Sustainability Performance Assessment of Farming Practices

Guidelines for developers of quantitative monitoring tools

Version - 1.0

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Note for the reader

This report presents guidelines for the Sustainability Performance Assessment of farming practices, as recommended by SAI Platform. It aims to guide developers of farm-reporting tools towards the use of more farmer-friendly, practical and uniform indicators, methodologies and approaches.

The current report should be seen as the 1.0 version, which will be revised and further developed in the coming years. Future versions will include suggestions for a sharper focus and further improvement, based on feedback received from end users. Moreover, the future version will include additional priority themes in the realm of animal welfare, economy and social issues.

Companies developing software tools for monitoring and reporting sustainable farming are encouraged to make use of these guidelines for further deployment of their tools.

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1 Introduction

In a nutshell
This report outlines the choices and calculation rules for a future computerised system for measuring sustainable farming. These general rules are meant to guide software developers and builders of farm-reporting tools towards more uniform assessment.

The project contributes to the following vision:

> Food companies across the globe, directly or through suppliers, ask farmers to collect and upload *the same set of farm data.* Uploading of the data is user-friendly (via computers, mobile appliances and internet) and standardized. Calculator tools are "standard agnostic": *they can handle most units* (acres and ha) and *all use the same uploaded farm data as input* for calculating the indicators. The output of the tools is also standardized. The *output is a standard set of indicators*. Companies may choose their own priority indicators for the output. Companies can also decide with which benchmark(s) they want to compare the indicators: average farm score per region, corporate average, trends per farm over the years, etc. Feedback to farmers is done via the same user-friendly system (uploading and downloading via the same appliance), allowing farmers to see the sustainability performance indicators of their own farm and comparing these to regional averages or the farmer's own previous year's performance.

Towards more uniform assessment of sustainable farming
The Sustainable Agriculture Initiative Platform (SAI Platform) is a food-company initiative to support development of sustainable agriculture. It groups together over 40 food companies and affiliate members. More information can be found at www.saiplatform.org.

SAI Platform has embarked on a project called Sustainability Performance Assessment (SPA). The aim is to arrive at more uniform criteria for measuring and reporting on-farm sustainability. In other words: food companies in the future would like receive from their suppliers robust and consistent data, allowing compilation of data on farmers' sustainability efforts in uniform formats.

This future SPA-system will allow:

- Farmers to compare their performance to other farmers in the same region (country/continent), and to track their own performance over the years.
- Farmers to understand the various impacts of their practices on the three pillars of sustainability, and to adapt these practices over time so as to mitigate those impacts.
- Food companies to assess performance of their supply base (farmers) over the years, and to some extent benchmark their scores to other food companies sourcing agricultural products in the same region.

This report outlines the choices and calculation rules for a future computerised system for measuring sustainable farming. These general rules are meant to guide software developers and builders of farm-reporting tools towards more uniform assessment.

From principles and practices to metrics
SAI Platform has already defined Principles & Practices for sustainable farming (P&P, to be found at the SAI Platform website). The challenge is to get from these general descriptive P&Ps to something that can actually be measured: to express performance into *metrics*. This step is outlined in this report.

First the main *issues* were identified: the big building blocks of sustainable farming. SAI Platform has decided to focus on the following issues:

1. Climate change and energy
2. Pesticides
3. Soil quality
4. Water quantity
5. Nutrients
6. Biodiversity
7. Land use
8. Animal welfare
9. Occupational Health and Safety
10. Financial stability

Criteria for choosing these issues are that the issue:

- is important in all agriculture sectors;
- is relevant at farm level;
- can meaningfully be put into numbers to measure trends, and these numbers can be derived from information easily collected and supplied by the farmer;
- is not covered implicitly by other themes.

Two examples of themes not explicitly included but implicitly covered are: water quality and waste. Farmers generally do not measure water quality in water courses around the farm, so asking farmers to enter data on local water quality is not feasible. Nutrient load and pesticide pollution are the most important drivers for water quality around the farm. Nutrients and pesticides are covered as separate issues. Therefore, water quality is thought to be sufficiently covered by these two issues.
Waste is not in the list of main issues. Organic waste is covered by the balances calculated in 'Soil quality' and 'Climate & energy'; inorganic waste (plastic, rubber) is not measured by farmers and is not extremely important at farm level.

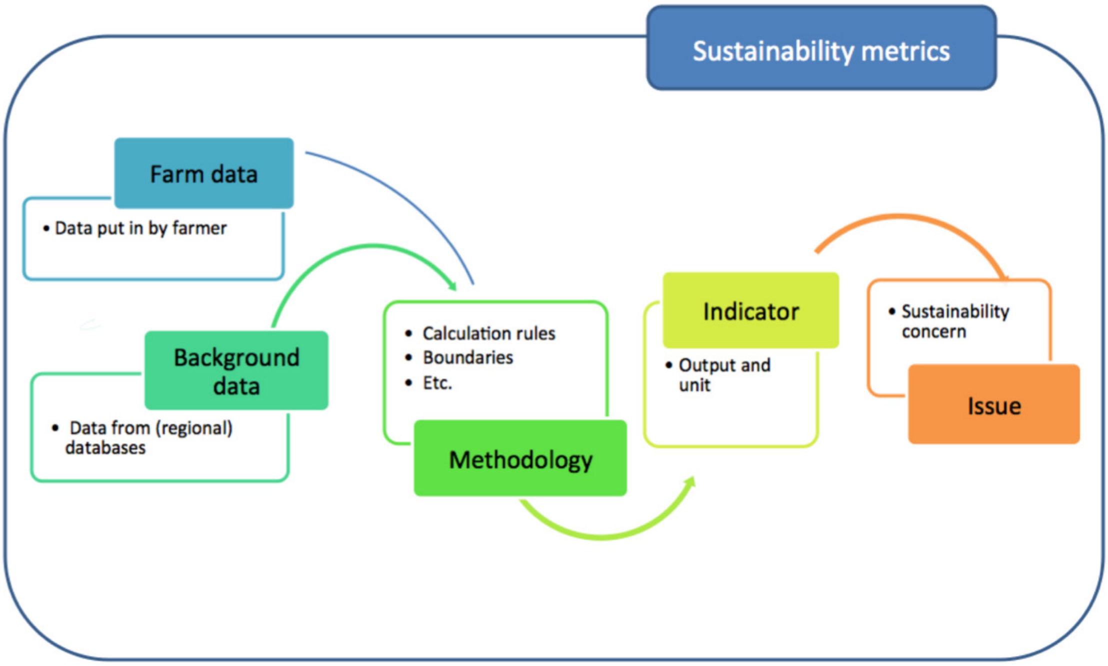
This report covers the first 7 "planet" issues. Further issues will be added in the future. SPA will build on work done by the dairy sector on indicators for animal welfare.

Core elements of sustainability metrics

We have defined "metrics" as "quantifying sustainable farming". When setting rules for how to do that, we work with four core elements:

- Essential farm data as input (data entered by the farmer).
- Essential background data as input (defaults and reference data for countries and regions).
- Methodology (calculation rules, boundaries etc).
- Output indicators (units in which performance is expressed).

These core elements together form the SPA Guidelines for software developers to build assessment systems or tools. The graph below outlines the coherence between the core-elements.



Basic demands for the system
SAI Platform recommends a system with the following basic requirements:

- Output must be quantitative data.
- The tool must be computer based; preferably internet based, and ideally also suited for smartphone.
- It must be user-friendly. Farmers enter data into the system in a limited time by themselves, unaided by advisors (though supported by a manual).
- Target group: (computer) literate farmers or their co-operatives.
- The system must feed back results real-time to the farmer; it facilitates learning and ideally gives practical suggestions.
- The system must compare farm results to a benchmark.
- It must provide reports at farm level.
- Output indicators must be compiled in a central database, anonymously.
- The system must allow flexible reporting and data comparisons.
- All SAI Platform priority issues (listed above) must be covered.

Following these basic criteria, the SAI Platform system is meant to be practical rather than scientific, simple and accessible rather than exhaustive.

Re-inventing the wheel?
Readers may be tempted into thinking that the SPA system will duplicate existing systems. It may do, partly. However, it responds to several needs that existing tools do not entirely satisfy. For instance, SPA overlaps with quantified parts of existing reporting systems like Unilever's Sustainable Agriculture Code - but that is a very extensive system for collecting yes/no data and individual data. Similarly, Nestle's RISE system covers (more than) all, but RISE requires several hours of interview and support by a farm advisor. Systems like Keystone Field to Market and Simpatica come very close to what SPA envisages, but for now cover too few crops or are too complicated for farmers to fill in, respectively. The many existing computerised farm management systems that farmers use for day-to-day management do not cover all SPA-issues. Finally, some single-issue tools exist which come very close to the SPA Guidelines in SPA – but these are single issue tools, like the Gaia Biodiversity Yardstick and the Cool Farm Tool.

So far no system exists that fulfils all basic requirements listed above.

A practical way of getting to a practical SPA-system would be to develop plug-in tools for existing farm management systems. For instance, the above mentioned single issue tools could be added to crop management systems.

What the system is not meant to do
It is important to note that the SPA system is not meant for enforcing compliance to standards. It is meant for data collection and aggregated reporting. At farm level it aims to raise awareness and track improvement.

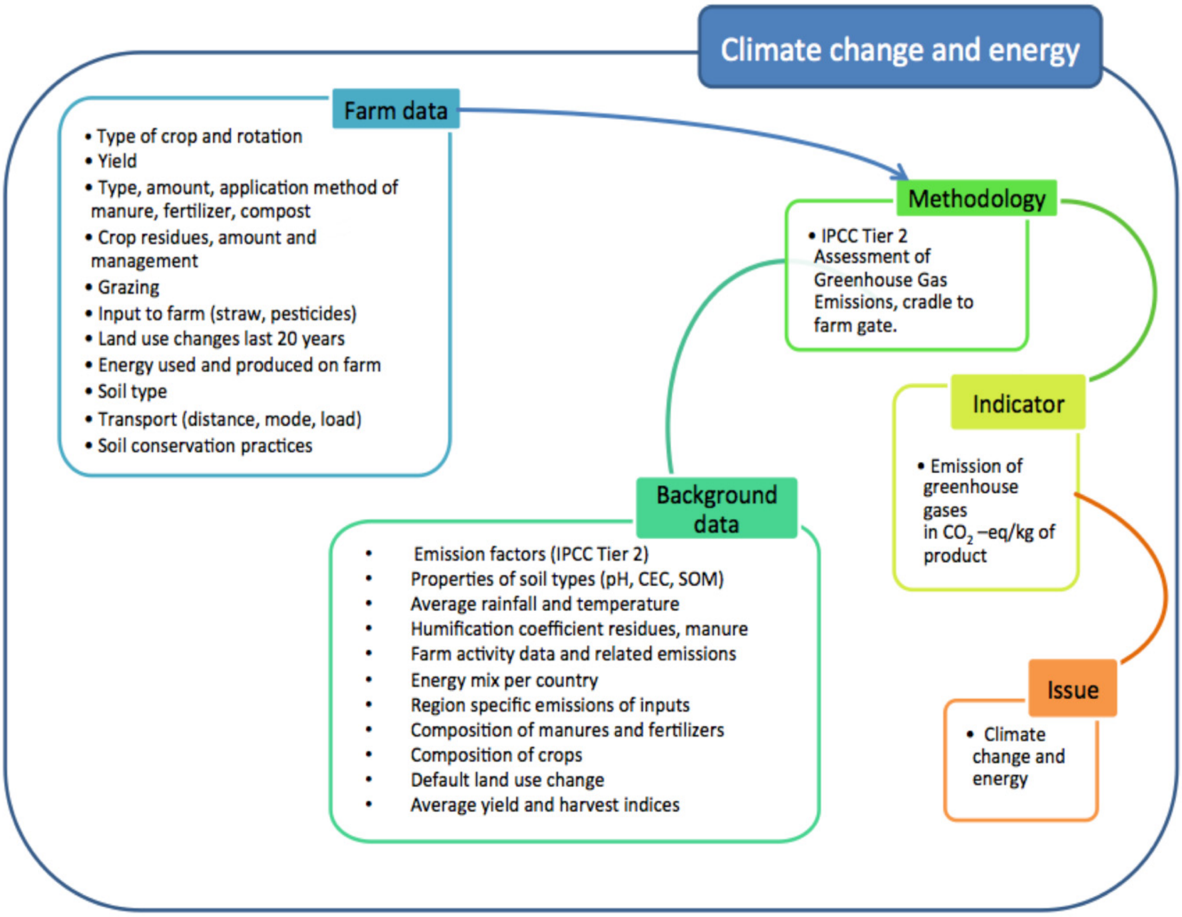
Sustainability B2B and B2C certificates are meant to assure general good performance, often more focused on good planning and management than on-the-ground quantified performance. Such certificates usually do not measure annual progress. The SPA system is meant as an additional source for insight, and not meant to replace market certificates.

Process of developing SPA Guidelines
The guidelines in this report build upon work done in 2011: setting priorities, identifying indicators and scanning existing sustainability tools. The Centre for Agriculture and Environment (CLM) in the Netherlands has carried out the work. Subsequently, in 2012 CLM described the draft SPA Guidelines. In spring 2012, external experts from science and practice were approached to reviews drafts. Some 11 experts provided input; their names are listed in the annex. It should be noted that, although these experts gave input, the final responsibility on the choices made and the contents of the report lie with SAI Platform and CLM.

Outlook
The SPA Guidelines (version 1.0) are published in April 2012. SAI Platform naturally has intellectual ownership of the SPA Guidelines but not of the tool(s) which will be developed or adapted to follow these. Everyone is free to use the SPA Guidelines as they like. Companies developing software tools for monitoring and reporting sustainable farming are encouraged to make use of the SPA Guidelines for further deployment of their tools – in a way that is endorsed by SAI Platform Members.

The International Dairy Federation (IDF) is currently working on a concerted approach to sustainability indicators and methodologies. A logical next step is to align the ideas in this report with the approach developed for the dairy sector by the IDF.

