Soil quality indicators in Life Cycle Assessment

Workshop Report

Bordeaux, France - 30th August 2015

1 SESSION 1: SETTING THE SCENE AND GOALS FOR THE WORKSHOP

1.1 Sandra Eady, CSIRO

This workshop was first initiated by CSIRO. There is a lot of LCA development for agriculture in Australia, and one of the request from the funders is to start looking at soil indicators. In this context, a first workshop was held in Australia with Australian soil scientists and agronomist. The particular focus was on soils in terms of ability to produce food, in order to be able to identify where it is relevant to increase food production while minimizing environmental footprint. More research is clearly needed on this topic, and international collaboration in this particular area is key.

Hence, this first international workshop on soil quality indicators aims at:

- Developing a shared understanding of soil quality issues and indicators in LCA
- Develop a roadmap for progress
- Form an informal network of relevant researchers and organisations on this topic

The format of this workshop was inspired by the pesticide consensus workshops that have happened over the last 2 years.

1.2 Vincent Colomb, ADEME

ADEME welcomes and supports this initiative, as consensus on key issues in developing agricultural LCIs is important. The Agribalyse project in France aimed at improving knowledge and developing agricultural LCIs in the aim to reach out to consumer.

More and more LCA data are available, it becomes important and critical to compare them. Therefore, it is key to have common ways to treat some aspects in LCA.

1.3 Cécile Bessou, CIRAD

CIRAD is in particular involved with soil organic carbon issues, and is welcoming this initiative.

1.4 Tim Grant, Life Cycle Strategies

See Tim Grant's presentation.

Soil functions need to not only be looked at locally for farm analysis but also more globally, when developing lifecycle data at regional and national levels.

Under the UNEP/SETAC Life Cycle Initiative guidelines on land-use impact assessment, it is not clear what the impact pathway for soil quality and functions should be.

The main questions for the group to answer and make progress on are:

- Is the current framework and guidance for impact pathway sufficient?
- What is required to further its development?

Ulrike Bos noted the importance of the reference situation (base line against which comparisons can be made). It is needed to have a common understanding, and the direction should be to refine existing frameworks.

2 SESSION 2: ATTRIBUTES OF SOIL FUNCTION IMPORTANT FOR ABILITY OF LAND TO DELIVER PRODUCTION

2.1 SOCLE project, general framework for soil carbon and soil function in LCA, by Cecile Bessou, CIRAD
See Cécile Bessou's presentation.

The SOCLE project (Soil Organic Carbon changes in LCA) will review and draw recommendations on how to model LULUC[1] and the impact of agricultural practices on soil organic carbon and greenhouse gas emissions.

Key aspects that will be considered are soil organic carbon dynamics, and attributional versus consequential modelling (including baseline-related issues) as well as reversible versus irreversible processes. Synergies and consistency with other soil functions modelling will also be investigated.

2.2 Integration of soil carbon changes in LCA studies, with focus on energy crop production , by Thomas Prade, Lund University
See Thomas Prade's presentation.

The objective of the project was to assess energy crop production environmental impacts in relation to the EU directive for fuels. Soil carbon changes are difficult to measure, long term experiments are used for calibrating SOC models.

In this project, SOC was calculated according to IPCC guidelines, calculating crop residues and then taking the average of the first 40 years. This result was then included in the LCA model. SOC appears to be a very high part of avoided emissions, and further work will be carried out to refine the models.

The results show that it is important to evaluate crop production systems, not only individual crops. Further, considering the relationship between soil carbon, fertility and yield is key.

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[1] Land Use and Land Use Change

2.3 Development of soil quality indicators in agricultural LCA application to pig production and vineyards, by Emmanuelle Garrigues, independent researcher
See Emmanuelle Garrigues' presentation.

A framework for assessing soil quality, in particular erosion, compaction and change in soil organic matter was developed with the objective to assess different sites with different agricultural practices. The method used is the ACV-SOL modelling approach: erosion is calculated based on RUSLE2, SOC change based on RothC. Soil specific indicators require additional parameters not typically used for other environmental indicators.

