Optimizing the LCA data processing for food products in the context of Life Cycle Sustainability Assessment: challenges and opportunities

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ABSTRACT

Life Cycle Inventory (LCI) is the most time consuming and cost intensive part of a Life Cycle Assessment (LCA) study. This is especially the case for Life Cycle Assessment (LCA) of food products, where the numerous underlying agricultural systems represent generally a major part of the environmental impacts and a considerable amount of data to be collected. In particular the modelling of direct field and farm emissions requires a large amount of parameters (e.g. field management, soil properties, climatic conditions etc.) and involves iterative calculation loops at several levels (crop, field, farm and product). Through the generic tools SALCA*crop* and SALCA*farm*, an efficient and modular solution in the frame of Swiss Agricultural Life Cycle Assessment (SALCA) is already existing. Most of the LCA projects for field, farm or food LCA can be described in a workflow including SALCA*farm* and SALCA*crop*, but some adaptations are necessary according to the goal and scope of the project under study. In addition, if the data provider is not a LCA practitioner or a specialist in agriculture, a data collection tool must be developed. This was the case in the CANTOGETHER (Crops and ANimals TOGETHER) European project aiming at the environmental assessment of case-study farms and regions. Conventional LCA software tools such as Simapro 8, but also specific modeling tools such as *SALCAfarm*, *SALCA-BD*, *SPACSYS*, *RUSLE2*, and the *SIKtool-EFM* were integrated. To minimize the time-consumption of such adaptations and developments, a broader IT solution that can manage a high variety of LCA projects must be established in the future. Based on the experience of *SALCAcrop*, *SALCAfarm*, CANTOGETHER, and other LCA studies of food products, such a solution is under development: *SALCAfuture*. The main components will be a user-friendly data collection website, a centralized calculation and administration tool, and an analysis and assessment tool. SALCA*future* will be able to integrate a wide portfolio of LCA and eventually Life Cycle Sustainability Assessment (LCSA) projects from the agrifood sector. The various components will also be accessible to external users.

Keywords: farm and food LCA, direct emissions LCI, data collection, LCA tools

1. Introduction

The Life Cycle Inventory (LCI) phase is generally the most time consuming phase of a Life Cycle Assessment (LCA) study. In food LCA, the numerous and diverse underlying agricultural production systems contribute generally significantly to the environmental impacts (Weidema and Meeusen 2000). To estimate these impacts, the indirect emissions from the technosphere, but also the field and farm direct emissions must be modelled. This requires a broad and large amount of data: field management and related product use, soil properties, climatic conditions, animal and manure management, location, infrastructure, machinery, etc. This data is present at different levels from the crop, the field to the farm level. For food LCAs the impacts must be allocated to the product level, which requires additional data, for example the ratio of internal use and the amount of products that are bought or sold[1].

Concerning the calculations, the complexity is also present since several stages of iteration are necessary according to the crop, field, and farm and product level. In addition to this, the use of linear and non-linear models, and the high amount of data leads to the requirement of an efficient calculation procedure. This is achieved by SALCA*crop* and SALCA*farm*, generic tools for field or farm and product LCA.

Since their release, these tools were used in a considerable number of projects, and some experience could be gained regarding their future development. In addition, the recent discussion and development of conventional LCA in the direction of Life Cycle Sustainability Assessment (LCSA) establish the need for tools that can incorporate new sustainability metrics (Guinée et al. 2011). The goal of this paper is to describe the concept of a next-generation of tools for field or farm and product LCAs. Firstly, the current workflow of SALCA*farm* and SALCA*crop* will be briefly described with the perspective of a typical LCA project. Secondly, the workflow developed specifically for the project Crops and ANimals TOGETHER (CANTOGETHER 2014), including an adap-

[1] In this paper a product can be anything that the farm produces: a food product, but for example also energy from a bioenergy facility. C*rop level*, do not refers only to the crop product itself, but also to the calculation that requires data at the detail level related to the crop.

tation of SALCA*farm* and the development of a flexible data collection tool will be presented. Finally the workflow of the next-generation of tools, in the frame of the project SALCA*future*, will be introduced.

2. The workflow of SALCA*farm* and SALCA*crop*

The current tools used for field or farm and product LCAs are SALCA*crop* and SALCA*farm*. These generic tools were already described in detail in the reference Nemecek et al. 2010, in particular regarding the emission methods, the calculation procedure, and the impact assessment methods. In this paper we focus on the overall workflow with the perspective of a typical LCA project.