2 Climate and energy



1. The issue

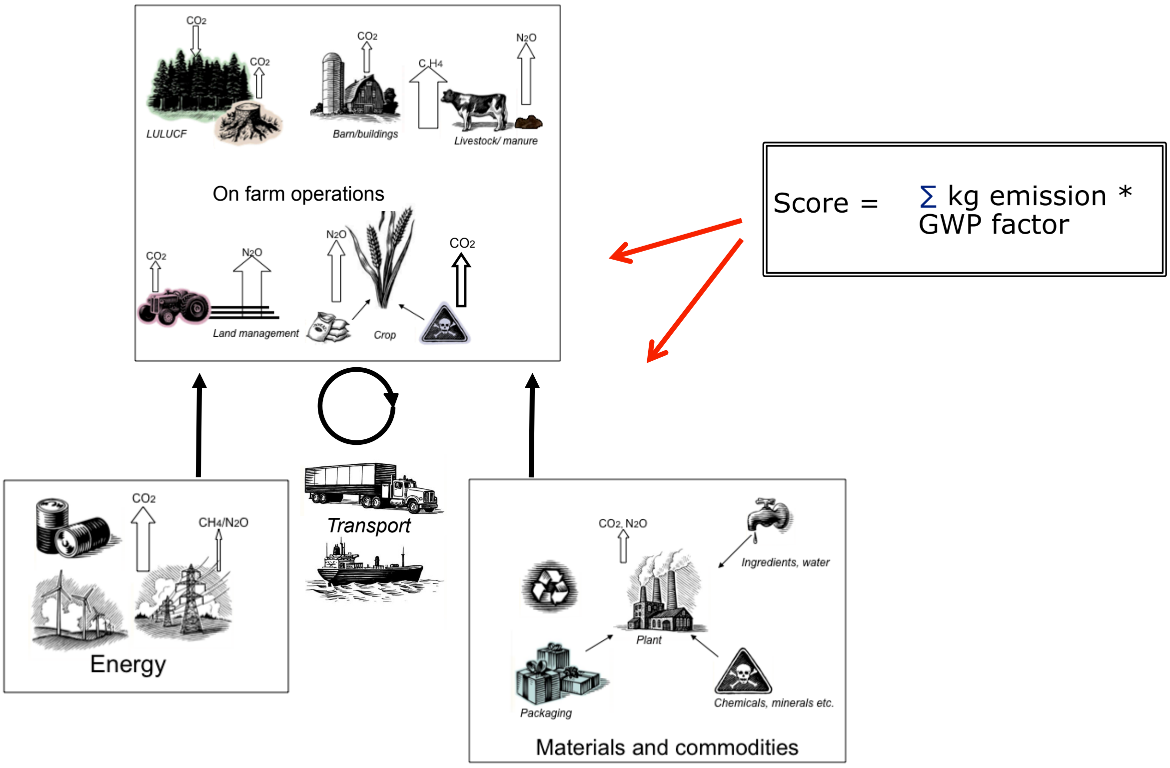
Climate change is a problem that affects people and the environment. Concern over climate change means that greenhouse gas (GHG) emissions are now a priority for many sectors of the economy. Agriculture is, on the one hand, an important emitter of greenhouses gasses (CO_2, N_2O and CH_4) but could also a prominent role in efforts to address climate change. Farmers can undertake activities that reduce GHG emissions or take GHGs out of the atmosphere. To evaluate current emissions and the effects of activities on farming, a methodology is required that can handle the diversity of farms and farm management, and which can be converted to a tool which gives sound and clear outcome with a minimum of farmer effort.

Important challenges are in identifying the system boundary, the sources of GHG emissions associated with farming/ agricultural products that fall inside the system boundary, the data requirements for carrying out the analysis, and the calculation of the results.

The methodology builds on existing methods for estimating and calculating greenhouse gas emission such as IPCC, PAS 2050, ISO 14040/ 14044 and IDF for the assessment of GHG emissions of agriculture and agricultural products.

2. Output indicators

The output indicator is: emission of greenhouse gases expressed in CO_2-eq/kg[1] of product.



3. Methodology

System boundary
The boundary is set at cradle to farm gate, from input production (e.g. fertiliser) up to products leaving the farm. This can include products that had an extra on-farm processing step, e.g. drying or storing. To distinguish between products that had and did not have an extra processing step, the product description should mention additional processing steps after harvesting and indicate what the extra GHG emissions are due to additional processing.

GHG emissions to be included: at least 95% of the overall GHG associated should be incorporated in the tool. Therefore, all inputs and activities that potentially contribute more than 1% to the overall GHG emissions up to the farm gate are taken into account. Therefore, unless shown that inputs and activities contribute less than 1%, the GHG emissions of the following inputs and activities are taken into account:

- **Energy:** The GHG emissions associated with the production and use of energy inputs (scope 1, 2 and 3). This includes emissions at the point of consumption of the energy (e.g. emissions from the burning of diesel and gas). But also emissions arising from the production of the energy, including the generation of electricity and heat, and the growing and processing of biomass for use as a fuel.
- **On-farm operations:** The GHG emissions arising from the agricultural operations, including those from field activities, heating farm buildings, use of machinery, etc, shall be included in the calculations. More specifically, if relevant these should include emissions from:
  - Rice cultivation;

[1] Units can vary according to region. The system should be able to automatically convert from, for instance, hectare to acre and v.v.

- Manure management;
- Agricultural soils, N_2O emissions, direct (manuring) and indirect (atmospheric deposition and leakage);
- Use of energy carriers, from e.g field activities, transport, heating, lighting;
- Emissions from waste-water;
- Land use, land-use change and forestry (LULUCF) incl. sequestration.

▪ **Production of materials and commodities:** The GHG emissions from all processes used in the formation, extraction or transformation of materials used in agricultural production, e.g. fertilizer, feed, pesticides, propagation material, shall be included in the assessment, including all sources of energy consumption or direct GHG emissions associated with that formation, extraction or transformation.
Example:
  - Fertilizer production: emissions arising from the production of the fertilizer including mining or extracting of minerals.

▪ **Pre-farm transport:** The GHG emissions arising from road, air, water, rail or other transport methods shall be included in the GHG emissions. Note: transport emissions are often already included in the GHG emissions of materials or commodities used on farm. It is not a tool requirement that the results indicate separately the GHG emissions of transport.

Not to be taken into account are:

▪ Capital goods: the relative share in total emissions is low, whilst obtaining all necessary data is very time consuming. Therefore, the GHG emissions arising from the production of capital goods (buildings, machinery, etc.) shall be excluded.

▪ Waste and waste recycling: post-farm GHG emissions arising from final disposal (e.g. waste disposed of through landfill, incineration, burial and wastewater) of the final agricultural product shall be excluded. Note: on farm composting, manure digesting, etc, is not regarded as waste recycling and shall be included.

▪ Biogenic carbon: carbon incorporated into food and feed products, plants or animals shall be excluded.

▪ Breathing: exhalation of CO_2 from human or animals shall be excluded. Note: if applicable, CH_4 resulting from enteric fermentation of livestock shall be included.

▪ Nutritional requirements: human and/ or livestock energy inputs to on farm processes and/or preprocessing.
Example:
  - if fruit is picked by hand rather than by machinery;
  - transport or draught power provided by animals;
  - transport of humans: transport of employees to and from their normal place of work or and of advisors and representatives of farm-input providers shall be excluded.

Allocation

To distribute impacts among products that emerge from the same origin, allocation is required. For instance, in wheat production climate impacts must be divided over straw and grain. There are various ways to allocate the impact of co-products. The choice for a type of allocation can have a significant effect on the results. However, there is no common established method. ISO 14044 and PAS2050 give the best guidance in this respect.

The preferred approach is:

1) If allocation can be avoided it should be. This can be achieved by systems expansion or by dividing the unit processes to be allocated into two or more sub processes.
2) If allocation cannot be divided or isn’t practicable the preferred allocation is physical allocation or mass allocation.
3) If applicable supplementary requirements are not available or a physical relationship cannot be established, economic allocation should be used. To counteract price fluctuations, a five-year average on market prices should be used.
   When used, the method and proportion based on economic value used between co-products should locally/ regionally be uniformly applied.
   Especially for major commodities, it is preferable that per economical region one institution determines the economic allocation.

Arable crops
Many arable crops generate more than one product. In such cases economic allocation is the recommended allocation, because:

- Subdivision of the system is not feasible.
- It's difficult to find a physical relationship between the co-products that reflects the relation between inputs and outputs. E.g. straw is used for a different purpose than the grain.

Animal manure - production
If animal manure or manure derivative has a positive economic value the environmental burden of the production chain of the manure or derivate should be economically allocated.
If the animal manure has a negative value, e.g. the arable farmer gets paid to apply the manure, the animal manure or derivative should be regarded as a waste and no environmental burden during the production should be attributed.

Animal manure - transport and application
The environmental burden of transport and application of the manure is not specifically allocated and shall be attributed to the crop.

Global warming potential (GWP)
GHG shall be measured by mass and shall be converted into CO_2-equivalents using the latest IPCC 100-year global warming potential (GWP) coefficients.
IPCC 2007 (the latest available at the publication of this document) gives:

Carbon dioxide, CO_2:	1 CO_2-eq
Methane, CH_4:	25 CO_2-eq
Nitrous oxide, N_2O:	298 CO_2-eq

Functional unit
The preferred functional unit is: kg/ product sold. If there is an explicit quality distinction, e.g. in nutritive value, between products a correction factor is allowed but should be mentioned explicitly.

Calculations
For calculating the on-farm emissions the suggested method is IPCC Tier 2 as published in Good Practice Guidance and Uncertainty management in National Greenhouse Gas Inventories (IPCC 2001). For some emission sources IPCC doesn't suffice e.g. production of inputs and transport. For inputs the preferred method for calculation is using regional specific emission figures based on attributional Life Cycle Assessments (LCA) and for transport the preferred method is using regional specific emission factors per tonne-km[2] for the modality used.

Example of calculation [please note: we will not reproduce all calculation rules here, but refer to IPCC]: Direct soil emissions (N_2O)

IPCC calculation: N_2O emission $= \sum E_{ij} * EF_{ij} * 44/28$
Where:
E_{ij} = amount N in source (i) and soil type (j) (kg N)
EF_{ij} = emission factor for source (i) and soil type (j), in kg N_2O-N/kg N
44/28 = conversion factor from N_2O-N to N_2O

Important N-sources are:

- Fertilizer
- Animal manure application
- Animal manure droppings
- N-fixing crops
- Crop residues
- Remaining N (mud, ashes, etc.)

2 The transport of one tonne over one kilometre

- If significant, N in irrigation water.

4. Farm data

A distinction is made in crucial and useful data:

- Crucial: farmer enters only relatively simple "crucial" data. For any data not entered, defaults from the background database are used.
- Useful: farmer also enters the extra "useful" information. In this case fewer background data are needed.

The ideal system is flexible, allowing for both routes (more or less farm data entered) to calculate the output scores.

	Crucial	Useful
Type of crop and rotation (split in 1st, 2nd or combined, incl grass and legumes))	x	
Yield (e.g. tonnes/ha)	x	
Soil conservation practices		x
Type and amount of fertilizer, compost, manure	x	
Application rate (e.g. kg/ha)	x	
Application method	x	
Emission inhibitor		x
Split application		x
Crop residues (e.g. kg/ha)		x
Crop residue management (burning/plowing)	x	
Distance, load weight and modality of transport (miles, km)		x
Grazing (nr days/yr, hrs/day)	x	
Type of product used on farm (straw, saw-dust, propagation material, pesticides, ..)		
Amount (kg/year)	x	
Land use changes last 20 years (forest to arable or grassland and vv)		x
Use and type of energy and fuels	x	
Energy produced on farm and type	x	
Soil type	x	

5. Background data

- Emission factors: IPCC rules, Tier 2.
- Biotic and abiotic factors of soil types e.g. pH, CEC, organic matter.
- Weather data (preferably 5 year average): precipitation, temperature.
- Humification coefficient of crop residues and manure.
- Farm activity data and related emission, e.g. manure application, etc.
- Energy mix per country or country specific emission factors per energy carrier.
- Country or region specific emissions of inputs (fertilizers etc).
- Composition of organic manures and fertilizers.
- Composition of crops (N-fixation, crop residues).

And additionally, when farmers only enter the crucial data.

- Default land use change.
- Average yield; region and crop specific, primary production and harvest indices.

6. Preferences and rationale

In this chapter we have made a number of choices. Below we outline the main choices and the arguments for our recommendation.

- System boundary: from input production (e.g. fertiliser) up to product leaving the farm. This gives farmers the most perspective, since all measures in the farmers' grasp (e.g. reduce fertiliser input, choose alternative fertilizers, application methods or type of dryer) are included.
- Type of GHG: The methodology includes the three most important gases from both fossil and biogenic sources; CH_4. N_2O and CO_2. Although, other gases can have a significant large global warming potential (GWP-100) the overall contribution is small in the on-farm setting. Calculation rules: The complexity of the Tier 2 method achieves reasonable certainty, using regional and technology specific emission factors. It also requires intermediate spatial/temporal activity data. Process-based models (Tier 3) give a higher certainty and are therefore scientifically preferred above Tier 2. Process-based models, however, require explicit fine scale data e.g. fine scale soil maps, daily/weekly climate data, detailed information on feed, land use and management. Generally farmers do not generally have access to such data, making a tool based on a process-based model too complex to use. For certain regions where local variability can be managed and data on land use and verified activities can be easily obtained or is available, a process-based model can be the preferred choice. However, in practice this means that the tool will be a Tier 2 model with very specific region and technology emission factors. Therefore a Tier 2 tool should currently be used. However, in the future it may be that farmers become more familiar with the systems and metrics required that they can provide Tier 3 data.
- Allocation is very important to the final results. We have described the general approach to handle allocation. However, this approach can become problematic if different regions use different approaches. Furthermore, some cases/ sectors/ products are so specific that a more tailored approach should be developed.

7. References

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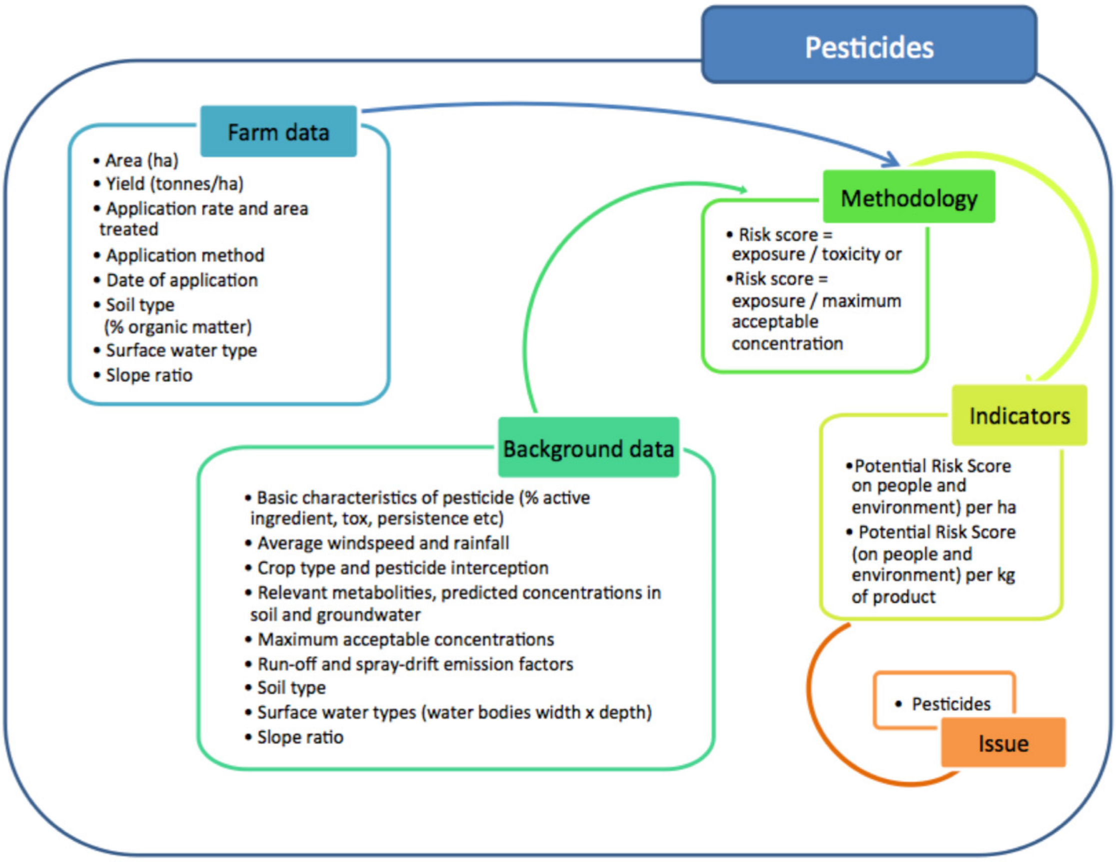
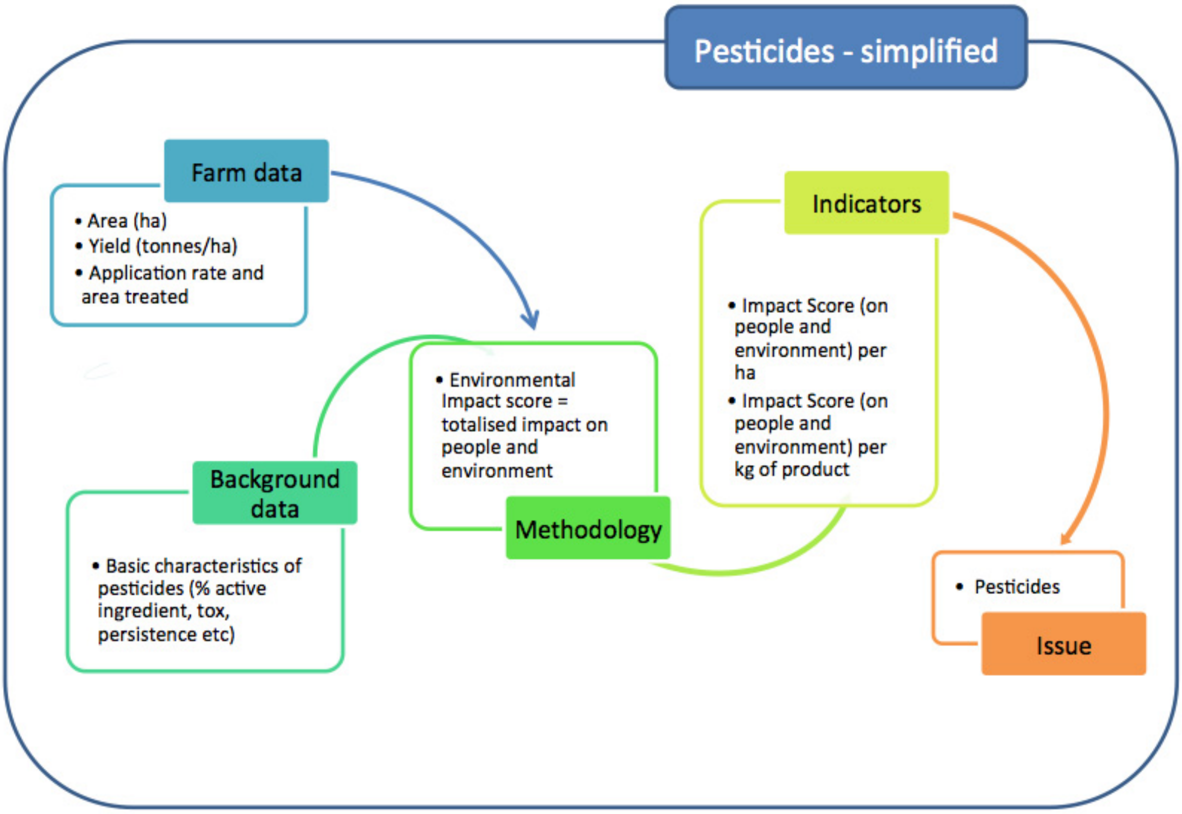
3 Pesticides