The first case study on including an anaerobic digestor for pig manure slurry shows not much effect on typical LCA indicators (such as …..), but reveals a high impact on soil indicators (SOM, compaction) and no effect on erosion.

A second case study on vineyards will be investigated, considering 5 types of management practices, 6 planting densities, 3 different slopes and 2 planting row orientations, making 180 combinations. For this modelling, erosion will also be predicted with the RUSLE2 model.

2.4 Crop specific erosion and runoff characterization factors for land use: are spatial and variability crop type relevant, by Manuele Margni, CIRAIG
See Manuele Margni presentation.

The objective was to analyze the relevance of archetypes for LCA spatialisation, in particular:

- Is the discrimination in characterization factors (CF) between crop types relevant?
- How important is spatial variability of CF across the world?
- Are archetypes relevant?

The CF were calculated for 3 crop types (corn, soybean, wheat) and using the harmonized world soil database (FAO).

Results show a high variability for erosion and runoff and that the same median values are observed for different regions across the world. However, at a single location, the results for different crops can vary. The calculated values are consistent with generic values under the UNEP/SETAC Life Cycle Initiative.

It appears that biomes do not seem to be a relevant regional differentiation, as intra-biome variability is higher than inter-biome variability. Further, it appears not necessary to differentiate between crops, but necessary to specify across the globe.

2.5 Session 2 discussion
Sandra Eady noted that this shows one example of where and to what extend it is needed to regionalize.

Ulrike Bos asked what these results mean with respect to the impact pathway framework.

Manuele Margni added that for the impact assessment, biome should not be used as the resolution scale, but that it seems preferable to keep the resolution of the inventory (eg country) and then to provide uncertainty results due to variability.

Tim Grant pointed out that if biome is not the appropriate scale, we need more testing to identify whether we need to go up or down regarding the resolution.

Manuele Margni added that the ecoregion scale is to be tested next.

Carole Sinfort noted that there are a lot of methods and practices for conserving soil. How are there methods accounted for in these models?

Emmanuelle Garrigues replied that nothing is done on this topic.

Ulrike Bos indicated that if a better resolution is available, this should be calculated. From their experience, the finer the GIS scale, the better the information, and then you can calculate your specific land use factor for the region of interest.

Manuele Margni indicated that the approach could be to use generic factors, and then adjust according to specific practices.

Tim Grant stated that the aim is to build an impact method generic enough for everyone to use, but that can allow specific characteristic if known by the LCA practitioner.

Marie Knudsen and Cécile Bessou pointed out that a consensus on time frame is needed, as different approaches are used (eg. for GHG, 40 years in Thomas Prade work, and 20 years for Emmanuelle Garrigues work).

Emmanuelle Garrigues added that the 20 years' time frame was chosen based on the fact that after 20 years, no carbon can be stored anymore. This is the usual timeframe recommended by IPCC.

Thomas Prade added that 20 years period is what the IPCC guidelines recommend. Using 40 years was a more conservative choice.

For Cécile Bessou, soil depth is another very important parameter.

Hansrudolf Oberholzer insisted that the time perspective is key when measuring effects.

Maricke van Leeuwen asked how the secondary consequences of a SOM loss as well as feedback processes are accounted for.

Emmanuelle Garrigues and Thomas Prade replied that no feedback processes were included. Soil compaction has no feedback on other indicators.

Manuele Margni added that the modelling of the consequences can take place through other indicators.

Cécile Bessou stated that in inventory development, time frame and carbon types need to be looked at. Different CF for different biogenic carbon will be needed depending on how stable the various carbon pools may be

Hansrudolf Oberholzer added that for SOC measurements, threshold effects are important.

Tim Grant asked whether there is a justification for representing different soil carbon in inventories.

> **The group agreed on the following key points to be considered in further work:**
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> - **Spatial scale**
> - **Time perspective, saturation-equilibrium**
> - **Feedback and interdependence of soil functions**
> - **Thresholds and properties**

3 SESSION 3: IMPACT ASSESSMENT

3.1 Salinization impact modelling in LCA: description of different, state of the art of salinization LCIA methods, limitations and recommendations, by Sandra Payen, CIRAD

See Sandra Payen's presentation.

