Soil quality indicators in Life Cycle Assessment

2nd Workshop Report

Dublin, Ireland – 18th October 2016

1 Session 1: Common session with LCA Pesticide Consensus Group

1.1 Peter Fantke, DTU

The usual assumption in LCA for dealing with the fate of pesticides is to consider that 100% of the quantity of active ingredient applied to the field ends up in soil. Over the last 4 years, a large group of scientists have worked together to improve this practice, using PestLCI as the starting point for simulating the fate of pesticides on the fields. The objective is to make available default pesticides fate factors that LCA practitioners can use in their studies.

This work followed a 4-step approach that we encourage other groups to follow, where there is a gap:

1. Build a team of international experts, practitioners and modellers
2. Strive toward consensus based on scientific state of the art and practicality
3. Provide financial frame for multi-year consensus building process
4. Identify and distribute work towards updating current LCA practice
    a. scenarios definition

We have counted 800 crops for commercial use at global scale. 172 crops have been retained based on their commercial value. 161 application methods and 2500 pesticides in use at the global scale have been counted.

This variability has been reduced to 18 crop classes (based on their morphology) and 6 application methods.

b. Emission model

The starting point was PestLCI. This software was modified to integrate consensual modifications over the last 2 years, in particular on:

- Wind drift
- Volatilization from leaves
- Degradation in crop
- Uptake into crops
- Volatilization from top soil

There is now a consensus version of the model.

Two types of distribution have been defined: primary distribution (first 5 minutes) and secondary distribution (first days after application).

c. Input data definition

Data are available for:

- 800 pesticides (physical chemical properties)
- 175 crop types
- 30 climate regions
- 122 soil classes

d. Output data definition

To make the output of the model usable, 2 sets of primary distribution factors will be available, depending on whether the agricultural process it is in your foreground or background system (default factors).

The aim is to make those factors available in LCI database.

For secondary distribution, it will take more time to develop partitioning factors.

1.2 Sandra Eady, CSIRO

The first workshop on moving forward on soil quality indicators in LCA aimed at understanding who is working on what aspect of soil quality. The objectives of this first workshop were to:

1. Establish a comprehensive list of soil processes and how they influence soil quality
2. Differentiate impacts and indicators
3. Get a common understanding and vocabulary
4. Understand the full comprehensive impact pathways
5. Start to think about characterization

The following workshop sessions after the introductory session held concurrently with the Pesticide Consensus Group covered progress against these objectives.

1.3 Q&A

Olivier Jolliet asked how the proximity to water was handled. Tim Grant indicated that very detailed spatial data have been looked at and that a probability of a water to be close to the field was derived. There are still some problems in specific regions.

Christel Renaud wondered if the inorganics are covered. One workshop member indicated that she is working on the evaluation of inorganic states of metals for LCA. It is the starting point for including inorganics in this approach.

Gérard Gaillard asked about the term “pesticides” and whether is covered the active ingredient only of the solvent as well. Peter Fantke indicated that pesticide means active ingredient that is applied. Solvent have been disregarded as they are often not known (proprietary data). The primary emission is more driven by the active ingredient type than the formulation. The most important point to consider is the metabolism of the active ingredient. Sometimes they quickly metabolise into something else, and it is that molecule that is to be considered (e.g.: DDT into DDE).

Someone asked if greenhouses plantations and crops that are grown for non-human consumption are included. Peter Fantke replied that greenhouse production is a different system. So far, only open fields have been considered. For non-human consumption crops, the same model can be used, there is no difference in the scenario.

Ulrike Bos asked about the level of uncertainties and whether farmers have been involved in this process. Peter Fantke indicated that farmers were not consulted. The primary target for this piece of work is LCA practitioners. Farmers are more about risk and contamination, whereas LCA people are more about emissions. Regarding uncertainties, we are just starting to identify the factors that influence the results and based on that we are looking into how to aggregate and capture the variability. Ulrike Bos asked for first/worst and average value. Peter Fantke agreed.

Thomas Nemecek asked if this framework is to be used with all toxicity indicators. Peter Fantke stated that yes, this was the initial scope of the project. However, we don't have all the categories covered. The model developers will come to PesLCI people and see how they can connect to your factors. With human toxicity, we tried to link best with the existing indicators. Ralph Rosenbaum noted that there is no reason why this wouldn't connect with terrestrial toxicity.