1. The issue

Pesticides are used to protect plants, to ensure adequate harvest output and economical food production. In some cases pesticides can also be harmful to the environment and humans. This risk depends on the characteristics of the active ingredient (e.g. toxicity, persistence, adsorption), the amount that is used, and the application method and circumstances. Often, farmers have opportunities to choose between pesticides and application methodologies that minimize the environmental risk.

Several tools to measure the environmental impact are available, often taking a different approach. The challenge is to identify a methodology that is globally useful, taking decisions about the system boundaries and the detail level.

2. Output indicators

The output indicator is: environmental impact of pesticide use expressed in a Potential Environmental Risk Score/ha and Score/kg product per year, on crop level and farm level. The score is based on pesticide characteristics, referred to a calculated predicted environmental concentration (PEC) after exposure.

If this is not feasible, a *fall-back approach* (see methodology) results in a less accurate output indicator: environmental impact of pesticide use expressed in an Environmental Impact Score/ha and Score/kg product per year, on crop level and farm level. This score gives the relative impact of pesticides, which can be used to rank them. Because exposure is not included in this calculation method, it does not give an indication of the real potential risk to people and the environment.

3. Methodology

System boundary
The system takes the following factors into account.

- Amount (kg/ha) per pesticide per field per crop per year.
- Potential impact of active ingredients (including relevant metabolites) on:
  - Surface water organisms (indicator species: algae, daphnia, fish)
  - Soil organisms (indicator species: earthworms)
  - Beneficial insects (pollinators, natural enemies)
  - Birds (indicator species: region specific)
  - Humans (people applying pesticides, pickers and consumers)
- Fraction intercepted by the crop (fraction on soil).
- Emission routes to surface water: spray drift and runoff.
- Persistence (DT_{50} on plant and in soil).
- Leaching to groundwater, predicted for 1-2 meters below ground level, based on persistence in soil, adsorption (K_{om}) and amount of rainfall.
- Impact on soil organisms is predicted for organisms in 0-1 meter below ground level.
- *Optional: Maximum acceptable concentrations (MAC's) are the reference values for the predicted exposure. MAC's concerning toxicity are based on the most sensitive organisms within the compartment multiplied by a certain safety factor (usually 10 or 100) and also the worst case value is chosen between the acute and chronic toxicity. The MAC's concerning leaching to groundwater in most (European) countries are 0,1 microgram/litre.*

Not to be taken into account are:

- Seed treatment with pesticides
- Emission routes to surface water through soil (and drainage) and atmospheric deposition
- Combination toxicity of different active ingredients together, nor the impact of repeated treatments.

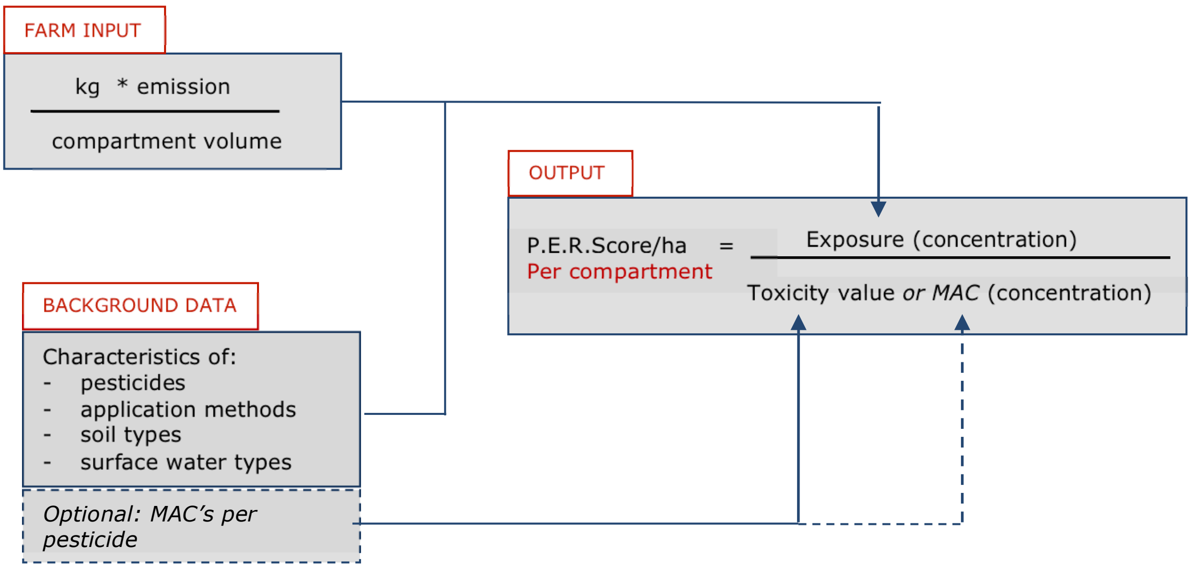
Allocation
Some pesticides are used to combat pests (e.g. weeds or nematodes) once in 2-3 years. The methodology allocates this use to the crop that is (to be) grown on the field in the season in which the pesticide is used. This is not the best way, but makes the input and calculation simpler.

Functional unit
The preferred functional unit for environmental impact is land and water surface: hectares/acres. The output of most other issues in other chapters of this report is kg/pounds of product. Therefore it is valuable to include an additional calculation to display the output in per kg product.

Calculations
For calculating the exposure of different organisms and elements of the environment there is no globally accepted and scientifically established guidance (like the IPPC for the climate methodology). The methodology described in this chapter is largely based on the European Guidance for the evaluation of pesticides necessary for registration (determined by the European Commission) and an analysis of existing pesticide risk indicators (see references). The methodology is in use in different existing systems such as EPRIP (Italy), EYP (CLM, Netherlands) and SYNOPS_2 (Germany).

In the calculation there is an option to compare pesticide impact with a reference level, like Maximum Accepted Concentrations (MAC), which are often part of (national specific) legislation.

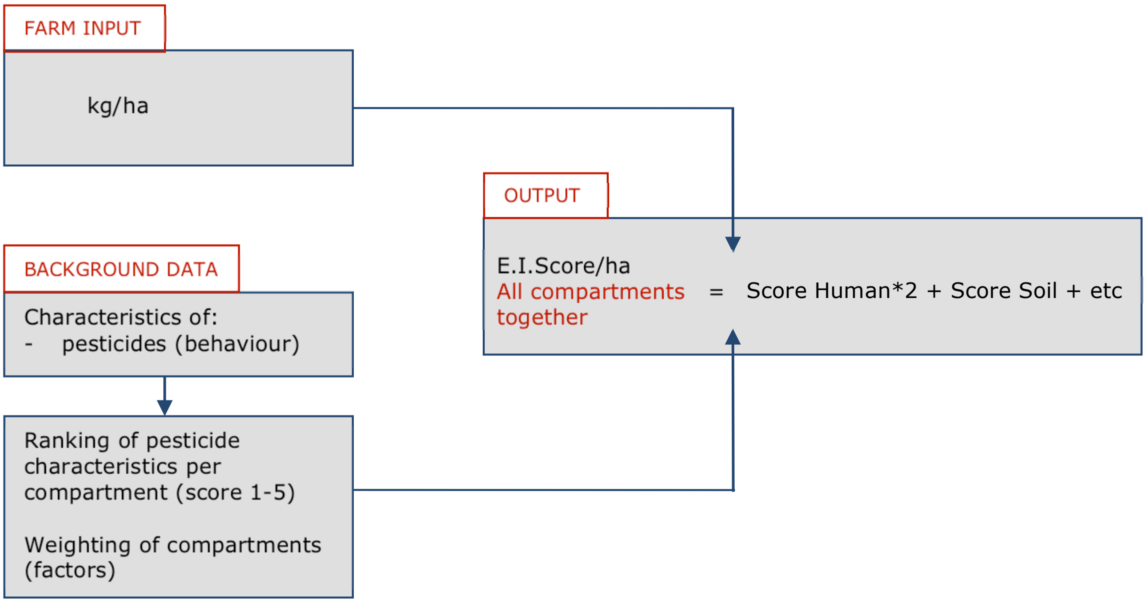
The methodology schematically is as follows.



Annex 3.A gives a more detailed example of the calculation rules.

Calculation - simplified fall-back option
The preferred methodology is to be based on substantive available background data and farm data. If such data are not available, a simplified version of the calculation can be used. This calculation excludes emission-routes and exposure. The simplified version is being used among others in the system called EIQ (USA).

The simplified methodology is as follows.



See Annex 3.B. for an example of the simplified calculation rules.

4. Farm data

A distinction is made in crucial and useful farm data:

- Crucial: farmer enters only relatively simple "crucial" data. For any data not entered, defaults from the background database are used.
- Useful: farmer also enters the extra "useful" information. In this case fewer background data are needed.

Farm data input	Crucial	Useful
Data below per crop	x	
Data below per field		x
Area (ha)	x	
Yield (tonnes/ha)	x	
Soil type (% organic matter)		x
Application rate: amount used per product name, area treated	x	
Surface water type (width x depth of receiving water bodies) in four classes		x
Slope ratio in four classes		x
Application method	x	
Date of application	x	

5. Background data

The following background data are needed for the preferred calculation:

- Average wind speed
- Average rainfall
- Crop type and pesticide interception dependent on height
- Basic characteristics of pesticides: % active ingredient per product name, relevant metabolites, toxicity, persistence, adsorption, etc.
- MAC's per active ingredient, if available

- Further characteristics of pesticides combined with application circumstances (soil and surface water types, application methods, weather) to predict exposure
- Run-off emission factors per slope ratio (may be simplified to for instance 4 classes)
- Spray drift emission factors per application method (and simplification to, for instance, 10 types)

And additionally, when farmers only put in the crucial data:
- Soil types (from maps)
- Surface water types (width x depth of receiving water bodies, may be simplified into 4 classes)
- Slope ratio (may be simplified to for instance 4 classes)

For the simplified calculation, the following background data are needed:
- Basic characteristics of pesticides: % active ingredient per product name, toxicity, persistence, adsorption, etc.

6. Preferences and rationale

In the methodology for assessing the use and impact of pesticides we have made a number of choices.

Output indicator: There are two approaches, one to minimize pesticide risk, and one to optimize pesticide use. Related to that, one can express the outcome in a Score/ha or a Score/kg of product. Both can be calculated, depending on the preferences of the user.

System boundary: We selected this boundary so that the most important environmental compartments and indicator organisms are included in the methodology. And all measures in the farmers' grasp (e.g. choice of pesticides and application methods) are included.

Calculation rules: The methodology simplifies the real world. This is necessary, because otherwise the tool becomes too complex. At this time no tool with the complete preferred methodology exists. But with all the information available it is relatively easy to develop a globally applicable tool based on the simplified calculation. It essentially means completing existing pesticide tools with all the pesticides used world-wide. Most complete databases at this moment are The Pesticide Manual from BCPC Publications: http://www.pesticidemanual.com/, the Pesticide Properties Database from the University of Hertfordshire: http://sitem.herts.ac.uk/aeru/footprint/en/ and, still for EU-MRL's only, the EU Pesticides Database: http://ec.europa.eu/sanco_pesticides/public/index.cfm). An extensive but less reliable source is the website of the Pesticide Action Network: http://www.pesticideinfo.org/. Also pesticide authorisation boards of individual countries sometimes give access tot pesticide information (for example, the CTGB in the Netherlands: http://www.ctgb.nl). For the full and preferred calculation this is also possible, but requires more data.

Background data: it is possible to use detailed background data such as monthly (or even weekly) rainfall, detailed data on water bodies etc. This does entail complex models to calculate impacts.
In practice, it is recommended to work with classes. For instance, for determining the slope ratio, the following classes might be used:
- Nearly level (0-2%)
- Gently Sloping (3%-6%)
- Moderately Sloping (6%-12%)
- Strongly Sloping (12%-18%) and steep slopes (18% or more)

For water bodies the same simplified classification can be developed, from no water bodies to extensive surface water present on farm. It is up to the tool developer to choose the level of detail.

7. References

Guidances for the evaluation of pesticides:

- EU: http://ec.europa.eu/food/plant/protection/resources/publications_en.htm#council)
- USA: http://www.epa.gov/pesticides/bluebook/

Existing pesticide risk indicators:

- AFT website: www.aftresearch.org/ipm/risk/index.php (results of a research in 2004).
- CLM report 'Comparing environmental risk indicators for pesticides' (1999).