To date, salinization is poorly included in LCA. There are 3 published methods on salinization but their scope is limited and they required intensive inventory data. There is clear need for a consistent approach.

The major methodological issue is the technosphere/ecosphere boundary:

- To account for impacts on soil → part of soil is in the ecosphere
- To account for management factors → part of soil is in the technosphere
- To account for impacts on agricultural land → soil has to be temporary included in technosphere

The LULUC framework is a good basis but doesn't allow for assessing off-site impacts. This could be pointed out as a limitation of the current LULUC framework.

3.2 Calculating soil quality indicators using LANCA® (Land Use Indicator Value Calculation) in Life Cycle Assessment, by Ulrike Bos, University of Stuttgart, LBP-GaBi
See Ulrike Bos' presentation.

The LANCA model calculates 5 indicators, and the background data is now caclulated using data from GIS maps :

- Erosion resistance
- Mechanical filtration
- Physicochemical filtration
- Groundwater replenishment
- Biotic production

User data availability is key and sometimes problematic, that is why an uncertainty study is conducted for the LANCA indicators.

The inclusion of SOM into LANCA is possible. The challenge is to agree on a consistent choice for the reference situation and land use types.

3.3 SALCA-Soil Quality, by Hansrudolf Oberholzer, Agroscope
See Hansrudolf Oberholzer's presentation.

SALCA-SQ is multi-indicator LCA with 9 soil quality (SQ), calculated by an excel tool. These indicators are physical, chemical or biological indicators.

Based on management practices and local climate/soil conditions, the tool calculates impact classes and aggregates them into soil indicators. Aggregation is suitable for communication purpose and doesn't affect the accuracy of LCA results but it is not suitable for advisory use.

The tool is currently based on Swiss conditions, but its design is modular and hence adaptable to other regions. The current focus is on arable land, grassland is in test phase.

The tool was designed for use in LCA as well as for advisory purpose. It is data intensive.

An approach to aggregate the 9 indicators, based on logical decisions, is currently under development. This would suit LCA objectives, but would not be precise enough for advisory at the farm level

3.4 Land use modelling: review of models, impact pathways, indicators and characterization factors towards a robust and comprehensive midpoint assessment of soil functions, by Serenella Sala, JRC
See Serenella Sala's presentation.

The aim of JRC undergoing work is to be spatially resolved as much as possible.

The ILCD handbook was published in 2011, and was used as the basis in the PEF as consistency is needed.

It is necessary to go one step further to achieve more practicality. Some models will be preselected and tests will be carried out. Model developers will take part to the tests?

Selected models calculate indicators for assessing soil properties/functions and or threats. These are not necessarily models for LCA, but are at least compatible with LCA.

The last impact pathway was published in 2011. There are discussions about an improved impact pathways, to take into account the models that have been developed since 2011.

The main findings to date are:

- A lot of reference information is required (= before intervention)
- It is difficult to identify mid or end point indicators

Issues that need to be addressed:

- mapping of the inventory flows
- discrimination power of the method, in comparison with the uncertainty of the inventory itself

3.5 Land use modelling: review of models, impact pathways, indicators and characterization factors towards a robust and comprehensive endpoint assessment, by Assumpció Antón, IRTA

See Assumpció Antón's presentation.

Two Expert workshops on biodiversity impact indicators in LCA were held in 2014 (San Francisco in October 2014 and Brussels in November 2014).

After a thorough revision of different LCA and non-LCA methodologies to assess biodiversity loss due to land use interventions, 30 models were included in the final assessment, of which 19 were developed specifically for impact assessment in LCA and 11 originated from non-LCA fields

Based on this process, the proposal for soil indicators could be:

- come to a consensus on what is the impact pathway for soil
- agree on the scope of soil impacts and indicators

For biodiversity, the main findings are that there is clearly a need to model CFs in terms of both:

i.   local damage factor for land use linked to the functional unit, and
ii. regional "state and pressure" weight to reflect broader biodiversity patterns and processes surrounding the location of land use

3.6 Session 3 discussion

Ralph Rosenbaum asked if there is any documentation for the LANCA model.