Carole Sinfort was surprised to see aerial application for Europe as this application method is forbidden. Tim Grant replied that they were a bit reluctant to exclude de facto certain scenario as they may happen in some very particular cases. Peter Fantke added that for the map, all possible configuration have been included. For the data to release we will focus only on realistic scenarios.

Erika Castanheira asked if GM crops are included. Peter Fantke noted that the FAO crops database was used and GM crops are not differentiated. However, GM crops may not grow in a very different way compared to non-GM crops. So this difference is not addressed in the model.

Angel Avadi asked if urban/peri-urban agriculture addressed. Peter Fantke replied that to date these systems are excluded. Only open fields outside urban areas are covered. To account for the proximity with cities would be a next step. Tim Grant added that the analysis of what is outside the field should pick up part of that issue. In the case of horticulture, there is likely to be cities just outside horticulture areas.

Xavier Bengoa asked how good and average practice are differentiated and how emissions to agricultural soil versus natural soil are differentiated. Peter Fantke noted that USETOX distinguishes the two types of soils. Good practice can be easily defined whereas to define average practice, data need to be collected from the users. Is it to be noted that the definition of good and average practices is not in line with regulations.

Someone wondered what should be done when the agricultural system lies in between background and foreground data and if regional level dataset will be available. Peter Fantke asked to follow up this discussion as it is very important to get input from users to see at what level the aggregation should be made. Ralph Rosenbaum added that the 2 datasets are 2 extreme cases and that something in between is needed.

Andreas Brekke from Research Norway asked how this framework links to non-toxicity impact assessment categories. Peter Fantke indicated that it is not planned to use these factors for other impact categories than the toxicity ones, as pesticides do not contribute to many other indicators. However, consistency between categories should be kept.

Tim Grant noted that the secondary processes modelling is breaking the rule of impact assessment, as it is going a bit further than the inventory stage. A similar approach is followed by the group on soil quality indicators. Peter Fantke added that it was a decision to move forward at the inventory level as we have good data to do so.

Olivier Jolliet agreed that it makes sense that the people doing the LCI are doing the partitioning as they have very good data. However, we need to think about the interface, this also applies at the consumption level. This pesticide secondary partitioning could still part of the impact assessment, but done by the practitioner.

Ulrike Bos noted that LANCA follows a similar approach to pesticides.

2 Session 2: Framework for Soil Quality Impact Assessment

2.1 Vincent Colomb, ADEME

See Vincent Colomb's presentation.

ADEME supports ecological transition in France and is a long-time supporter and user of LCA. There is a demand for soil to be better considered in LCA – from industry and food producers as well as from government. The priorities in accounting for environmental impacts from agricultural practices are GHG accounting, followed by biodiversity and by soil quality.

In developing the area of soil quality and LCA it is important that the framework accounts for positive and negative effects, is able to capture best agricultural practices. A too global approach will not provide a useful tool for the industry.

The application of LCA needs to be understandable and acceptable for non-LCA specialists, discussion with agronomy community are needed.

Operational case studies are also important to ensure the practicality of the approach developed.

2.2 Assumpció Antón, IRTA

See Assumpció Antón's presentation.

The Global Guidance project on Life Cycle Impact Assessment (LCIA) hosted by the UNEP-Setac Life Cycle Initiative can provide useful insight for the development of soil quality indicator.

The phase 1 of this project dealt with biodiversity loss and land use. The proposed name of the indicator is "Potential Species Loss from Land Use". A Biodiversity impact pathway has been developed over the past years and slightly updated over the last month.

The phase 2 of this project is to build consensus in several LCIA areas, and in particular on ecosystem services with initial focus on soil quality. There is an EOI form for people to participate in this task force. The action plan is the following:

- Method review (starting point Vidal et al JCP 2015, extend review?)
- Pathway agreement (starting point biodiversity TF)
- Reference states for soil quality assessment
- Stakeholders workshops (when? where? budget?)
- Call for case studies

Case studies will happen early rather than waiting to the end of the work plan.

2.3 Sandra Eady, CSIRO

See Sandra Eady's presentation.

There has been a lot of research on land use mainly in the context of biodiversity (Int J. LCA 2013 on "global land use impacts on biodiversity and ecosystem services in LCA").