Pesticide models (toxicity and environmental fate):

- http://www.epa.gov/pesticides/science/models_db.htm

Annex 3.A. Example of calculation for preferred methodology

Example based on the EYP (Netherlands), EPRIP (Italy) and SYNOPS_2 (Germany)

Surface water organisms

$$\text{PERSw} = \frac{\text{PEC}}{\text{most critical LC50 (acute tox) or NOEC (chronictox) fish, daphnia or algae}}$$

$$\text{PECw (mg/l)} = \frac{\text{dosage (kg/ha)} * \text{emission percentage to surface water (\%)} * 0.1}{\text{ditch depth (m)}}$$

Emission percentage to surfacewater (%) = drift % + run off %

This is a rather simple way to calculate the PEC. In literature you can find more detailed and complex calculation rules, encountering also for example degradation. Available computer simulation models are:

- USA: PRZM, EXAMS, GENEEC2 and MUSCRAT (both based PRZM/EXAMS), WARP (in testing phase)
- EU: FOCUS, TOXWA, SWASH.

There are different rules, models and tables available to calculate or derive drift and run off percentages, sometimes as part of the models mentioned above.

Soil organisms

$$\text{PERSs} = \text{most critical} \quad \frac{\text{PECs acute (2,5cm)}}{\text{LC50 (acute tox) earthworms}} \quad \text{or} \quad \frac{\text{PECs chronic (2 years, 20cm)}}{\text{NOEC (chronic tox) earthworms}}$$

$$\text{PECs acute (mg/kg)} = \frac{\text{dosage (kg/ha)} * \text{(1- fraction crop interception)}}{\text{depth of ground layer (0,025 m)} * \text{surface (1ha)} * \text{soil bulk density (kg/m}^3\text{)}}$$

PECs chronic (mg/kg) = (% of pesticide in soil after 2 years) * PECs acute (20 cm)

There are different rules and models available to calculate the % of pesticide in soil after 2 years in different soil types.

Contamination of ground water by leaching

PERSg =
dosage (kg/ha) * (1- fraction crop interception) * PEC upper (1-2 meter) groundwater (microgram/l)

There are several computer simulation models available to calculate the predicted environmental concentrations (PEC):

- USA: SCI-GROW, PRZM and WARP (in testing phase)
- EU: PEARL, PELMO, PRZM and MACRO.

Most important parameters in these models are the pesticide characteristics half life time

(DT50) and adsorption coefficient (Koc or Kom), soil types and weather conditions (rainfall).

<u>Other compartments</u>

Models exist for calculating the exposure of beneficial insects, birds and humans. These are not described in this example.

Annex 3.B. Example of calculation for simplified methodology

Example based on the EIQ (USA).

EIStotal =
dosage * (C(DT*5)+(DT*P))+((C*(S+P)2*SY)+(L))+((F*R)+(D*(S+P)/2*3)+(Z*P*3)+(B*P*5)))/3

Symbol	Description & Units	(one of the) Indicator(s) for:
B	ranked beneficial arthropod toxicity	tox terrestrial system
C	chronic toxicity small mammals classification	tox human
D	ranked LC50 bird value	tox terrestrial system
DT	ranked dermal LD50 small mammals value	tox human
F	ranked LC50 fish value	tox surface water system
L	ranked leaching potential of the pesticide a.i.	exposure human via drinking water
P	ranked plant surface half-life value	exposure human (applicator, picker, consumer) and terrestrial system via plant(product)
R	ranked runoff potential of the pesticide a.i.	exposure surface water system
S	ranked soil half-life value	exposure human (consumer) and birds
SY	systemic pesticide classification (absorprtion by plants)	exposure human (consumer)
Z	ranked LD50 bee value	terrestrial system

The ranking scheme consists of different sections for which the pesticide characteristics are ranke
An example of the ranking is given below:

Mode of Action (S):

Rank	
1	non-systemic
1	all herbicides
3	systemic

Acute Dermal LD50 Rats/Rabbits (DT):

Rank	
1	>2000 mg/kg
3	200-2000 mg/kg
5	0-200 mg/kg

Long Term Health Effects (C):

Rank	
1	little / none
3	possible
5	definite

Plant Surface Residue Half Life:

Rank	
1	1-2 weeks
3	2-4 weeks
5	> 4 weeks
1	pre-emergent herbicides

Soil Residue Half Life (P):

Rank	
1	< 30 days
3	30-100 days
5	> 100 days

Fish LC50 (S):

Rank	
1	> 10 ppm
2	1-10 ppm
3	<1 ppm

Bird LC50 (D):

Rank	
1	> 1000 ppm
3	100-1000 ppm
5	1-100 ppm

Bee Toxicity (Z):

Rank	
1	relatively non toxic
3	moderately toxic
5	highly toxic

Beneficial Toxicity (B):

Rank	
1	low impact
3	moderate impact
5	severe impact
3	post-emergent herbicide

Groundwater Potential (L):

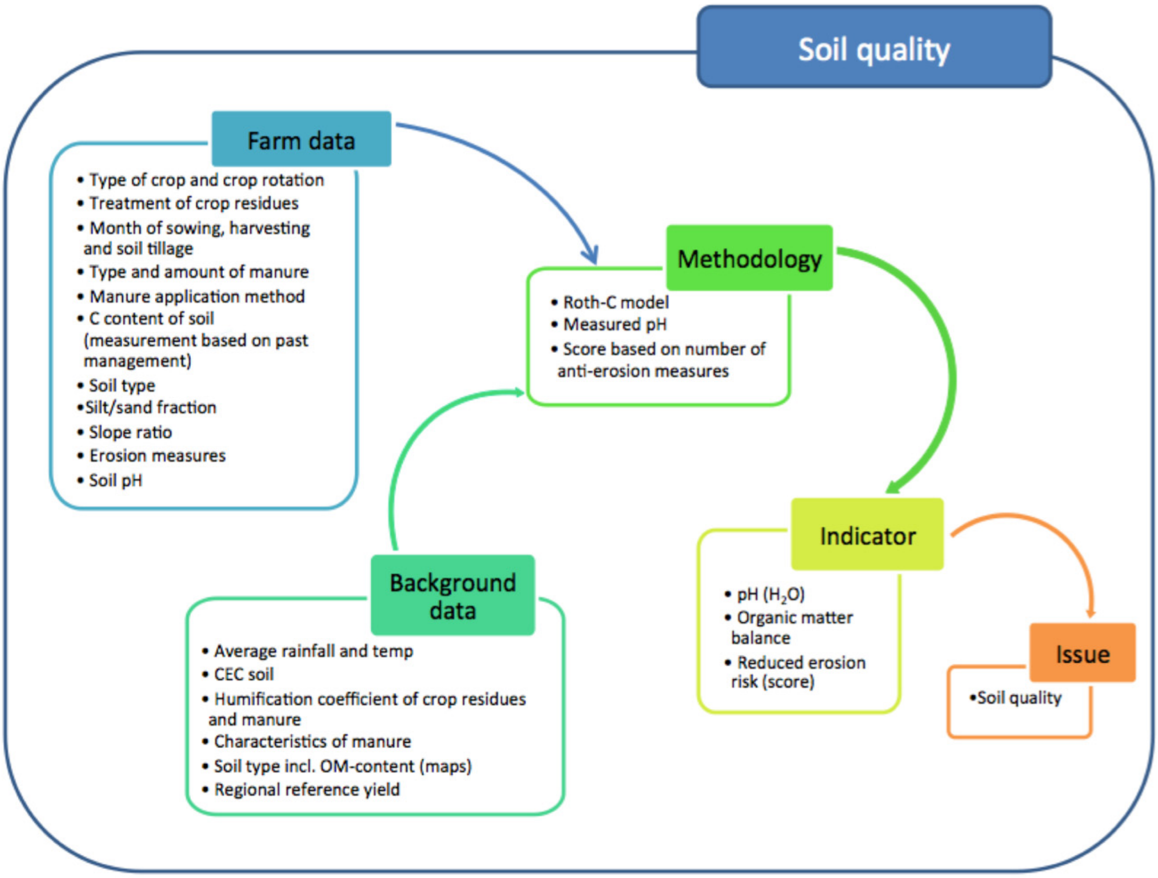
Rank	
1	small
3	medium
5	large

Runoff Potential (R):

Rank	
1	small
3	medium
5	large

There are different databases available on the internet which contain most of these pesticide characteristics. Preferred databases are those which have scientifically reviewed and reliable data, like the data used in the risk assessment for the authorisation of pesticides (e.g. EPA in the US, EC-Sanco in the EU), the Pesticide Manual (BVPC Publications, UK) and the database of the International Union of Pure and Applied Chemistry (IUPAC).

4 Soil quality



1. The issue

Soil provides many natural services for plants to grow, such as nutrient availability, clean water and resistance to pests and diseases. The soil cycle system of growth, death and decay is a natural system. Farmers use this but push it to the limit by removing/harvesting plant material, adding fertilizer and pesticides. In some situations the soil system undermined, for example when erosion takes place or an excess of nutrients run of the system to ground or surface water. Starting point of good agricultural practice is to maintain the organic matter content of the soil. Organic material strengthens the soil structure, feeds soil organisms, provides nutrients and contributes to the water holding capacity of the soil. Organic matter is an important indicator for soil quality. Another indicator that is more easily measured is pH (soil acidity). One of the greatest impacts on soil quality on a worldwide scale is water erosion. Therefore erosion potential is the third indicator for a soil quality model.

2. Output indicators

For *Organic matter* the indicator is the calculated organic matter content for the current farm situation (and future 30 years) expressed in % Soil Organic Matter in the top 30 cm of the soil.

Reduced erosion risk (caused by wind and/or water) is expressed in a score between 0 and 14, determined by the natural situation of the field and erosion prevention measures by the farmer.

For *Acidity* the indicator is acidity in water expressed in pH (H_2O)

3. Methodology

3.1 Determining the organic matter balance

Calculation: organic matter inputs and outputs are quantified and soil and farm characteristics are described. The result is a build-up of organic matter or a net loss.

The recommended model is Roth-C. This is a broadly-accepted model for the turnover of organic carbon in non-waterlogged topsoils that allows for the effects of soil type, temperature, moisture content and plant cover on the turnover process.

Before running the model, a reference value for SOM needs to be determined, as an approximation of the current SOM-level. This can be done in three ways (in order of preference):

- Actual measurement of SOM from soil sample analysis, on the farm. In many cases farmers have such soil samples analysed
- Reference data from regional soil maps
- Calculated SOM based on a model run with past soil management as main driver.

3.2 Determining reduced erosion risk

3.2.1 Methodology in brief

The methodology determining erosion risk is a simple score based on the number of counter-erosion measures taken, related to the erosion risk.

Erosion risk is considered negligible on farms with permanent grassland only, and on arable farms with coarse sandy or peat soils.

3.2.2 Determining erosion risk

Soil type: in case of wind erosion
Water erosion can occur in nearly every soil type that is used for agriculture. In the SPA system it is assumed that wind erosion in agricultural areas occurs when the soil contains silt (diameter 2-50 µm, silt fraction 70-90%) and/or sand (diameter 50-2000 µm, sand fraction 0-100%) and clay particles are absent.

Slopes: in case of water erosion
Steepness and length of slope determine risk of run-off. Steepness and length can be measured and classified into groups. However, in SPA we assume that farmers do not have detailed data on slopes on their land. Therefore we use a simplified classification into 4 classes:

- Nearly level (0-2%)
- Gently Sloping (3%-6%)
- Moderately Sloping (6%-12%)
- Strongly Sloping (12%-18%) and steep slopes (18% or more).

3.2.3 Erosion prevention: determination of measures

Nine erosion prevention measures are chosen that can be checked by the farmers in case of water or wind erosion. There are three groups of measures, based on: crops, management and "landscape".

Landscape measures:

- Buffer strip
  A buffer strip is an area of land maintained in permanent vegetation that helps to control air, soil, and water quality. Buffer strips trap sediment, and enhance filtration of nutrients and pesticides by slowing down runoff that could enter the local surface waters.
- Terracing (only for water erosion)
  Terraces are used in farming to cultivate sloped land. Graduated terrace steps are commonly used to farm on hilly or mountainous terrain.
- Windbreak (only in case of wind erosion)
  A windbreak or shelterbelt is a plantation usually made up of one or more rows of trees or shrubs planted in such a manner as to provide shelter from the wind and to protect soil from erosion. They are commonly planted around the edges of fields on farms.

Crop measures:

- Minimal crop rotation
  Can improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants. It is assumed that a minimal rotation is necessary of 1 in 3 rotation for deep rooting crops (grain) vs shallow-rooting crops (= a 1 in 3 year grain crop).
- Cover crops
  They are often grown for the sole purpose of preventing soil erosion. Dense cover crop physically slows down the velocity of rainfall before it contacts the soil surface, preventing soil splashing and erosive surface runoff. Additionally, vast cover crop root networks help anchor the soil in place and increase soil porosity.
- Perennial crops
  Perennial plants often have deep, extensive root systems, which can hold soil to prevent erosion.

Management practices:

- Contour plowing/ contour bunding (only for water erosion)
  Contour plowing or contour farming is the farming practice of plowing across a slope following its elevation contour lines. The rows formed slow water run-off during rainstorms to prevent soil erosion and allow the water time to settle into the soil. A similar practice is contour bunding where stones are placed around the contours of slopes.
- Conservation tillage
  Keeps the soil (partly) covered or prevents the soil structure being damaged by intensive agricultural tillage like plowing. Conservation tillage can be: no-till, strip-till, mulch-till, rotational tillage and ridge-till.
- Strip cropping
  Strip cropping is a method of farming used when a slope is too steep or too long, or when other types of farming may not prevent soil erosion. Strip cropping helps to stop soil erosion by creating natural dams for water, helping to preserve the strength of the soil. Certain layers of plants will absorb minerals and water from the soil more effectively than others.

3.2.4 Scoring erosion prevention

Translating the erosion potential and erosion prevention into a numerical score is done as follows.

- Farmers tick the box if their farm is in a hilly area, and indicate the soil type. This determines if there is an erosion risk.

- Farmers tick the measures taken on-farm. They receive one point for each measure to a maximum of 3 for wind-erosion susceptible farms and 4 for water-erosion susceptible farms.

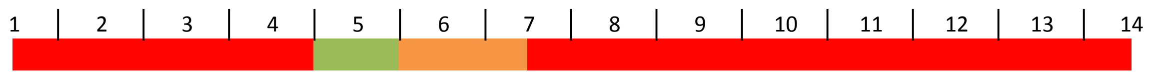
Table: Summary erosion measures.

	Risk of water erosion	Risk of wind erosion
Risk determination:		
Farm in hilly area	x	
Farm soil mainly sand or sandy loam		x
Landscape:		
Buffer strips	x	x
Terraces	x	
Wind breaks		x
Crops:		
Minimal crop rotation	x	x
Cover crops	x	x
Perennial crops	x	x
Management:		
Conservation tillage	x	x
Contour plowing	x	
Strip cropping	x	
Score	**1 point for each measure to maximum of 8**	**1 point for each measure to maximum of 6**

3.3 Determining the acidity

The pH of soil in water (pH-H_2O) is available from most crop management systems. Otherwise the pH can be determined by a farmer or an expert by taking a soil sample that will be analyzed in the field with pH paper or an electronic meter.

Soil pH conditions for agriculture (scale may vary according to regional circumstances).
Good pH: 5,5-7,5
Moderately pH: 4,5-5,5
Bad pH: 1-4,5 and 7,5-14



4. Farm data

A distinction is made in crucial and useful data:
- Crucial: farmer enters only relatively simple "crucial" data. For any data not entered, defaults from the background database are used.
- Useful: farmer also enters the extra "useful" information. In this case fewer background data are needed.