Ulrike Bos replied that documentation is freely available online.

Sandra Eady asked the group how far there is an agreement on impact pathway for soil.

Sandra Payen raised the question on what to consider as an area of protection for soil. She pointed that it is important to avoid double counting and overlapping with other indicators.

Jeremy Rodriguez wondered if this question doesn't relate to the transparency of endpoint models.

Sandra Payen noted the difference between top down approaches and bottom up approaches. The latter allow to follow the impact pathways. For salinization, she added that if different methods are used, there may be a consistency issue.

Assumpció Antón stressed that first, mid-point and end-point indicators need to be identified.

Peter Fantke agreed that with a single method, the path from mid to end point is done in a consistent way, and that it is difficult to ensure consistency when mixing methods.

George Michalopoulos asked is there an ideal situation we would like to be regarding biodiversity, and that should be taken as the reference point.

Ralph Rosenbaum answered that it is difficult to answer this question, it is as much an ethical choice as a reference choice, and there is no scientific way to define this.

Cécile Bessou agreed that it is really important to agree on impact pathway, building on the work done for the biodiversity indicators as similar processes and indicators enter into play.

Serenella Sala added that JRC is considering other impact indicator, and try to align. The major question is how to combine existing models to assess all the midpoint indicators related to soil.

4 SESSION 4: FRAMEWORKS FOR THINKING ABOUT SOIL FUNCTION, SUBSEQUENT IMPACT ASSESSMENT, PRIORITY OF WORK

4.1 Soil attributes in LCA: mid-point and end-point framework and indicators, issues with land-use and biodiversity, by Ralph Rosenbaum, IRSTEA, ELSA-PACT
See Ralph Rosenbaum's presentation.

Land use was historically a resource impact category. Based on the land-use and biodiversity work, the main questions to consider are:

- Is land use an impact category or an elementary flow?
- Which midpoint indicators are relevant for soil quality attributes?
- What about double counting with other midpoint impacts?
- How many indicators can LCA take?
- Which endpoints are relevant?

A link should be made with the work carried out under the UNEP/SETAC Life Cycle Initiative group on cross-cutting issues. This group deals in particular with issues such as reference state and time horizon. Some consistency is probably needed across indicators and methods.

4.2 Discussion
Ralph Rosenbaum added that what is called an intervention could be a collection of elementary flows.

Ulrike Bos noted that these questions of consistency are really important. For addressing the local specificity and agricultural practices, the LANCA model allows to adapt to different agricultural practices.

Marguerite Renouf stressed that if this process moves forward, it is needed to be coherent with the framework and processes.

Tim Grant noted that food production and subsequent link to human welfare are not considered as an area of protection in any of the impact pathways.

5 BREAKOUT SESSIONS
The group broke down into two groups.

5.1 Breakout session on impact pathways
The group discussed the topic of what should be the impact pathways for soil, starting from the impact pathway proposed by the JRC and the one proposed during the work on biodiversity indicators.

The group noted that some processes and indicators for soil are missing from the diagrams:

- soil biodiversity
- soil acidity

Some other indicators should be accounted for differently for soil quality such as albedo.

There was a lot of debate regarding the definition and scope of midpoint indicators.

For Cécile Bessou, SOC change is not a midpoint indicator for a particular impact category (although it is used as proxy for soil function in the Land use impact category by Milà I Canals et al.), but rather contributes to many other impact categories including climate change and soil quality.

Ralph Rosenbaum indicated that it is better to make the distinction between processes and indicators: there is first an intervention, then some processes take place, leading to an impact.

Cécile Bessou added that under this working definition, erosion would be a process, and soil loss an elementary flow contributing to one or more impact indicators.

Peter Fantke noted that if there is some emission identified here as impacting soil quality, then it should maybe be taken into account in an emission based indicator. For example, nitrogen and carbon emissions that are treated under e.g. eutrophication and climate change indicators.