The follow-up task from the previous workshop was to develop impact pathway for soil quality that:

- identifies all soil processes
- establishes definitions for terms and a common language
- indicates whether these soil processes should be considered as elementary flows in inventory or parts of the impact pathway (e.g. how is soil acidification included in the acidification impact pathway?)
- establishes more broadly which impact categories elementary flows contribute to
- and proposes a characterisation factor that allows diverse soil quality measures to be aggregated for impact assessment.
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Sandra Eady presented the results of a categorization of what, in current impact pathways, are baseline soil conditions, soil processes, elementary flows and impact indicators for soil quality.

For the particular case of Australia's concern regarding soil quality, 3 important soil processes were selected as case studies: mineralization and immobilization of organic matter, soil acidification and soil erosion. Some practices (e.g. retaining stubble and planting in between rows) have a demonstrated benefit on soil quality in Australia and should be reflected in a soil indicator.

Once the processes are selected, the starting point is to define soil processes, the associated soil baseline properties, activity data and elementary flow as well as to what indicator the elementary flows contribute.

The main observation is that a lot of information is already available at the inventory development stage (biogenic CO_2, N_2O, H^+ to soil water, quantity of soil to air and water, …) .

The next step is to decide where to include these information on soil quality

1. Entering a particular land use as the inventory flow and relying on characterization factors in the impact assessment
2. Assess the elementary flows associated with soil processes and include them directly in the LCI

Today, we already indicate CO_2, CH_4, N_2O, NH_4, P and N flows in the inventories that are associated with land use.

In practice, an attempt to quantify all these parameters was made :

- Soil acidification: can be calculated based on current soil pH and a mass balance accounting for fertilizers and lime input and grain cation export rate

- Soil erosion: RUSLE (Revised Universal Soil Loss Equation for soil loss to water) was implemented. However, quantifying wind erosion was difficult.

- Soil carbon (mineralization and immobilization of soil organic matter): this was difficult to assess in the case of crop rotations. Using a production system model is possible (e.g. APSIM) to capture the range of management interventions that influence SOC. After quantifying these processes, the next step is to aggregate them into an indicator, using characterization factors. None of the existing models appeared to be satisfying. An alternate approach could be to use plant growth models to determine how soil attributes affect biomass production (in kg/ha) and take "yield gap" approach that determines the influence of soil quality attributes on achieving potential biomass yield.

3 KEY OUTPUTS FROM THE INTERMEDIATE DISCUSSION

There are a lot of different potential impacts affecting soils. We need hence to take into account that:

i. Not all the potential impacts are to be assessed at the same time scale;
ii. Not all impacts have the same importance in terms of severity across the globe;
iii. If not all impacts can be assessed, we should nevertheless first focus on critical irreversible impacts;
iv. Not all impacts on soil are related to quantified fluxes, which is critical within the LCA framework
v. There are critical aspects also related to the spatial assessment of impact on soil quality, e.g. erosion upstream and downstream impacts

Before continuing with the presentations and discussions, the group agreed on the fact that lots of work and development have been carried out and that the group does not start from scratch. The objective of the group is to work toward a consensus building based on the existing work and the existing consensus on the LCA framework that should be considered, i.e. starting from the work from the biodiversity taskforce and the JRC model review. Despite this reach baseline, a clear common understanding on soil quality, involved processes, existing models and LCA implementation constraints need to be reached in order to build-up together a road map for a quick uptake of existing models and an agreed trajectory towards improving further impact pathway modelling.

4 SESSION 3: OPTIONS FOR CHARACTERISATION OF SOIL QUALITY ATTRIBUTES

4.1 Gérard Gaillard, Agroscope

The first important point to note is that this discussion takes place in the context of a full LCA, including the 4 phases, not only in the context of the impact assessment only. The goal and scope of the study is important at first to define which impacts and methods we need to look at depending on the objective of the LCA. We also have to think for which type of LCA we need to characterise soil quality.

In an LCIA, 2 steps are compulsory: classification and characterization of impacts. Thus, before characterization, we need to speak about classification. Is there a soil quality in LCA? Or several categories contributing to soil quality? If everyone wants to work with endpoint, then there is no need for midpoint indicators.