The ideal system is flexible, allowing for both routes (more or fewer farm data entered) to calculate the output scores.

Table: farm input data.

	Crucial	Useful
For organic matter		
Type of crop	x	
Crop rotation	x	
Treatment of crop residues (incorporation in soil or remove from field)	x	
Month of sowing, harvesting and soil tillage	x	
Type of organic manure	x	
Amount of organic manure	x	
Manure application method (broadcast, incorporated into soil etc)	x	
Initial C content of soil from soil sample measurement		x
Past farm management: crop-manure combinations (for calculating initial C-content of soil)		x
For reduced erosion risk		
Soil type (basic type)	x	
Soil silt/sand fraction		x
Slope ratio (simplified into 4 classes)	x	
Erosion measures	x	
For acidity		
Soil pH	x	

5. Background data

Background data needed:

- Monthly rainfall
- Average monthly mean air temperature
- CEC of the soil
- Humification coefficient of crop residues and manure
- Characteristics of manure

And additionally, in case farmer enters only crucial data:

- Average yield; region and crop specific, primary production and harvest indices
- Soil type including Organic Matter-content (from soil maps)

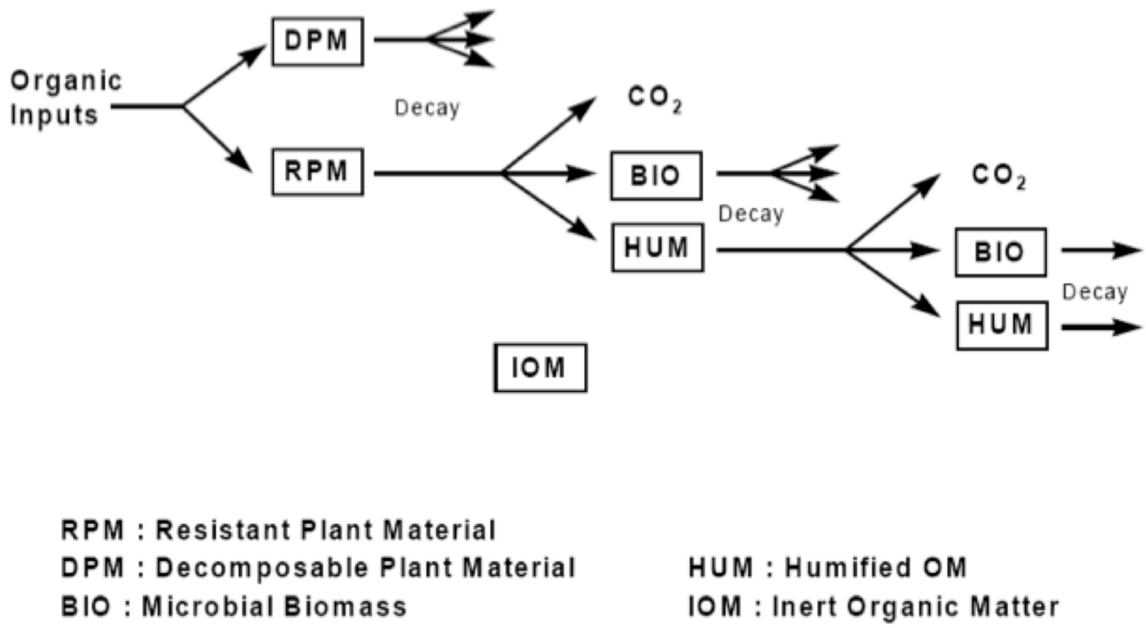
6. Preferences and rationale

Organic matter

In earlier work on SPA, two options were proposed for determining the soil organic matter on farm level. The first one was 'measured average soil organic matter content on farm (%)', but this output indicator has many disadvantages. It is too difficult to (require farmers to) measure in large parts of the world. Especially in regions where farmers are not used to or able to do soil sampling analyses every year. Default data is difficult to determine because organic matter contents are highly dependent on local climatic and human influences. The second option, a 'calculated organic matter balance' is more feasible. The necessary information can be more easily provided by farmers without help of (laboratory) experts. If farmers can't provide information about their crops and manure, input default data could be used.

The recommended model is Roth-C. This is a worldwide-accepted model for the turnover of organic carbon in non-waterlogged topsoils that allows for the effects of soil type, temperature, moisture content and plant cover on the turnover process. There are many

systems that can model organic carbon, but the Roth-C model is chosen for the simplicity of the input data and realistic output. The reliability of the model is enhanced by the use of different pools of carbon.
Soil organic carbon is split into four active compartments and a small amount of inert organic matter (IOM). The four active compartments are Decomposable Plant Material (DPM), Resistant Plant Material (RPM), Microbial Biomass (BIO) and Humified Organic Matter (HUM). Each compartment decomposes by a first-order process with its own characteristic rate. The IOM compartment is resistant to decomposition. The structure of the model is shown in next diagram.



Erosion risk
A world-wide applicable erosion model is difficult to find. The new RUSLE model has been considered, but judged not sufficiently applicable in general. Therefore, soil type and erosion measures are taken as the basis for calculating an erosion prevention score.
Soil texture and structure affect wind erosion risk. Loams, clay loams and silt loams are generally more resistant to aggregate breakdown, and thus are more resistant to wind erosion. Soil structure is the combination of individual soil particles into aggregates. Aggregates are heavier than individual particles and so are harder for wind to move. Organic matter helps to hold aggregates together and so soils with more organic matter are more resistant to wind erosion. Sandy soils are very susceptible to erosion. Clay soils which have been pulverized by frequent freezing and thawing are also very erodible.

The question also arises if steepness (and or length) of a slope can be included in the methodology. Expressed in simple classes for erosion risk, the steepness of a slope could be evaluated as follows:
- Nearly level (0-2%). Has no limitation on its uses. Any limitations are the result of other factors, such as drainage.
- Gently Sloping (3%-6%). May have erosion problems.
- Moderately Sloping (6%-12%). May have severe erosion problems.
- Strongly Sloping (12%-18%) and steep slopes (18% or more). Severe erosion risk.

In the methodology we assume a farmer can estimate the steepness of the slopes in these categories. If not, background data from detailed maps can be a fall-back. These can help determine slopes at regional level. The estimates by the farmer may be more precise since the farmer knows the specific fields.

Acidity

The pH is a rough indicator of soil quality. It also depends on natural soil characteristics and preferences of the crop (and therefore the farmer) in a particular year.
The pH of the soil can be most easily measured by dissolving soil in a water solution and using some pH indicator paper to determine the acidity of the soil. A more accurate method is the pH in a KCl solution, but this needs to be done by a laboratory expert. The range of good agricultural soil acidity is broad; therefore a very accurate method is not necessary. When no pH indicator is available default data is provided.
Both macro and trace nutrient availability is controlled by soil pH. In slightly to moderately alkaline soils, molybdenum and macronutrient (except P) availability is increased, but P, Fe, Mn, Zn Cu, and Co levels are reduced to such a low level they may affect plant growth. In acid soils, micronutrient availability (except Mo and Bo) is increased. Nitrogen is supplied as ammonium (NH_4) or nitrate (NO_3) in fertilizer amendments, and dissolved N will have the highest concentrations in soil with pH 6-8. Concentrations of available N are less sensitive to pH than concentration of available P. In order for P to be available for plants, soil pH needs to be in the range 6.0 to 7.5. If pH is lower than 6, P starts forming insoluble compounds with iron (Fe) and aluminum (Al) and if pH is higher than 7.5 P starts forming insoluble compounds with calcium (Ca).
Most nutrient deficiencies can be avoided between a pH range of 5.5 to 6.5, provided that soil minerals and organic matter contain the essential nutrients to begin with.

7. References

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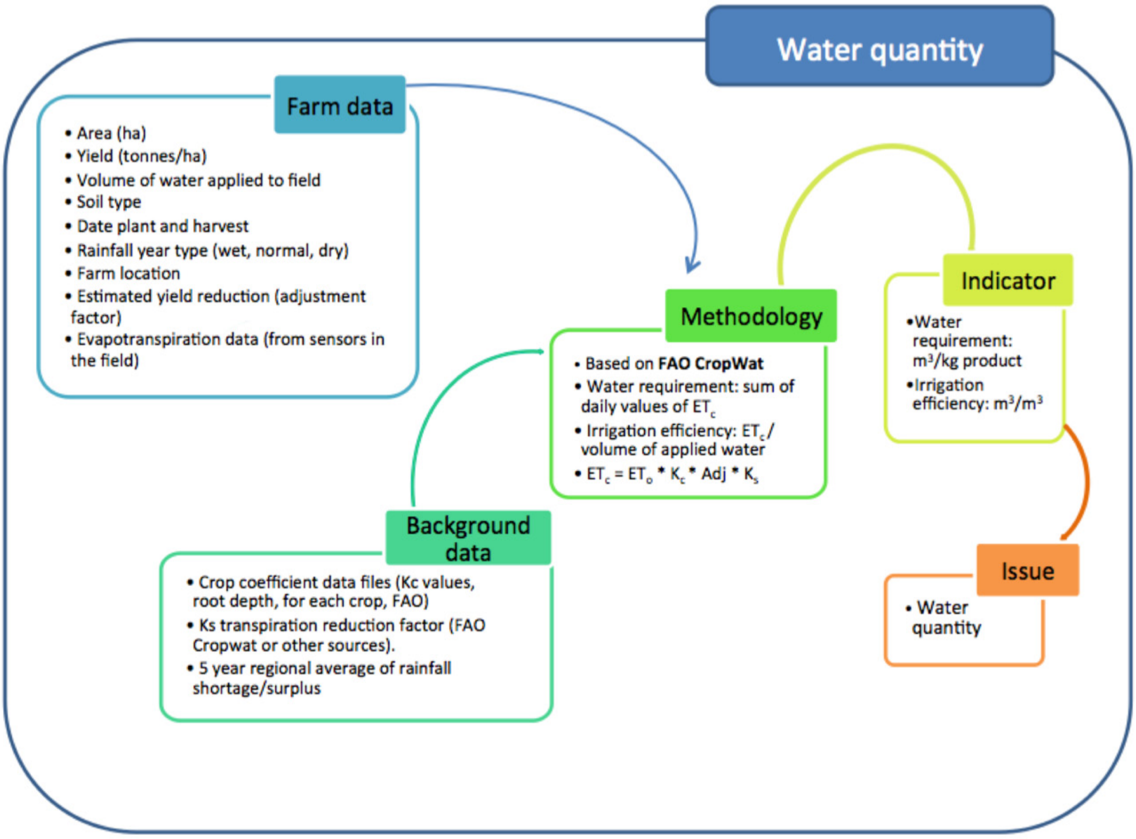
5 Water quantity



1. The issue

Crops require sufficient amounts of water to grow. In some areas there is sufficient surface water and/or ground water available for agriculture. In other areas water can be limited. In those areas irrigation is needed to prevent crop losses.
The impact of water usage by agriculture depends on:

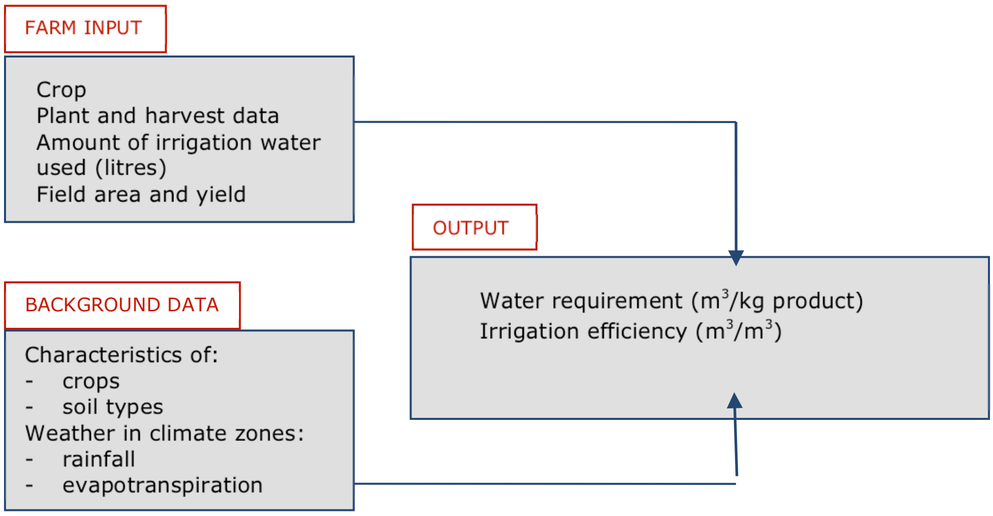
- the type of crop (water demands differ)
- the origin of the water (e.g. irrigation, groundwater or surface water)
- the availability of water
- competition between usage
- percolation of pollutants due to application of manure and/or agrochemicals e.g. fertilizers and pesticides
- efficiency of water application practices.

Water requirement by crops is determined by evapotranspiration. Evapotranspiration is the combination of two separate processes whereby water is lost from the soil surface by evaporation and from the crop by transpiration. Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. The evapotranspiration rate is normally expressed in millimetres (mm) per unit time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, decade, month or even an entire growing period or year.

The actual crop evapotranspiration depends on climate parameters (which determine potential evapotranspiration), crop characteristics and soil water availability. When water availability is locally limited, irrigation is often applied. The amount of water used for irrigation compared to the total water requirement is an indicator of how efficient irrigation water is used.

2. Output indicators

The output indicators and functional units are:
- water requirement in m^3/ha and/or m^3/kg product harvested
- irrigation efficiency in m^3/m^3



3. Methodology

System boundary and allocation
- Water requirement:
  - Total volume of water required by the crop for evapotranspiration. This includes rainwater and irrigation water used from ground or surface sources.
- Not to be taken into account is indirect water requirement:
  - The amount of water required for the production of seeds.
  - The amount of water required for the production of agrochemicals or other inputs e.g. pesticides or fertilizer.
  - The influence of the water quality used on crop health (pH. CE, etc). It is assumed the water quality has no negative effect on the growth of the crop.

Functional unit
For water requirement two indicators are used:
- Water requirement: m^3 /kg product.
- Irrigation efficiency: m^3 (crop evapotranspiration) / m^3 (applied irrigation water).

Calculations
Calculations are based on FAO 1998 *Crop evapotranspiration - Guidelines for computing crop water requirements* and Mekonnen en Hoekstra 2010 *The green, blue and grey water footprint of crops and derived crop products.*

a. Water requirement
Water requirement is calculated by summing up the daily values of ET_c (mm/day) over the length of the growing period (ET_c see below).

b. Irrigation efficiency
Irrigation efficiency is determined as ET_c / volume of applied water (m^3/m^3)

c. Evapotranspiration
Crop Evapotranspiration ET_c is the central unit needed for the two output indicators. It is recommended to calculate ET_c (rather than measure it, or take it from background databases).

ET_c is calculated according to the formula:

$$ET_c = ET_o * K_c * Adj * K_s$$

with the following elements:
- ET_c crop evapotranspiration [mm d^{-1}], the determining factor to be calculated
- K_c crop coefficient [dimensionless], which varies predominately with the specific crop characteristics and only to a limited extent with climate. The crop coefficient varies in time, as a function of the plant growth stage. Kc values can be obtained from different sources e.g. FAO (1998) Hoekstra (2004).
- ET_o reference crop evapotranspiration [mm d^{-1}], a reference value related to the regional climate (temperature, humidity, sunshine, wind speed). ET_o can be calculated using the Penman-Monteith equation in the tool (most accurate), be calculated using the CROPWAT tool of FAO (somewhat less accurate) or be obtained from reference sources like Chapagain and Hoekstra (2004) (more general data).
- Adj is an adjustment factor, correcting theoretical ideal circumstances to the real farm situation. It is based on an estimate of reduced crop cover or yield by the farmer.
- Ks is a dimensionless transpiration reduction factor with a value between zero and one. It corrects for reduced soil water availability. Ks needs to be calculated and should be embedded in the tool. Data required and the equations can be obtained from FAO 1998.

