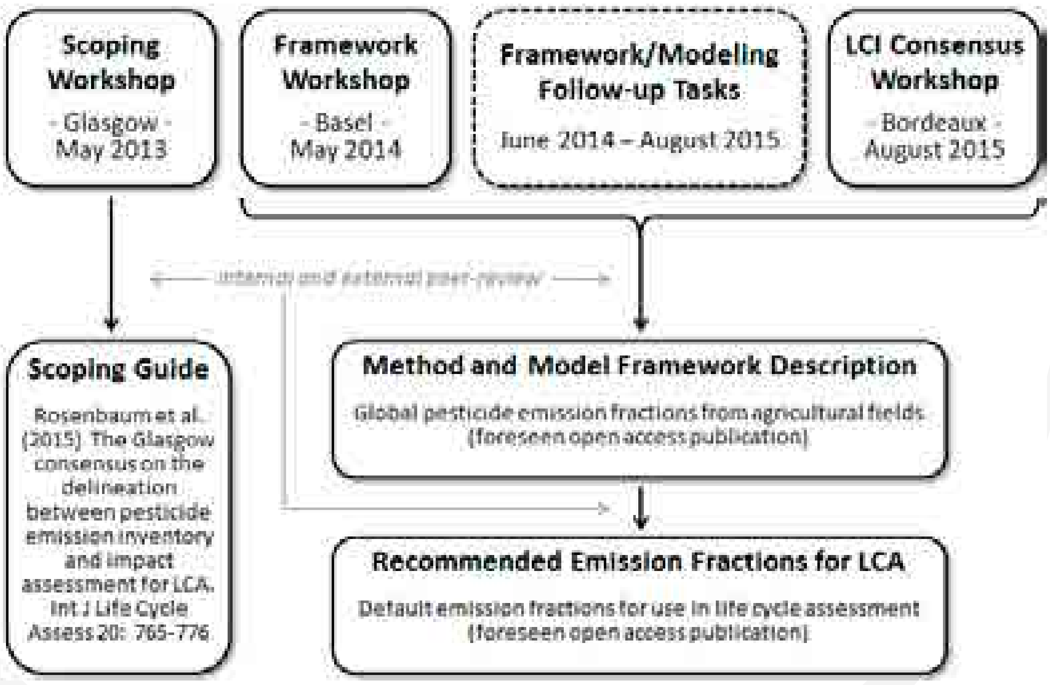

Figure 1: Overview of the global consensus building process to arrive at recommended default pesticide emission fractions readily usable in life cycle assessment.

3. Results

A set of consensual decisions of how to consistently quantify pesticide emission fractions to the environment is summarized in the following as outcome of the three workshops and follow-up work by several international research teams:

(a) At this stage, only primary pesticide distributions are used as direct inputs for life cycle impact assessment (LCIA) and further investigation is required about how to couple secondary emissions to LCIA models,

(b) Guidelines and a full documentation will be compiled regarding the model framework and how to combine LCI primary pesticide distribution and secondary emissions results with LCIA toxicity characterization results,

(c) The emission quantification framework will be based on a model that builds on a completely reworked and extended PestLCI 2.0 including adjustments for the implemented drift functions,

(d) Average drift values are needed and will be provided by German (Rautmann et al., 2001) and Dutch (Holterman and van de Zande, 2003) drift modelers as well as additional functions for scenarios not covered by the available drift functions,

(e) To ensure a broad coverage of assessing agricultural practices, pesticide application methods will be complemented as input to build emission scenarios for tropical regions,

(f) Climate, soil and pesticide application method scenarios will be selected based on sensitivity analysis,

(g) Default emission estimates for LCA will be derived as pesticide production (mass)-weighted averages across detailed emission results,

(h) Emission fractions will be reported spatially (geographically and politically) disaggregated as function of climate zones, crop production, and administrative regions (e.g. countries),

The conceptual framework of how to model pesticides from application to agricultural crops to emission fractions reaching different environmental media and receptors as developed and agreed in Basel in 2014 (Figure 2) was used as starting point for improving the PestLCI 2.0 model towards the agreed points.