SALCAcrop and SALCAfarm are currently used for each project in the workflow of Figure 1, following the conventional phases of a LCA project. Firstly a data collection tool, generally based on Excel is used, or the data is entered directly in the input files PIfarm or PIcrop by LCA practitioners or agriculture specialists. This results in the agricultural Production Inventory (PI). In case a data collection tool exists, it was developed according to the specific goal & scope of the project. The development of such a tool can be intensive in terms of resources, in particular if the users aimed are for example farmers, and the required flexibility is high.

The next step is the calculation of the intermediate inventory, containing direct emissions, and inputs and outputs from technosphere. This is done with either SALCAfarm or SALCAcrop and results in an ecospold1 file that is imported in the conventional LCA software SimaPro7. It involves linear and non-linear calculations at the crop, field, and farm and product level with several direct emission calculation modules. The treatment of numerous farms is possible (batch processing). For most of the projects some adaptations are necessary, also according to the goal and scope of the study, for example the adaptation of national emission factors or the implementation of country-specific product commercial names.

Finally the results are imported and analyzed in SimaPro7 and extracted generally in MS Office tools for further assessment, analysis, and reporting. This includes several manual steps, which are reduced by generating one ecospold1 file with several farms in the case of a batch calculation procedure.

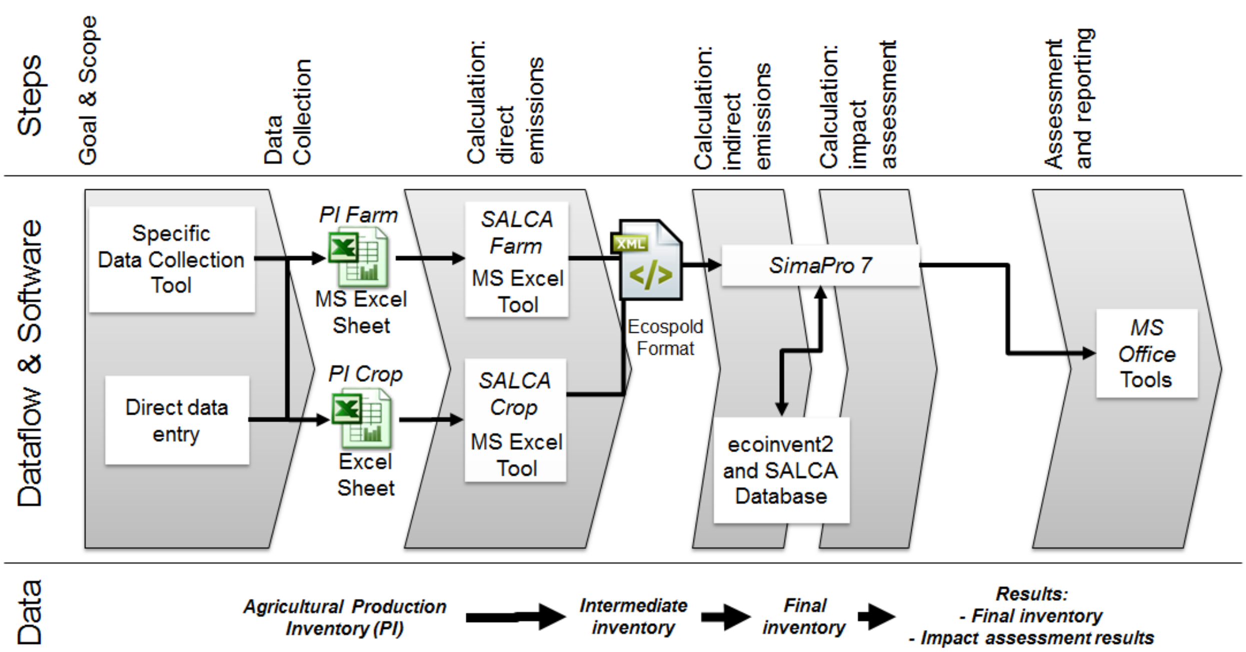

Figure 1: Current workflow, dataflow, and tools, according to the steps of a typical agricultural or food LCA project with SALCA*farm* and SALCA*crop*.

In this general workflow, the main strengths of SALCA*crop* and SALCA*farm* tools are:

- high scientific quality
- reliability, automation, and efficiency of the calculation of direct emissions at crop, field, and farm and product level
- modular construction of emission models (models parameters and calculation can be rapidly adapted to the goal and scope)
- possibility to perform batch calculation of several farms
- based on a conventional software (Excel) that is understood by a important share of the LCA practitioners or agriculture specialists, and that allows quick adaptations.