4. Farm data

A distinction is made in crucial and useful data, needed to calculate the output scores:
- Crucial: farmer puts in relatively simple and few data ("crucial"); need for an extensive background database.
- Useful: farmer puts in more data ("useful"); in this case fewer background data are needed.

Farm data input	Crucial	Useful
Data below per crop	x	
Area (ha)	x	
Yield (tonnes/ha)	x	
Volume of water applied to field	x	
Soil type	x	
Date of plant crop	x	
Date of harvest crop	x	
Rainfall year type (wet, normal, dry)	x	
Farm location (for determining the climate zone)	x	
Estimated yield reduction (for calculating adjustment factor)		x
Evapotranspiration data (from sensors in the field)		x

5. Background data

The following background data and defaults are needed:
- Crop coefficient data files: including Kc values, root depth, for each crop (FAO or Allen et al., 1989).
- Transpiration reduction factor dependent on available soil water (Ks), calculated by use of FAO calculations (1998) or from qualified sources.

And additionally, when farmers only put in the crucial data:

- Climate data: 5 year average of rainfall shortage or surplus in a region to classify the availability of water; and evaporation

6. Preferences and rationale

The simplest approach is to calculate water requirement based on average literature values for ETc. This means using average values of evapotranspiration per crop per region. This would entail each farmer in a region getting the same water requirement score. Subsequently, farmers can calculate irrigation efficiency based on this average ETc. This gives them insight into the irrigation efficiency on their farm, and could help them to reduce it over the years, and also allows for comparison with neighbouring farms.

There are, however, other factors which influence the water needs, factors that are under the farmers influence: crop type planted, planting time and harvest time. If we want farmers to "play" with these variables, they should be given a place in the assessment. This is what we have chosen to do. The result is a water footprint calculation that is complex for the tool builder, but should be simple for the farmer to use: the farm data required as input are all within the farmers' grasp.

There currently is much discussion on water use metrics, in both plant and animal production sectors. We have chosen the above methodology as an intermediate step, covering the larger share (up to 80%) of all water used in the product's life cycle. The International Dairy Federation plans to publish its approach to water metrics in 2013. SAI would like to as much as possible align the ideas in this report to the IDF-approach.

7. Outlook

For deciding if agriculture is sustainable, it is important to know not only the water needs of agricultural practices, but also what the impact of that requirement is on the availability in the area surrounding the farm (for example more downstream).

Two indicators that are related to this impact are the attendance of renewable water sources (m^3/year) and water scarcity (differentiated in physical and economic scarcity). The FAO has databases with this information for every country in the world. But this is often not detailed enough for individual farmers since impacts are always fully local-context dependent. And the farmer himself does not know these parameters for his own local situation. It might be interesting to develop a score from (for example) 1-5, depending on the relation between farm water use and regional water scarcity, which is easy to fill in by farmers. However, at this moment there is no suitable methodology available for this.

8. References

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Annex 5.A. Water requirement calculation methodology in more detail

There are three ways to determine crop Evapotranspiration
- measure actual ETc
- calculate seasonal ETc
- obtain seasonal ETc from a source

Measuring ETc is the preferred methodology however is not feasible for most farmers. Obtaining ETc from a source doesn't distinguish enough between farmers and preferably is not used. Therefore we recommend that the ETc is calculated. This is done in 2 stages: the basic (standard) conditions of an ideal farm (with year round sufficient water everywhere) and a stage which corrects for real life.

1. Calculated ETc standard conditions

Under standard conditions crops are grown in large fields under excellent agronomic and soil water conditions. ET_c, is calculated by multiplying the reference crop evapotranspiration, ET_o, by a crop coefficient, K_c:

$$ET_c = K_c * ET_o$$

Where:

ET_c crop evapotranspiration [mm d^{-1}],
K_c crop coefficient [dimensionless],
ET_o reference crop evapotranspiration [mm d^{-1}].

Most of the effects of the various weather conditions are incorporated into the ET_o estimate. Therefore, ET_o represents an index of climatic impact on the plant and soil evaporation. ET_o can be based on daily, weekly or monthly climatic data: minimum and maximum air temperature, relative humidity, sunshine duration and wind speed. Whereas daily or weekly data give more accuracy; using monthly averages is accurate enough.

ET_o can be obtained as follows.
- It can be calculated using the Penman-Monteith equation in the tool, which is the most accurate approach. For such a calculation data with regard to radiation, air temperature, air humidity and wind speed data is required.
- A more generalised approach is to calculate ET_o using existing tools like CROPWAT from FAO to build one's own regional set of default data.
- Thirdly, least accurate but also sufficient for SAI purposes, average ET_o can be obtained from reference sources like Hoekstra (2004).

To determine ET_o from a reference source the climatic zone is required and the weather year type e.g. wet, normal or dry.

K_c varies predominately with the specific crop characteristics and only to a limited extent with climate. The crop coefficient varies in time, as a function of the plant growth stage. During the initial and mid-season stages, Kc is a constant and equals Kc,ini and Kc,mid respectively. During the crop development stage, Kc is assumed to linearly increase from Kc,ini to Kc,mid. In the late season stage, Kc is assumed to decrease linearly from Kc,mid to Kc,end.
The crop coefficient, K_c, is basically the ratio of the crop ET_c to the reference ET_o, and it represents an integration of the effects of four primary characteristics that distinguish crops:
- Crop height
- Albedo (reflectance) of the crop-soil surface
- Canopy resistance
- Evaporation from soil, especially exposed

Kc values can be obtained from different sources e.g. FAO (1998) Hoekstra (2004)

2. Non-standard conditions
In well-managed fields, the standard conditions are generally the actual field conditions.

Where the conditions encountered in the field differ from the standard conditions, a correction on ETc is required. Low soil fertility, salt toxicity, soil waterlogging, pests, diseases and the presence of hard or impenetrable soil horizons in the root zone may result in scanty plant growth and lower evapotranspiration. Soil water shortage and soil salinity may reduce soil water uptake and limit crop evapotranspiration.

Under non-standard conditions ET_c is calculated as follows:

$ET_c = ET_o * K_c * Adj$

Under non-standard conditions with reduced soil water availability ET_c, is calculated by:

$ET_c = ET_o * K_c * Adj * K_s$

In line with the Stewardship Index for Specialty Crops (based on work of the University of California), adjustments need to be listed and may be estimated by field observations. For instance if the crop covers due to bare spots only 80% of the area the Kc factor needs to be multiplied by an adjustment factor of 0.8. The same when crop vigor is below optimal due to a pest or disease pressure.

Reduced soil water availability needs to be corrected by a transpiration reduction factor Ks. Ks [t] is a dimensionless transpiration reduction factor dependent on the available soil water, with a value between zero and one. Ks can be determined by the equation:

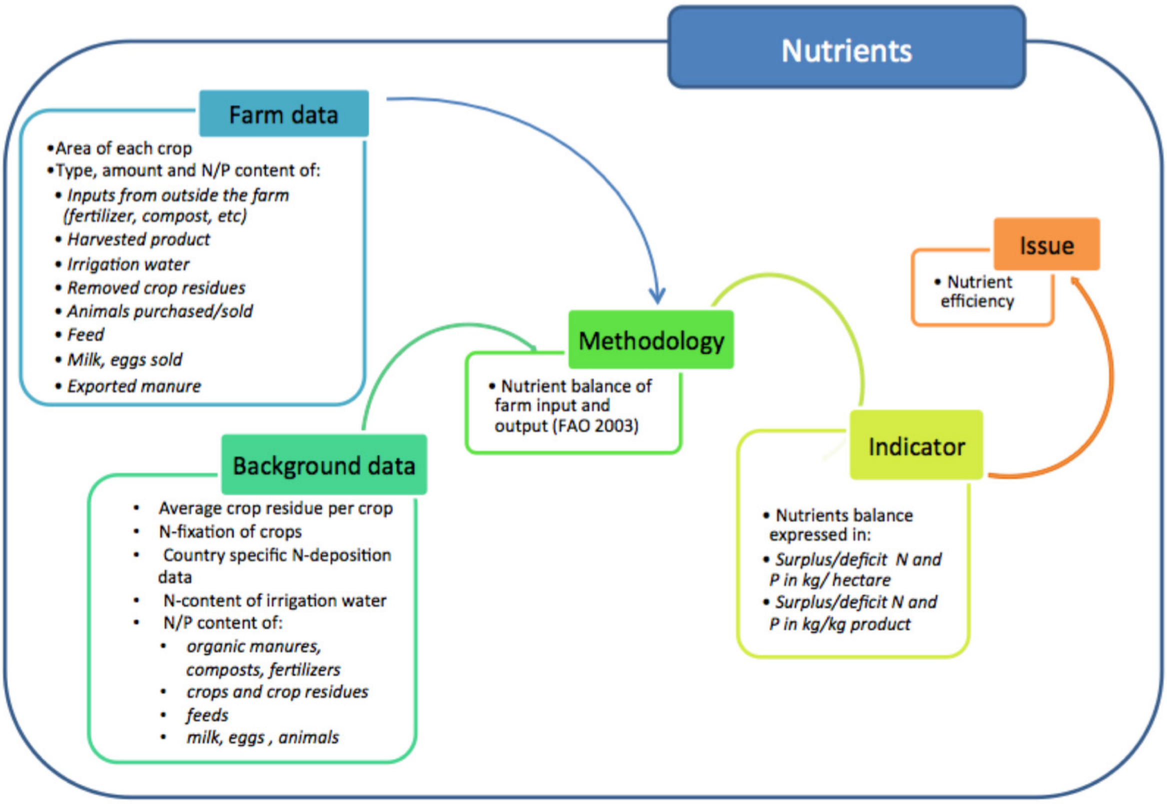
$$K_s = \frac{TAW - D_r}{TAW - RAW} = \frac{TAW - D_r}{(1-p)TAW}$$

Where
- K_s is a dimensionless transpiration reduction factor dependent on available soil water [0 - 1]
- D_r root zone depletion [mm]
- TAW total available soil water in the root zone [mm]
- RAW the readily available soil water in the root zone [mm]
- p fraction of TAW that a crop can extract from the root zone without suffering water stress [-].

For more in depth information and the required data see FAO (1998).

When farmers irrigate their fields by use of an irrigation planner it can be assumed that reduced soil water availability doesn't occur and therefore Ks is 1.

6. Nutrients



1. The issue

Fertilizers, organic as well as synthetic, are used to enhance the growth and quality of crops. Application of fertilizers leads to risk of nutrient losses (from soil) to the environment, causing eutrophication of surface water and soil, pollution of the groundwater and of air. On the other hand, nutrient depletion of the soil due to ? is a major form of soil degradation in parts of the world.

A farmer has several ways of managing the right nutrient balance. One way is appropriate fertilizer application (amount, time, method, etc.). Improving the soil quality via management measures (optimal crop rotations, crop residues, use of green manure or catch crops in winter) also has a great impact on both nutrient deficiencies and losses.

The nutrient balance described below considers the two most important nutrients, N and P.

2. Output indicators

Output indicator is the the nutrient balance expressed as:

- surplus/deficit of nutrients (N and P) in kilograms per hectare (kg/ha)
- and surplus/deficit deficit of nutrients (N and P) in kilograms per kg of product (kg/kg).

3. Methodology

System boundary and allocation

- The system boundary is the farm gate. For a field nutrient balance, the same data are needed as for the farm nutrient balance, only on field scale.

Input and output considered

- Inputs to the system considered are:
  - synthetic and organic fertilisers (manure, compost, …)
  - atmospheric deposition of N
  - N in irrigation water (surface and ground water)
  - nitrogen fixation by leguminous crops
  - purchased feeds and animals
  - other material that can contain a substantial amount of nutrients.

  At least 95% of all nutrient input must be incorporated in the methodology (the type of input that has to be incorporated depends on regions and crop systems).

- Outputs of the system are all nutrients leaving the arable farm in crop/meat/animals/milk, (un)processed crop residues and manure.
- Only nutrients that are transferred from outside the farm and actually used are counted as input to the system. Not considered are:
  - fertilisers in stock (not yet used)
  - manure used on the farm and "homemade" green manure applied on own fields
  - home-grown feed
  - crop residues left on the field
- Not taken into account are: losses caused by leaching, volatilisation, denitrification and erosion and losses during storage or processing of crop residues.

Functional unit

The preferred functional unit for soil balances is kg N per hectare and kg P per hectare.
If desired, an additional unit could be kg N or P surplus per kg product.

Calculations

The calculation of the nutrient balance are to be based on the FAO Assessment on soil nutrient balances (2003) - see Roy, R.N., Misra, R.V., Lesschen, J.P., Smalling, E.M. (2003). Assessment of soil nutrient balance, FAO.

4. Farm data

A distinction is made in crucial and useful data, needed to calculate the output scores:

- Crucial: farmer puts in relatively simple and few data ("crucial"); need for an extensive background database.
- Useful: farmer puts in more data ("useful"); in this case fewer background data are needed.

Farm data input	Crucial	Useful
Area of each crop (ha)	x	
Irrigation water used		x
Nutrients from outside the farm		
Type (synthetic fertilizer, compost, manure, ..)	x	
Amount (kg/ha)	x	
Content (kg N/kg, kg P/kg)	X	x
Harvested product		
Yield (kg)	x	
Nutrient content (N/kg, P/kg)		x
Removed crop residues, including processed products e.g. compost		
Amount (kg)		x
Nutrient content (N/kg, P/kg)		x

In farming systems with livestock following data are extra needed

Farm data input	Crucial	Useful
Animals purchased/sold		
Number and weight	x	
Purchased/sold feed		
Type and amount (kg)	x	
Nutrient content (N/kg, P/kg)		x
Sold milk, eggs		
Amount (kg)	x	
Nutrient content (N/kg, P/kg)		x
Exported manure		
Type and amount (kg)	x	
Nutrient content (N/kg, P/kg)		X

5. Background data

Type of data required:
- N-fixation of crops
- Country-specific N-deposition data
- Region-specific N-content of surface water

And additionally, when farmers only put in the crucial data:
- average amount of crop residue per crop
- and the N and P content of:
  - organic manures, composts, fertilizers and other relevant materials
  - crops
  - crop residues
  - feeds
  - milk, eggs
  - animals.

6. Preferences and rationale

In the methodology for assessing the nutrient balance we have made a number of choices. Below we outline the main choices and the arguments for the preference.

The simplest method for assessing nutrients-use on farms is application rate per hectare. Such information is easily available to farmers. A somewhat more sophisticated indicator is input of N and P per kg of product (yield). A third level is calculation of the nutrient balance. This takes into account accumulation in organic matter and actual (modelled) losses to the environment, and therefore is a more accurate method – which is why we choose this indicator.

In addition, in the chapter on Soil quality, SAI requires farmers to also calculate the C-balance to estimate soil organic matter. Farm data used for the C-balance overlap with data the farmer needs to put in for the N- and P-balances.

Farmers generally have access to the crucial input data: inputs used, material leaving the farm. We assume that in some cases farmers also know the N and P content of fertilisers, manure, compost etc. – the "useful" data in the table. In such cases they can enter such data, making the calculation more accurate. This is why we propose to include two levels, one based on actual data and one based on defaults.