What is very important in the impact pathways is the link between different blocks. For example, the challenge is how to define erosion in relation to “exergy”. Establishing this link is the hard task.

There is a need to clearly define clearly what is soil quality prior to LCA scientists jumping in. LCA people are the ones structuring the information. Not the ones creating it.

Soil quality can be defined as “interaction of soil functions and soil properties in an ecological context” or as the “capacity of soil to function”.

It has to be kept in mind that there is also a soil use. In that context, soil quality can mean “ecological functions” or “anthropogenic uses”, or both! This single word can be used for different meanings. As LCA people, we can study both, but not necessarily under the same impact category.

Regarding ecological functions of soil, a lot of soil scientists think it is not possible to compensate between functions. We need to take this into account. For example, improvement of soil organic matter is useless if there is erosion! In some literature, soil biodiversity, water, climate are important impacts in relation to soil. We need to be consistent with other working on soil related issues and indicators.

Regarding anthropogenic uses, it is difficult to define a meaningful use. Biomass can be for food, fiber, feed, fuel.

An alternate approach could be to use grouping which brings in a totally subjective grouping and ranking of impact, which is done more at the interpretative stage not at the LCIA stage.

As a conclusion, defining the context and objective is key. The way soil quality is defined influences the way impacts on soil quality might be assessed. The ecological point of view could lead to consider soil quality as a resource, which would have consequences on the modelling impact pathways potentially directly up to the endpoint. The anthropogenic point of view rather focuses on characterizing how soil use and practices may affect the degree to which soil functions can be fulfilled. As soil quality is defined by various properties and functions, it seems rather counter-productive to seek for a single impact category. Sub-categories could be defined at various points on the impact pathway (i.e. as done in SALCA SQ or LANCA). As the various functions may not necessarily be affected in the same way and do not compensate, aggregation of sub-category indicators for the purpose of interpretation and decision-making process might only be relevant at the interpretation stage, using logical sciences to weight and group indicators based on the scope and objective and the stakeholders co-construction..

5 Session 4: Models to provide Key Data for Soil Attributes, Elementary Flows and Characterisation

5.1 Serenella Sala, JRC

There is a need to better distinguish impact due to different land management. The charts of characterization factors (CF) are very telling. There is not much differentiation.

In the context of the product environmental footprint (PEF), the recommendation is to use the soil organic matter to approach land use impacts. However, this indicator disregards many important soil functions.

Several Land Use models and characterisation factors were reviewed. The current evaluation found that none of the models fully meets all features required by the defined criteria. However, LANCA, which provides CFs for soil functions reflected on 5 indicators (erosion regulation, groundwater replenishment, mechanical filtration, physiochemical filtration, biotic production) appears as the most complete from different point of views, such as environmental relevance, elementary flows coverage, availability of CFs at country scale.

Following this review, the recommendation is to use 4 of LANCA indicators (erosion resistance, mechanical filtration, groundwater replenishment and biotic production) as mandatory indicators.

There is a high need in complementing these indicators with other soil quality parameters (salinity, desertification, compaction …), to reduce redundancy amongst indicators, to improve nomenclature and description, and to improve the link between these indicators and endpoint indicators. The spatial resolution of datasets is also a difficulty to overcome.

All this information will be made available through the Product Environmental Footprint (PEF) website (http://ec.europa.eu/environment/eussd/smgp/dev_methods.htm)

6 Questions

Regarding the grouping approach, Marie Trydeman Knudsen asked how this is done in practice. Gérard Gaillard replied that logical sciences and logical trees could be used to that end. He added that all midpoint indicators are not at the same levels and that the grouping allows to rank and identify what is important for the goal of a particular study. It is a qualitative approach.

Sandra Payen asked if ecological functions of soil covered in the biodiversity task force. Assumpció Antón answered that they are not fully covered, but should be included there.

Someone wondered why, when we deal with the anthropogenic uses, we are not talking about the impact of soil degradation on ecological function? In the end we want to know if we degrade the soil or not and its impact on both the ability of the soil to deliver food, fibre and fuel as well as ecological functions. Sandra Eady replied that in Australia, the interest is on the impact of agricultural production on the ability of soil to deliver anthropogenic uses (food, fibre, fuel). The ecological functions is something different.