In practice, an important amount of projects requires the development of a specific data collection tool. In addition, although the modular construction of SALCA*crop* and SALCA*farm* allows some rapid adaptations of the models, this is not the case anymore if the adaptations change the input structure of the modules (e.g. adding new inputs, or increasing the detail level of the inputs). In summary theses developments and adaptations are time-intensive and may increase the resources needed to perform field or farm and product LCAs, depending on the goal and scope of the LCA project considered. In the next section we will illustrate theses adaptations by taking the example of the CANTOGETHER project.

3. The workflow of CANTOGETHER

In the CANTOGETHER project, a goal and scope was set with the assessment of 10 case-studies for 17 products and 7 scenarios. The case studies were made of either conventional farms, experimental farms, or pool of farms at regional level. Some case studies were containing an important number of fields, with a maximal number of about 45 fields. The data providers were agriculture specialists but could also be farmers in some cases. In this context, a data collection tool with demanding requirements for flexibility and user-friendliness had to be developed.

In addition, the methodological choices that were made for CANTOGETHER implied the use of various tools, including conventional LCA software tools such as Simapro 8, but also specific modeling tools such as *SALCAfarm*, *SALCA-BD*, *SPACSYS*, *RUSLE2*, and *SIKtool-EFM* (Cederberg et al. 2013). This resulted in the workflow described in Figure 2, with the following elements:

- **CANCollect:** Excel-based data collection tool. A high flexibility is available, with for example the possibility to add pesticides, mineral and organic fertilizers with the corresponding properties (e.g. N, P2O5, K2O content) and the possibility to describe field management events with a high level of detail (e.g. including the date of the event). The inputs of each modelling tools were analyzed in-depth and synergies were exploited in order to reduce the amount of data to be collected.
- **CANCalc:** Excel-based tool that contains two modules:

  1) The data transmission module, which extracts the data from CANCollect and implements it in each calculation tool (adapted SALCA*farm*, SIKtool-EFM, RUSLE2, SPACSYS, SALCA-BD). This includes some sorting, mapping, and database queries. In other words the data is translated from a user-friendly perspective to a software-friendly perspective.

  2) An adapted version of SALCA*farm* that controls the calculations and extracts the outputs of the SIKtool-EFM, SPACSYS and RUSLE2, and integrates new inputs and methods (e.g. for the water stress index). The inputs needed are at crop, field and farm level.

- **SIKtool-EFM:** Excel-based tool that calculates the livestock enteric fermentation and manure management emissions. The inputs needed are mainly at farm level (Berglund and Cederberg 2014).

- **SPACSYS:** C++ based stand-alone tool with inputs and outputs of all components organized as a database in either Microsoft SQL Server 2000, Access 2000 or MySQL5.0. This tool simulate root systems, nitrogen cycling, phosphorous cycling, water flows, plant growth and direct emissions (Wu 2013). The inputs needed are mainly at crop and field level, including daily data for weather and field management.
- **RUSLE2:** C++/SQLite based stand-alone tool that is used to compute the erosion caused by rainfall and its associated overland flow (USDA 2008). The inputs needed are mainly at crop and field level, including daily data for weather and field management.
- **SALCA-BD:** Java and Excel based tool that assess the impact of agricultural land use on biodiversity (Jeanneret et al. 2008). The inputs needed are mainly at crop and field level, including monthly data for field management.
- **CANAnalyse:** Excel-based tool that extracts the results of the various tools involved and allows in-depth analyzes.