System boundary: the nutrient balance can be made on field or farm level. As crop residues of one field can be composted and used on another field, the farm gate is best taken as system boundary. All nutrients entering the farm, including fertilisers, filling soil, irrigation water, atmospheric deposition of N and nitrogen fixation by leguminous crops, are inputs and all nutrients leaving the farm (farm products, removed crop residues and manure) are outputs of the model. Most important farm products are harvested crops, milk and animals/meat.

Calculation rules: with the described methodology, the nutrient balance expresses the risk for the environment. Gaseous, leaching and erosion losses are not seen as output to the system but as nutrient losses to the environment. N/P that is not exported off the farm, volatises or stays behind in the soil and can leach to groundwater sources or run-off to surface water. This risk is dependant on the soil and management conditions taken into account by other sustainability issues.

7. References

- IFA Task Force on Fertilizer Best Management Practices, 2009: The Global "4R" Nutrient Stewardship Framework. Developing Fertilizer Best Management Practices for Delivering Economic, Social and Environmental Benefits. IFA, Paris, France.
- International Plant Nutrition Institute, 4R Nutrient Stewardship Portal, april 2012. http://www.ipni.net/4r
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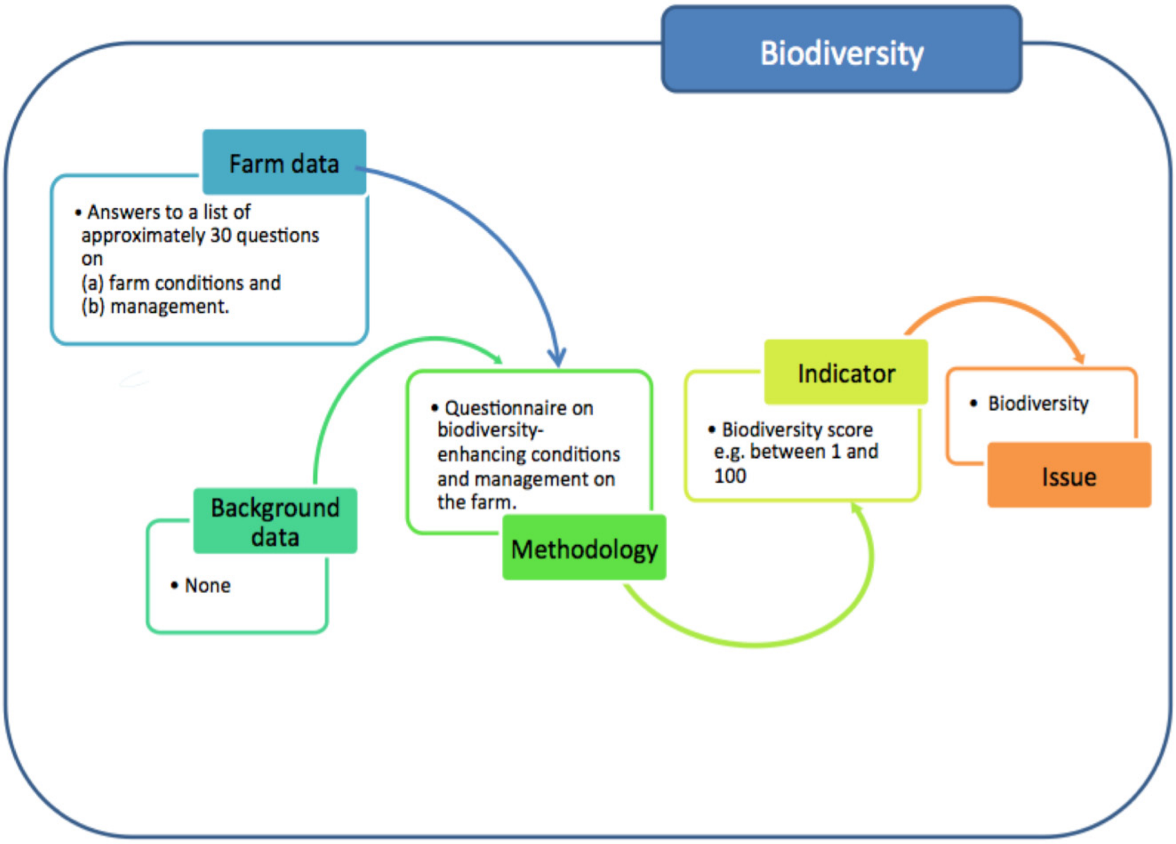
7. Biodiversity



1. The issue

Agro-biodiversity covers life on the farm, from crop and cattle species to minute organisms in the soil to wild flora and fauna in field borders or natural habitats which are part of the farm area. Such non productive areas are essential for resilient agro-ecosystems and are valuable to society. However, biodiversity is complex and difficult to measure and monitor, especially for a farmer with limited time and/or limited knowledge of flora and fauna.

Beyond the farm, the food chain must also take into account its impact on biodiversity, most notably in susceptible regions where agricultural inputs are commonly sourced. The best-known example is the production of fodder in tropical regions, which contributes significantly to the environmental footprint of the meat and dairy products that rely on this feed.

In the framework of SPA, we include only on-farm biodiversity in the assessment for this theme. Additional impacts on biodiversity via water pollution are covered under Nutrient balance and Pesticides. The impacts on off-farm ecosystems, like tropical rainforests, are not included here but are implicitly covered by the indicator for land use.

2. Output indicator

The proxy to be used for biodiversity impact is a score based on efforts to maintain and enhance biodiversity. The biodiversity score is a number on a relative scale, for instance from 1 to 100 (the scale can vary based on the number of questions included in the questionnaire - see below under Methodology).

3. Methodology

The basis of the biodiversity score is an assessment containing approximately 30 questions[3]. Positive characteristics and management efforts on the farm earn biodiversity points in accordance with the questions, which are structured according to six components:

A. Productive area
   1. Crop and animal varieties used
   2. Farm management resulting in biodiversity benefits for crop production (pest predators, soil life, resilient soil, crops and cattle)
   3. Productive areas under targeted nature management (e.g. extensive cropping to tolerate wild herbs or weeds)

B. Non-productive area
   4. Area and management of non-productive elements around the fields (e.g. water courses, hedgerows, copses)
   5. Management of natural/semi-natural areas, with or without formal legal protection, either owned or maintained by the farmer (e.g. extensive grazing of natural reserves)
   6. Natural elements and shelters for fauna in the farmyard

An example of such a list of questions is in Table 2 below – in this case 27 questions. National applications of this approach may lead to a smaller or larger number of questions and different features than the ones listed.

Getting from customized questionnaire to score:
- There are a limited number of questions for each of the six components outlined above.
- There are two approaches to choose from:
  - Approach 1: Yes/No questions, with a 1 point score for each "Yes". *For our 27-question example, there is a theoretical maximum score of 27 points*.
  - Approach 2: Multiple-choice options with 1 point for each option ticked. *In our example, this leads to a theoretical maximum score of 110 over all 27 questions.*
- Scores are added up for each of the six components. The final biodiversity score is composed of these six scores weighted equally and calculated thus:
  - *End score = Score per component * Contribution factor*. An example is shown in Table 1 below.

Table 1 Example calculation of contribution factors for maximum score of 110 biodiversity points over 6 components.

max. Score	100
# components	6
weight per component	16,7

component nr.	max score	contribution factor	rel.max.score
1	20	0,8	16,7
2	20	0,8	16,7
3	20	0,8	16,7
4	30	0,6	16,7
5	10	1,7	16,7
6	10	1,7	16,7

[3] This methodology was developed in 2011 by CLM, in cooperation with farmers, nature organisations and several large food companies.

4. Farm data

The farm data in this case consist of the farmer's answers to a list of approximately 30 questions on biodiversity-enhancing farm conditions and management measures. As outlined in Section 3, these can be simple yes/no questions or, alternatively, multiple-choice options. It is likely that some multiple-choice options will need to be adapted to regional circumstances, as will some of the basic yes/no questions.

Example for the multiple choice options

Are there small wooden elements present on the farm between the fields (minimum areas can be demanded, management practices are assessed in next questions)? Please tick:

- *Hedgerows (minimum 1 m wide, 50 meters long, (e.g. hawthorn, beech))*
- *Outgrowing shrubs (thickets) of for example brambles or hawthorns (minimum 2 m wide, 50 meters long)*
- *Treelines (minimum of 10 trees in line along the field)*
- *Free standing trees (minimum of 5 trees)*
- *Coppices/brushwood (minimum of 0.1 ha)*
- *Woodbanks (minimum 2 m wide, 50 meters long)*
- *Standard orchard (minimum of 20 trees)*

The table below lists an exemplary set of basic questions from which the score is calculated. All questions concern the current situation on the farm.

Table 2 Biodiversity conditions and management questionnaire.

	Themes	Questions on 6 themes	Score examples *Approach 1: yes/no questions; 1 point per yes*	*Approach 2: multiple options; 1 point per option ticked*	SUM *approach 1*	*approach 2*
1. Cattle, cultivars and crops			5	14		14
1.1	Variety of cattle species	Which number of cattle species are present in the farm (minimum or multiple choice of three classes)	1	3	1	
1.2	Variety of cattle breeds	Number of varieties (likewise)	1	3	1	
1.3	Variety of crop species	Number of species (likewise)	1	3	1	
1.4	Variety of crop varieties	Number of varieties (likewise)	1	3	1	
1.5	Variety of green manure crops	Number of species (likewise)	1	3	1	
1.6	Variety in grassland composition	Presence of mix of grasspecies or clover and herbs (four classes: monoculture, mix of grasses, mix with herbal species, mix with clover)	1	4	1	
1.7	Presence of honeybees	Do you have 1 or more beehives on your farm?	1	1	1	
2. Cultivation practices: benefits for soil life, natural enemies and pollinators			5	20		20
2.1	Crop protection	Do you take measures to spare natural enemies during crop protection implementation on your	1	4	1	
2.2	Manure application	Do you apply organic materials, fertilisers or additives to stimulate the soil life?	1	4	1	
2.3	Provision of nectar/pollen in crops (non-grass)	Do you take measures to provide flowers (pollen/nectar) within the actual plots?	1	4	1	
2.4	Soil cultivation in arable fields	Do you take other measures to stimulate soil life or natural enemies in the fields/plots?	1	4	1	
2.5	Soil care in grassland	Do you take other measures to encourage soil life or natural enemies in grassland fields/plots?	1	4	1	
3. Cultivation practices: benefits for wildlife			5	20		20
3.1	Measures in arable fields for field flora	Do you take specific measures in favour of the field fauna or flora?	1	4	1	
3.2	Measures in grassland for field flora	Do you take specific measures in favour of field flowers in your grassland (on at least 0.5 ha)?	1	4	1	
3.3	Measures in arable fields for farmland birds	Do you take measures in the arable fields to protect farmland birds?	1	4	1	
3.4	Measures in grassland for farmland birds	Do you take measures in the grasslands to protect meadow birds?	1	4	1	
3.5	Measures to prevent invasive exotic species	Do you take measures to prevent intoduction and expansion of invasive exotic species?	1	4	1	
4. Small and linear nature and landscape elements (linear or < 0,5 hectare)			6	30		30
4.1	Small wet elements	Are small wet elements present on the farm between the fields, like ditches, ponds, marshlands (minimum size, which elements?	1	5	1	
4.2		Do you carry out wildlife-friendly measures in these wet elements?	1	5	1	
4.3	Small herbaceous elements	Are small herbaceous elements present on the farm between the fields, like ditches, ponds, marshlands (minimum size, which elements?	1	5	1	
4.4		Do you carry out wildlife-friendly measures in these herbaceous elements?	1	5	1	
4.5	Small wooden elements	Are small wooden elements present on the farm between the fields, like ditches, ponds, marshlands (minimum size, which elements?	1	5	1	
4.6		Do you carry out wildlife-friendly measures in these wooden elements?	1	5	1	
5. Large natural elements			2	10		10
5.1	Grounds designated for nature conservation and/or other large plots for nature conservation (>0.5 ha)	Are large natural elements present on the farm (which types like grassland, marsh, open water, shrubland)?	1	5	1	
5.2.		Do you carry out management measures (which, like mowing, grazing, cutting?	1	5	1	
6. Wildlife-friendly elements in the farmyard			2	10		10
6.1	Green elements in the farmyard	Are green elements present in the amryard (which, like orchard, tree lines, pond, ornamental garden)?	1	5	1	
6.2	Shelter places for animals in the farmyard	Are shelter places for animals present in the farmyard (which, like woodstock, pile of stones, compost heap)?	1	5	1	
		Total	27	104	27	104

5. Background data

In this case there is no need for background data.

6. Preferences and rationale

Proxy for biodiversity
As outlined above, biodiversity is complex and monitoring it is difficult. Farmers usually lack the knowledge of plant and bird species necessary to reliably monitor occurrence. Other biotic life, like insects and soil organisms, require extensive effort to monitor, even for trained biologists. Although reported actual flora and fauna found on and around the farm may be the most accurate indicators, it is impossible to impose monitoring obligations on farmers.

Seeking a proxy, one arrives at conditions that potentially enhance biodiversity. Many assessment systems rely on biodiversity conservation practices that address protected species, protected areas and general farm management. The SPA methodology takes these general notions further, transposing them into activities that are usually within the grasp of the farmer: targeted management, non-cropped areas, soil quality, etc. The SPA methodology then translates the conditions (e.g. presence of hedges) and activities (e.g. maintenance of hedges) into a meaningful relative score (e.g. likely occurrence of woodland bird species).

The questions are phrased such that they are generally applicable worldwide and can be used in the yes/no mode. The questions may need to be phrased more specifically for different regions. If desired, tool developers can take a more sophisticated approach by including regionally applicable, multiple-choice options linked to the questions.

Correlation with other priority issues
There are correlations with biodiversity in several other themes covered by SPA. The impact on biodiversity off the farm, for example via sourcing of inputs, can be important. This impact is addressed in the SAI land use indicator rather than the biodiversity indicator. Implicitly, good scores on pesticide use, nutrient efficiency and soil quality (organic matter) all have a positive correlation with biodiversity.

Core elements of the methodology
The starting point for the methodology is that every element present may increase biodiversity value, because it adds a new habitat for different flora or fauna species. In the same way, different management practices on the same farm and neighbouring fields may provide more different habitats and thus increase biodiversity. Thirdly, presence of different crop species and cattle species (including goats, horses and other farm animals) provide food (e.g. through their manure) for additional wildlife species, starting with micro-organisms and soil life. So the biodiversity scoring system rewards the variety of biotopes on the farm, as well as active management in support of biodiversity. More biotopes and more active management result in a better score.

Basic premise is that all biodiversity in all 6 compartments (from cattle and soil-life to surrounding nature areas) is valuable – to society and to the farmer. This is why scores in the 6 compartments are weighted equally. In theory. giving extra weight to certain categories is thinkable, and can be done on a regional scale.