Angela Fiore noted that the two dimensions are necessary. The reference state for anthropogenic use might be "yield gap" while for ecological function might be a natural reference state (that could be quite low yielding for biomass).

Montse Nuñez asked if there are any case studies under the PEF. Serenella Sala replied that case studies have been carried out on electricity mix, laptop, but not only agricultural products. A difference between products is observed when land flows are leading to erosion.

Gerard Gaillard asked in what context the PEF approach is valid. Serenella replied that in the PEF context, the aim is to make a comparative assessment, to work towards ecoinnovation. This approach is valid for a general purpose of comparison in the context where there is a lot of uncertainty about the location of the production.

7 Session 5: Reference States for Land Use impacts such as Soil Function

7.1 Tim Grant, Lifecycles

Reference states were discussed during the Pelston workshop in Valencia, January 2016. There are reference states in most methods, but we don't realize it. Some reference states are fixed, some other evolve with time or location. In land use, there is almost always an explicit reference state:

- Pragmatic vs normative: Predominantly pragmatic ref state.
- Fixed or flexible: Often fixed
- Transformation impact: degradation x time to recover
- Occupation impact: time x lower state of quality

Are reference states needed? In consequential LCA, we observe the difference between 2 systems with the same reference state. In theory, a reference state is not needed. However, as the impact is not linear, you do need a reference state.

What are current reference states? It is the potential natural vegetation (PNV) or the undisturbed natural vegetation?

7.2 Questions

Vincent Colomb asked whether a time related (ex: 20 years old) situation could be used as reference state. For Tim Grant, time plays a big role depending on the land use (arable or forest). It might be difficult to define the proper time period.

Ulrike Bos indicated that in the LANCA model, the reference state is the "best" reference situation. There are other land use type that are better than the reference situation.

Cécile Bessou stated that we need to have a reference state that is globally applicable. The reference states also depend on the goal and scope of the study.

Ralph Rosenbaum added that in practice, reference states are dictated by data availability. The discussion around reference stated is important for awareness raising, but it is very theoretical as it relates to data availability. There is a big consistency issue with reference state in LCA. For attributional LCA, you would need completely different characterization factors because most of the characterization factors we have are marginal CF. In consequential LCA, non-marginal CF are needed (?).

Tim Grant noted that the biodiversity task force produced average and marginal factors.

Peter Fantke called for stabilizing what we call a reference state. That could be capacity, or optimal capacity. Any change marginal or large scale will be measured against its natural optimal.

Gerard Gaillard added that we need to be more situation or context senstive. An ideal reference state is ok, but if it is to compare different wheat, it is not that relevant. So it depends of goal and scope.

8 CONCLUSION

8.1 Conclusion by Tim Grant, Lifecycles and Assumpció Antón, IRTA

This work is now part of the UNEP/SETAC task force. This will run until 2020, but we need to start now. The proposed structure of the tasks is as follow:

- **Group 1:** Soil quality definition and data. The objective is to clarify what soil quality and soil quality attributes are.

Skills: soil science, agronomy, forestry, ecosystems, agronomic modelling

- **Group 2:** LCA Method Development for Soil Quality: how to incorporate soil quality into impact pathways, impact assessment models.

Skills: modelling, impact assessment.

- **Group 3:** Case studies: Case studies of LCAs using existing and new approaches for incorporating soil quality into LCA to demonstrate and explore how each works and how results are sensitive to methods.

Skills: applied LCA

Tim Grant added that in the pesticides consensus group, the PestLCI model was a starting point for improvement. What is the status of LANCA and its openness to evolve through a group like this?

Ulrike Bos replied that LANCA is an umbrella for calculating indicators and can evolve to integrate new indicators and models. The CF are available on the website.

- **Group 4:** Link soil function contribution to other impact categories and link through to the endpoint (ecosystems, but all other endpoints as well)

Tim Grant stressed that there should be interactions between these 4 groups, and a similar timing.

The group agreed on the fact that the method developed needs to be sensitive to management interventions.

Regarding the participation to the task force: to level of commitment exists:

- **Task force members:** actively participate in the task force and contribute to the method development

- **Agenda members:** stay informed of the task force progress

The Worshop presentations and report will be circulated to all participants and posted to the Soil Quality website.

9 PARTICIPANTS LIST

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