He recommended to be exhaustive and comprehensive, and then to identify what should be covered under existing indicators and what should be considered under soil indicators.

5.2 Breakout group on "transversal issues"

Six key issues were identified by the group consisting of

- Reference system
- Soil as part of ecosphere, technosphere or both
- Time scale of inventory
- Time scale in LCIA
- Spatial scale of analysis
- Land use inventory development for new impact assessment – are new inventory flows need to model soil quality

Reference system

The group first discussed the reference system to be considered and raised the question whether we should consider a reference state that is representative anthropogenic demands on land rather that referencing back to a natural state. It's possible that cultural perspectives may be needed to develop model alternatives similar to the ReCiPe and EcoIndicator 99 method.

Land use inventory development for new impact assessment

The starting point is that land occupation/transformation flows already exist. Discussion around inventory flows took place. Change in SOC was seen as possible flow to include

directly in the inventory, however archetypes for this may also be need to more general LCA databases not focused on agricultural LCA specifically.

Soil as part of ecosphere, technosphere or both

The question is what else should be included? Should some of the environmental mechanism be assessed at the inventory level, in order to account for the effect of good agricultural processes? The line between processes assessed at the inventory level and those assessed by the impact model needs to be decided. How can the impact assessment models take into account the effect of good agricultural process?

Spatial scale of analysis

The group discussed the scale of application of LCA. The indicator we want to develop may not be suitable at the farm scale. Defining archetypes would be useful to come to a practical solution, otherwise it will be needed to wait for spatialized LCA to develop and become the common practice.

As a first conclusion, there is an agreement that there should be different modelling approaches, allowing for refining the results if more information is available locally: tier 1 approach with default values, tier 2 approach with more refined data.

The discussions moved to spatial scale. The group noted that there is a need to check if there is a benefit to improve the scale and the resolution. In particular, how good is the ecoregion scale? By definition, these regions might be too much ecological and not agricultural focused.

The group also discussed on multi-origin LCA and how to account for different regions and regionalized CF into a single LCA.

6 CONCLUSIONS AND NEXT STEPS

6.1 Conclusions

Based on the discussions on impact pathways, the following was agreed:

1. **Collect all processes connected to soil and land to soil quality.**
2. **Put the puzzle together in relation to whether parameters are elementary flows in inventory or parts of the impact pathway (agree on the terms, language and definitions, and whether they are processes or indicators).**
3. **When possible, allocate these to impact categories to components of the impact pathways that already treat that flow (eg SOC related to climate change).**
4. **If the impact is not already captured elsewhere, or if it is a factor that influence soil quality (eg. SOC related to soil fertility), allocate it to a soil quality indicator.**

Later, when aggregating midpoint indicators into a possible soil quality indicator, it has to be kept in mind to carefully ensure that positive effect on soil quality do not counter negative effects.

The following considerations should be kept in mind:

- Consistency with existing frameworks
- Technosphere/ecosphere boundaries
- Inventory/Impact assessment boundaries
- Data availability and practicality
- Variability and discrimination power (good versus average practice)
- Global versus local approaches

6.2 Next steps

Serenella Sala, Cécile Bessou and Sandra Eady will look into adapting the impact pathway to account for soil processes, impacts and indicators.

The second important task is to think a bit more about the reference situation and what could a non-natural reference state.

The group agreed on other actions to keep the momentum of this workshop:

- **Setting up a diffusion list to allow for group discussions**

- **Report part of this work to the UNEP/SETAC Life Cycle Initiative Pellston workhop to take place in January 2016**

- **Link with the UNEP/SETAC Life Cycle Initiative group on cross cutting issues, in particular regarding the evolutions of the midpoint/endpoint framework**

- **Next meeting in 2016 in Dublin, back to back with the food LCA conference**

Recommend/promote the topic to the next UNEP/SETAC Life Cycle Initiative indicator development group

7 ANNEX 1 – PARTICIPANTS LIST

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8 ANNEX 2 – PHOTOS