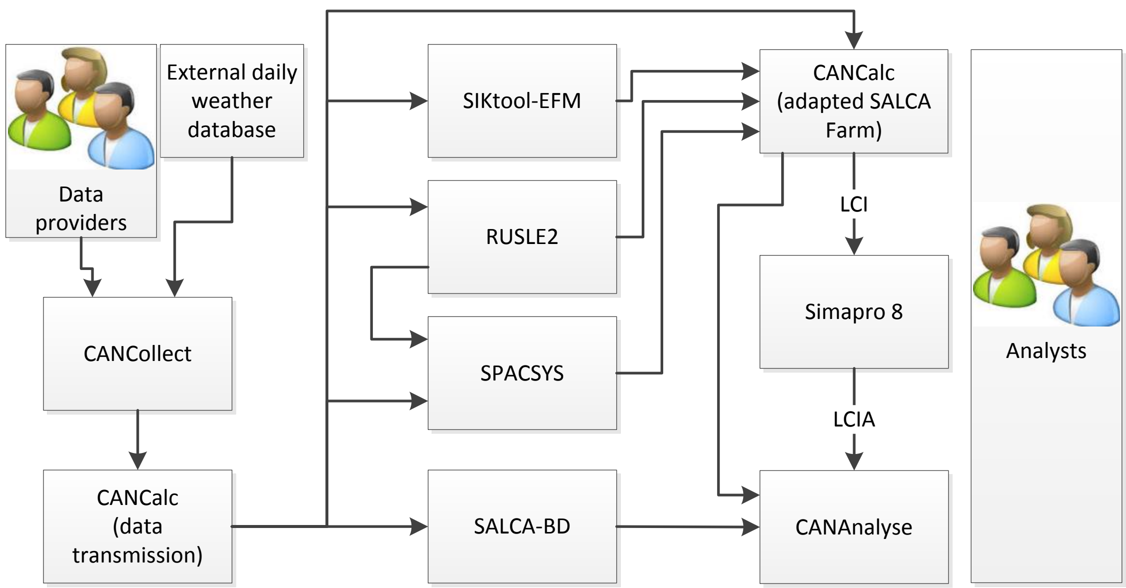

Figure 2: Workflow of the CANTOGETHER project, including the data collection tool CANCollect, the calculation tools (CANCalc, SIKtool-EFM, RUSLE2, SPACSYS, SALCA-BD and Simapro8) and the analysis and assessment tool CANAnalyse.

Most of the impact assessment results are calculated with the help of a traditional LCA software based on the inventory extracted from CANCalc. However, some tools deliver directly results at impact assessment level to CANAnalyse. For example, CANCalc provide the Water Stress Index (Pfister et al. 2009) for the water consumed at field level, and SALCA-BD provides a biodiversity assessment.

In summary, the development of the data collection tool CANCollect and the calculation tool CANCalc were resource intensive for the following reasons:

- Overall complex workflow for the data processing, with a high variety of links between the various tools
- Requirement of a user friendly data collection tool that can be transmitted to farmers and that allows to enter all the necessary data for the tools
- The presence of at least one crop or field level modelling tool with daily data requirements
- The presence of several stand-alone tools with their own lists of input data (i.e. their own terminology) and automation possibility
- The very large amount of data coupled with the presence of stand-alone tools: the overall solution must be automatized as far as possible.

Based on this experience of the CANTOGETHER project, the next generation of SALCA*farm* and SALCA*crop* should allow more extensive adaptations and avoid the development of a specific data collection tool for each LCA project.

4. The workflow of SALCA*future*

Projects in the field of agricultural or food LCA may have a high variety of goals and scopes which leads to different data collection needs, calculation models, and representation of results. As it was described in the previous sections, the tools SALCAcrop and SALCAfarm must be adapted and modified for most of the projects. In addition, the current excel input file is originally made for LCA practitioners and agriculture specialists and cannot be directly circulated to other stakeholders. This results in the development of specific data collection tools in most of the projects.

As described in the case of the CANTOGETHER project, some existing tools are already delivering some results at impact assessment level. This is due to the fact that some metrics are not integrated in traditional LCA software, because they are for example too specific to agricultural systems, or too recent. In the future, similar pathway would be necessary for new sustainability metrics that might not be supported in traditional LCA software (for example animal welfare, soil quality, social aspects etc.). Eventually this would allow integrating LCSA projects in the workflow presented before.

In this context, the project SALCAfuture was started with the aim of developing the next generation of SALCcrop and SALCA*farm*. The fundamental improvements are (Figure 3):

- A web-based application for the data collection, SALCA*collect*, with a high user-friendliness, and a data quality control. The data quality control will reduce the necessary number of data collection iterations.
- The merging of SALCA*crop* and SALCA*farm* in a centralized tool, SALCA*tools*, for the modelling of direct emissions. For the transparency and reproducibility of results, a version and user management will be implemented. In addition, it will be possible to import data based on .XML format
- The Implementation of Simapro 8 with the ecoinventV3 database
- A flexible analyzing and assessment tool (SALCA*analyse*)
- A high automation of the workflow
- A framework that allows the development of new sustainability metrics and eventually the integration of LCSA projects
- An improved accessibility for external user for SALCA*collect* but also for SALCA*tools* and SALCA*analyse*. This will improve the collaboration with partner in some projects, and also allow more transparency, allowing for example external reviews