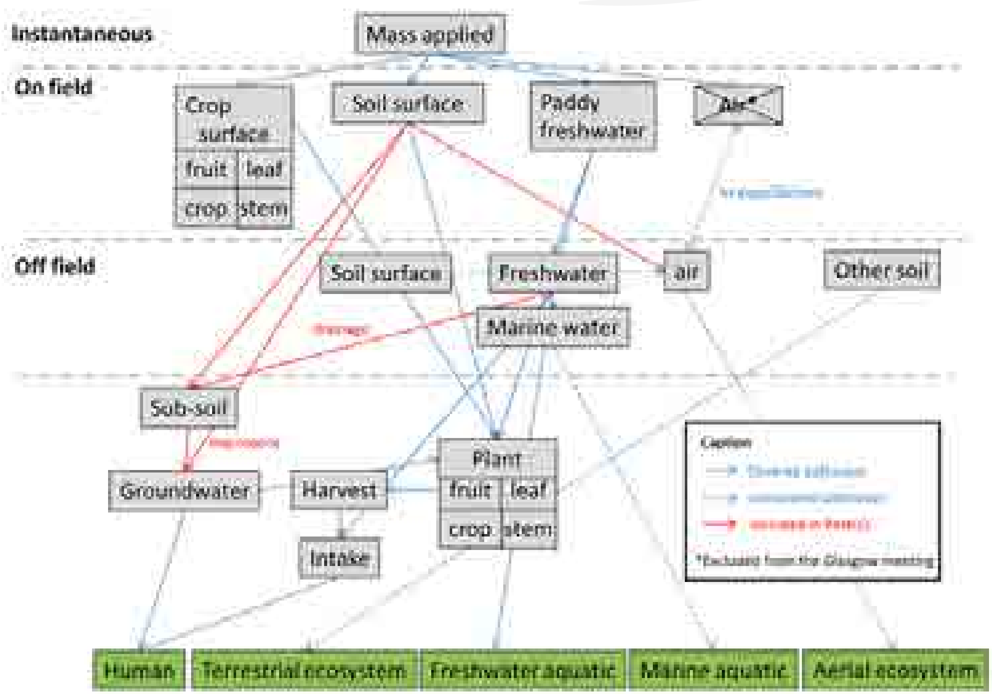

Figure 2: Conceptual framework of how to model pesticides from application to agricultural crops to emission fractions reaching different environmental media and receptors. Emissions or residues will be reported in LCA databases for the following compartments “Soil surface”, “Freshwater”, “Marine water”; “Air”, “Groundwater”, and “Plant”.

The set of scenarios agreed to combine crop class, pesticide target class and application methods is shown in Figure 3 and was used to cover the main globally occurring combinations.

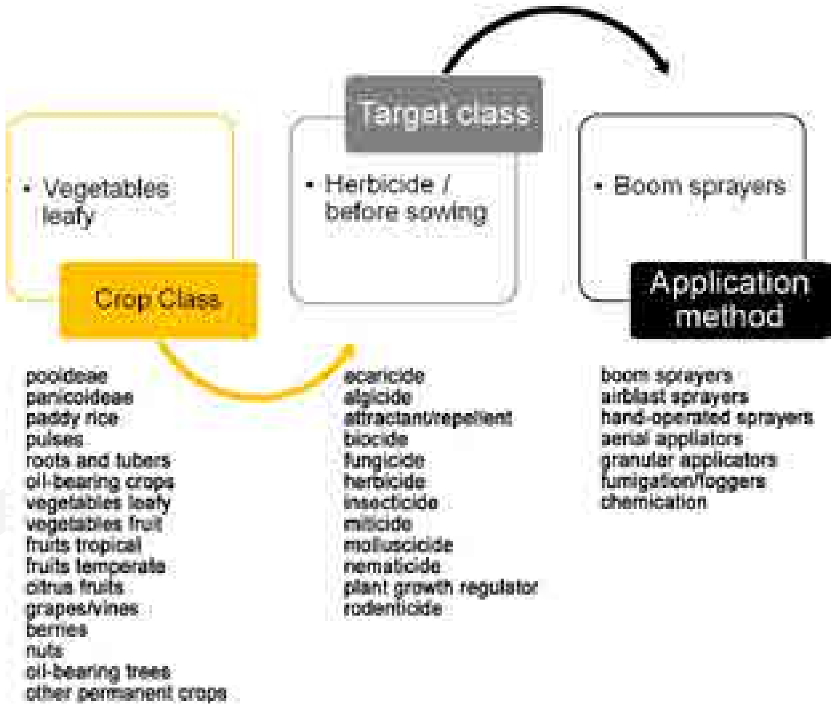

Figure 3: Archetypal classification of crop class-pesticide target class-pesticide application method scenarios used for estimating initial pesticide emission fractions for LCA.

Based on the set of agreed decisions about the assessment framework, a set of recommendations was established for LCA practitioners and software developers:

(a) In the goal and scope section of an LCA, it should be stated whether the agricultural field belongs to the technosphere or to the ecosphere,

(b) Pesticides, crops, pesticide mass applied to agricultural fields, application method, presence of buffer zones, application location and time, and adherence with good agricultural practice should be reported as part of the LCI to quantify pesticide emissions from agricultural fields,

(c) Both, emissions after primary distribution processes (i.e. immediate) and after secondary fate processes (i.e. with longer time horizon) should be reported during the LCI phase,

(d) LCIA methods should allow for treating the agricultural field as part of the technosphere and as part of the ecosphere,

(e) In LCIA, secondary drainage, runoff, degradation/dissipation, volatilization, leaching, crop uptake and related food residue exposure, and exposure of bystanders, applicators and field workers should be included,

(f) If detailed information on pesticide application location and time is not available, default emission estimates for LCA should be used as derived as pesticide production (mass)-weighted averages across detailed emission results,

(g) All assumptions about buffer zones, application scenario, impact assessment methods, considered fate and exposure processes and pathways, and spatiotemporal resolution should be reported by LCA practitioners.

4. Discussion

After implementing, testing and fully documenting all consensus-based agreements, results are presented and disseminated together with agreed recommendations for LCA practitioners and database and model developers to strive for broad acceptance at a dedicated Stakeholder Workshop back-to-back with the LCA Food 2016 conference in Dublin (Ireland) on October 18, 2016[2]. Objective of this workshop is to seek broad stakeholder acceptance and agreement on recommended default agricultural pesticide emission fractions to environmental media in LCA. The target is the feasibility to implement these pesticide fractions along with associated data requirements into LCI databases to improve current LCA practice with respect to impacts from the use of agricultural pesticides.

5. Conclusions

The international consensus building effort emphasizes the importance of involving the broad range of stakeholders for which a consistent consideration of agricultural pesticides in LCA is relevant. A combination of state-of-the-art science-based methods and feasible scenarios and assumptions are required to arrive at agreement for advancing the assessment of the various agricultural practices in LCA. For practitioners, the results of the global effort constitute an improvement with respect of comparing agricultural practices, striving towards a consistent interface between LCI and LCIA, and a clear guidance of how to evaluate pesticides. Follow-up efforts are required to adapt LCIA models, especially with respect to groundwater emissions and on-field impacts, and to also address agricultural nutrient emissions in LCA.

6. References

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[2] http://www.qsa.man.dtu.dk/Dissemination/Pesticide-consensus/Stakeholder-workshop-Dublin-2016