In summary, SALCA*future* will be able to integrate a wide portfolio of LCA and eventually LCSA projects from the agrifood sector at an international scale. The web-application SALCA*collect* will, by definition, be easily circulated to any users, and will not require any installation of software. Typical users would be farmers, consultants in the agricultural sector, partners from others research institutes, or other specialists, and should be able to fill the data without any LCA knowledge. The modelling and calculation tool SALCA*tools*, and the analyzing and assessment tool SALCA*analyse* will be accessible to partners with LCA expertise, and will require the use of a widely available client software. The overall resources needed for the adaptations of the tools to a specific project will be reduced, allowing the data providers to enter data more efficiently and LCA practitioners to perform more in-depth assessments.

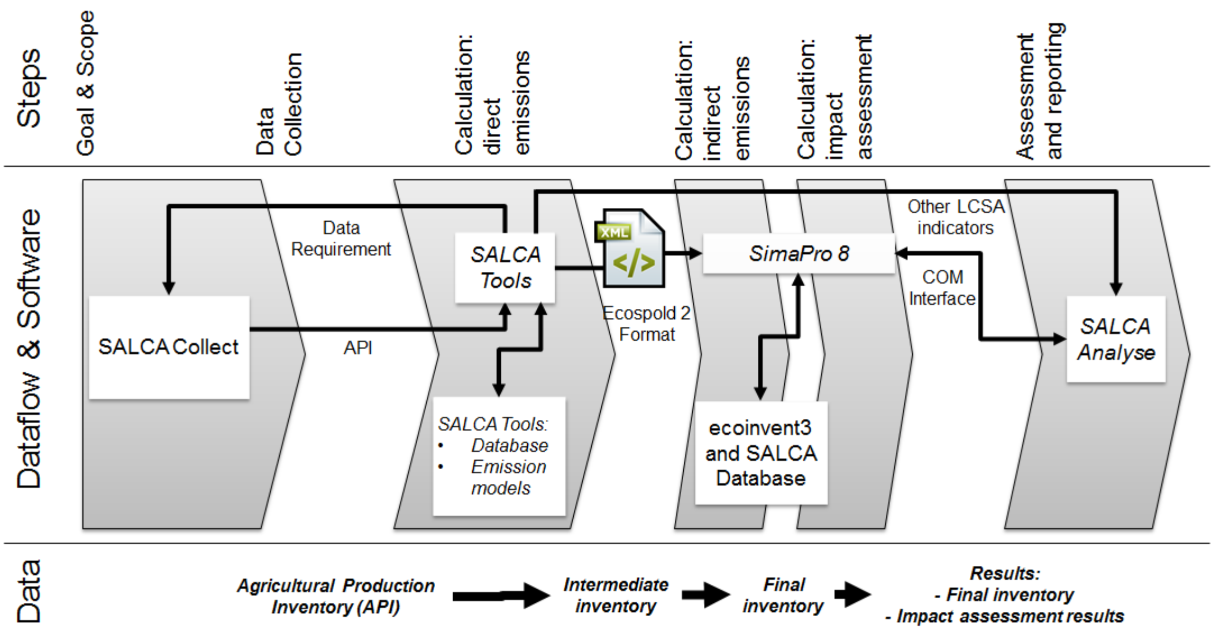

Figure 3: Workflow of SALCA*future* according to LCA Steps, dataflow, data, and the involved software.

6. Conclusion

In this paper, it was showed that current generic tools such as SALCA*crop* or SALCA*farm* can perform efficient calculation of Life Cycle Inventory (LCI) of agricultural systems. However, due to the very high variety of goal and scopes in LCA projects, a specific data collection tool must be developed, and some considerable adaptations of the existing tools must be achieved specifically for most of the projects.

This was typically the case for the project CANTOGETHER, with the development of a decentralized and flexible data collection tool, and with a vast adaptation of SALCAfarm including some integration of external stand-alone modelling tools.

Such developments and adaptations, specific for most of the projects, needs generally intensive resources and should be reduced with a higher flexibility of the tools. In addition, the specificity of agricultural systems and the emergence of Life Cycle Sustainability Assessment (LCSA) further increase the requirements in regards to the flexibility. To take these facts into account, the next generation of SALCA*crop* and SALCA*farm* was presented in the frame of the project SALCA*future*. In particular, SALCA*future* will handle these challenges and improve the availability of the tools for external users.

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