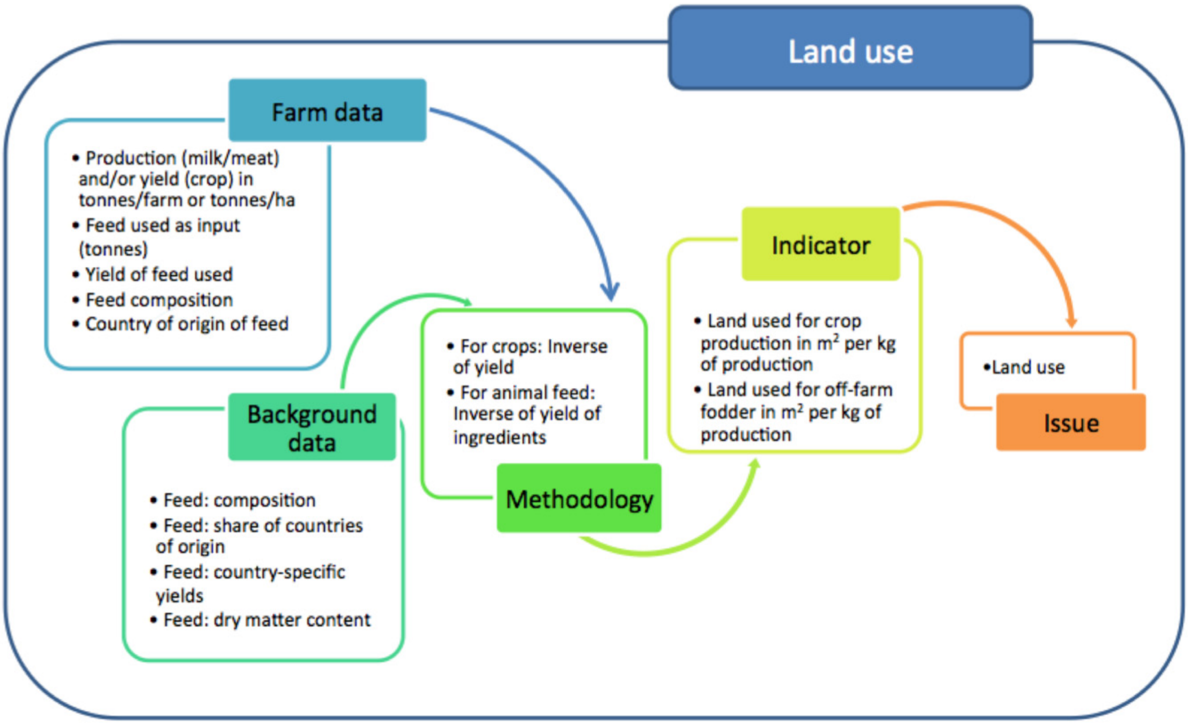
The scoring system does not distinguish between larger or smaller sizes of biodiversity-rich area. This is in line with the principle above: diversity is rewarded in general. However, a minimum size (area) should be defined for every element and applied measure to ensure an impact.
In a more advanced system, additional scores could be given for larger areas where a measure is applied – especially for non-productive areas, so for components 4 and 5. It should be investigated whether this could be applied globally, or more specifically for regions or countries.

Hunting is not included in the biodiversity assessment. It is assumed that farmers (and hunters) adhere to the law, in which case hunting cannot be assessed as having a definitive impact on local biodiversity.

7. Outlook

Biodiversity is a crucial but complex issue; there is great need for simplification. There is debate in different fora such as the International Dairy Federation on biodiversity metrics. This will hopfully lead to further aligment, including with SPA, in 2013 and 2014.

8. Land use



1. The issue

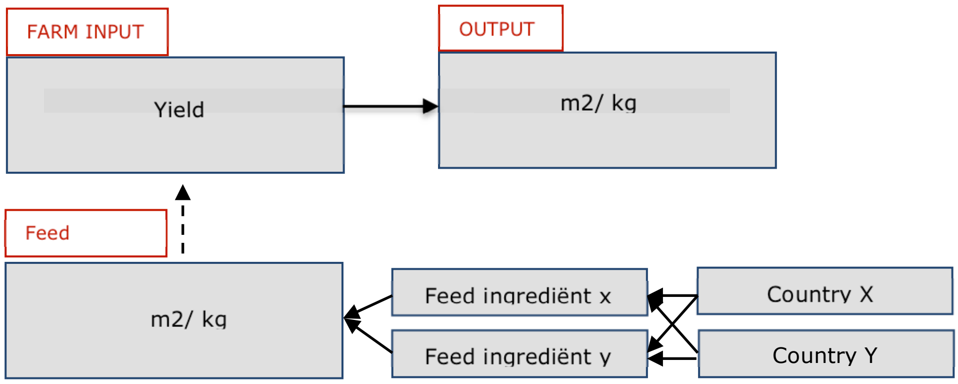
Currently approximately 40% of the land on earth is used for food production. This has led and still leads to transformation of forests, wetlands, savannahs, waterways and other landscapes, creating in turn loss of biodiversity, desiccation and other impacts. Due to population growth and increase in consumption (high quality) land becomes scarce. Furthermore, land for agriculture is competing with land for water and shelter.

Land use is an indication of the area required to produce a product. The indicator puts agricultural production into perspective at the regional or product level. Land use data are a prerequisite to measuring some of the other SAI indicators such as water use and nutrient balance.

Determining land use is rather straightforward. Important challenges are mainly related to livestock on how to include indirect land use effects e.g. identifying the system boundary and data requirements for carrying out the analysis.

2. Output indicators

The output indicator is: land used for production expressed in square meters per kg of product, or square meter per farm.



3. Methodology

System boundary
Land use in agriculture is mainly related to cultivation of the crop with yield as an important driver.
Livestock farms that use rented grazing lands and purchase feed also have to incorporate the land required to cultivate the feed – the *indirect land use*. The contribution of indirect land use due to other inputs used on-farm, e.g. seeds, packaging materials etc. is usually minor and is therefore not taken into account.

Allocation
Arable crops
Many arable crops generate more than one product. In such cases economic allocation is the recommended allocation.

Dairy
For dairy, allocation follows the guidelines set by the International Dairy Federation (IDF), see *A common carbon footprint approach to dairy The IDF guide to standard lifecycle assessment methodology for the dairy sector* (IDF, 2010)

Functional unit
The preferred functional unit is: kg product.

If there is an explicit quality distinction between products, e.g. in nutritive value, a correction factor is allowed but should be mentioned explicitly (following the guidelines of the IDF).

Calculations
The inverse of the yield is taken for obtaining the land requirement per crop.

Single feed sources
- When a single feed source is purchased (whole crop or by-product) and the selling farmer is known, preferably the actual yield is used.
- If the selling farmer or his yield are unknown but the country of origin is, the country or regional average yield will suffice.
- If the country of origin is not known, preferably a weighted average is used. A weighted average is based on the share of every country in the total amount of the feed imported [to the country where the farm is located] and the average yield of that country. A weighted average can be determined or be purchased from literature, or LCA database.
- If a weighted average cannot be determined due to lack of data, the world average yield should be used.
- The land requirement needs to be corrected for feed losses during the product's life cycle and takes into account dry matter differences between crops and feed ingredients.

Concentrates
Feed concentrates are produced out of different feed ingredients e.g. whole crops or by-products from processed food crops. Concentrates have affixed and balanced nutrition, however the feed ingredients used differ throughout the year and per supplier due to market prices of feed ingredients. It is not feasible to determine per farmer the land requirement per batch of concentrate used. Therefore, an average feed composition needs to be determined before the land requirement of the concentrate can be determined. If the average feed composition is determined a weighted average, based on average country of origin of each ingredient, is used for each feed ingredient to determine the weighted land requirement of a concentrate.

The land requirements needs to be corrected for feed losses during the feed product's life cycle and takes into account dry matter differences between crops and feed ingredients.

4. Farm data

A distinction is made in crucial and useful data:
- Crucial: farmer enters only relatively simple "crucial" data. For any data not entered, defaults from the background database are used.
- Useful: farmer also enters the extra "useful" information. In this case fewer background data are needed.

The ideal system is flexible, allowing for both routes (more or fewer farm data entered) to calculate the output scores.

	Crucial	Useful
Yield (tonnes/ ha)	x	
Yield of feed source(s) (tonnes/ha)		x
Feed use	x	
Feed composition		x
Country of origin of feed		x
Product produced (e.g. kg, liters,..)	x	

5. Background data

To calculate land requirement of feed/concentrates the following data are needed:
- Composition of feed concentrates
- Dry matter content of crops and feed ingredients
- Average share of country of origin in ingredients in specific feeds (import and export statistics of feed crops/ ingredients)
- Average country specific yields of crops used as feed ingredients

6. Preferences and rationale

In methodology for assessing land use we have made a number of choices. Below we outline the main choices and the arguments for the preference.

Data input
The amount of feed and type of feed required differs per livestock type and depends on the feed quality (e.g. nutritive value) and on other aspects like farm management. Therefore, the amount of feed used per farm is a crucial variable. For this reason the total feed fed (incl on farm feed losses) must be used as input in the system and be attributed to the product.

Ingredients used for feed differ in land requirements due to different yields per ha. First of all feed ingredients originate from different crops (e.g. wheat, tubers, oil crops etc) which have different yields and/or nutritive values. Secondly, yields of the same crop differ per parcel, per farm and per country, due to differences in growth circumstances. These different qualities are incorporated in background data.

Determining land requirements of concentrates is complex and requires large amounts of data. Furthermore, differences in composition of feed have a significant effect on calculated land use. However, farmers have often little or no influence on the composition. Therefore, it is advised to use a generic average composition per region or country per type of livestock and per type of concentrate. Defaults are preferably updated yearly and can be determined by specialized consultancies, from (scientific) literature or LCA databases.

System boundary
From input production (e.g. feed) up to product leaving the farm. This gives farmers the most perspective, since all measures in the farmers' grasp are included.

Calculation rules
More advanced and complex calculations are possible. These include indirect land use due to other farm inputs and/or environmental degradation and/or soil quality but are regarded as too complex and require much more data compared to the additional information gained for agricultural products.

Allocation
To distribute impacts among products that emerge from the same origin allocation is required. For instance, in wheat production land use must be divided over straw and grain. There are various ways to allocate the impact of co-products. The choice for a type of allocation can have a significant effect on the results. However, there is no common established method. ISO 14044 and PAS2050 give the best guidance in that respect.

The preferred approach is:

- If allocation can be avoided it should be. This can be achieved by systems expansion or by dividing the unit processes to be allocated into two or more sub processes.
- If allocation cannot be divided or isn't practicable the preferred allocation is physical allocation or mass allocation.
- If applicable supplementary requirements are not available or a physical relationship cannot be established, economical allocation should be used. Due to price fluctuations a five-year average on market prices should be used.

When used, the method and proportion based on economic value used between co-products should locally/regionally be uniformly applied. For major commodities it is especially preferable that one institution determines the economic allocation per economical region.

Economic allocation has become the practical norm in the food chain, which is why we have chosen that approach. In dairy, however, the industry is close to agreeing upon allocation based on physical properties and is broadly agreed upon in the IDF, which is why we advise this type of allocation for dairy products.

7. References

- FAOSTAT, april 2012. http://faostat.fao.org/.
- International Dairy Federation, 2010: A common carbon footprint approach for dairy. The IDF guide to standard lifecycle assessment methodology for the dairy sector. Bulletin of the International Dairy Federation 445. IDF, Brussels, Belgium.

9. Considerations on data

Data quality
Reliability of the results from the tools strongly depends on the extent to which data quality requirements are met. Ideally the tool is backed up with a document that reports the data used such that it can be checked by an independent controller. In accordance with standards like ISO and PAS, the following parameters should be taken into account:

- Time-related coverage: data that are time-specific shall be preferred.
- Geographical coverage: data that are geographically-specific shall be preferred.
- Technology coverage: data that are technology-specific shall be preferred.
- Precision, completeness and accurateness of the data: data that are most precise, complete and accurate shall be preferred.
- Consistency and reproducibility of the methods used throughout the data collection.
- Uncertainty of the information and data gaps.

Data collection
Primary activity data collection
Primary activity data shall be as specific as possible for the farm or farm product assessed. Preferably the data is collected on-farm by use of the farm's documentation. Preferably all data refer to the same time period (in most cases one year). Preferably average weighed data is used in contrast to data that represents a single moment, for instance 5-year average market prices.

Data inputs should be collected in the units most familiar to the intended user, farmers and co-operators. The tools need to convert the data to allow consistent output.

Secondary or background data
Secondary or background data shall be used where primary activity data have not been obtained, are not farm specific or are too specific for a farmer to know. An example of the latter are emission factors of manure.

Determination of the source of the secondary data shall recognize that secondary data arising from competent sources (e.g. peer-reviewed publications, well-established and recognized databases, national governments, statistical offices, official United Nations publications and publications by United Nations-supported organizations) are preferred over secondary data from other sources.

Annex 1: Full list of farm data and background data

Farm data

	Importance of data		Notes and units
	Crucial	Useful	
General			
Farm location	x		
Crops			
Types of crop	x		
Type of crops in rotation	x		split in 1st, 2nd or combined, incl grass and leguminous
Area per crop	x		ha
Yield	x		tonnes/ha, N: kg
Estimated yield reduction compared to average year		x	%
Dates of sowing/planting and harvest (per crop)	x		month
Crop residues		x	kg/ha
Crop residue management	x		burning, ploughing, removed from field
Removed crop residues		x	kg, including processed products, e.g compost
N and P content of crop		x	kg/kg
N and P content of removed crop residues		x	kg/kg
Soil characteristics			
Soil type	x		
Organic matter content		x	% from measurement
Sand and silt fraction		x	
Acidity	x		pH
Soil conservation practices			
Type of tillage		x	
Tillage date		x	
Measures taken to prevent erosion	x		From list, for instance: contour plowing
Irrigation			
Water volume	x		m3 per farm or per field
Livestock			
Types of animal on farm	x		
Animals purchased	x		number and weight
Animals sold	x		number and weight
Grazing	x		days/year or hours/day
N and P content of animals		x	N/kg and P/kg
Livestock feed			
Type	x		
Amount	x		kg
N and P content		x	N/kg and P/kg
Country of origin of feed		x	
Livestock products leaving the farm			
Type	x		milk, eggs
Amount	x		kg
N and P content		x	N/kg and P/kg

	Importance of data		Notes and units
	Crucial	Useful	
Input brought to farm			
Type	x		Manure, straw, pesticides, saw-dust, compost etc.
Amount	x		kg
N and P content		x	N/kg and P/kg
Use of fertilizer, compost, manure			
Type	x		
Application rate	x		
Application method	x		spreading and/or incorporation in soil
Emission inhibitor		x	
Split application		x	
N and P content		x	
Manure leaving farm			
Type	x		
Amount	x		kg
N and P content		x	N/kg and P/kg
Pesticides			
Amount of pesticides	x		kg or liter of product name
Applied area	x		ha/field
Application method	x		
Date of application	x		dd-mm-yy
Transport			
Transport distance		x	miles or km
Transport load weight		x	
Transport modality		x	
Land use history			
Land use changes last 20 years		x	forest to arable or grassland and vv
Past farm management		x	crop/manure combinations
Energy and fuel use			
Type	x		
Amount	x		
Energy production on farm			
Type	x		
Amount	x		
Environment and terrain			
Size of watercourses		x	may be simplified to 4 classes, dep. on width x depth
Slope ratio		x	simplified into 4 classes
Weather			
Estimated rainfall year type	x		3 classes: wet, normal or dry
Evapotranspiration		x	field sensors
Biodiversity			
Range of conditions on farm, benefitting biodiversity	x		From list, for instance non-cropped area, presence of hedges
Management measures taken for benefit of biodiversity	x		From list, for instance field margins, maintenance of hedges

Background data

Climate data

Emission factors (IPCC Tier 2)

Energy mix per country or country specific emission factors per energy carrier

Country specific N-depostion data

Default land use change

Soil characteristics (from soil maps)

Soil types

Organic matter content

pH

CEC

Weather

Rainfall (5 year and monthly average)

Rainfall shortage or surplus (5 years average)

Evaporation

Air temperature

Wind speed

Crop characteristics (averages per region and per crop)

Yield

Primary production and harvest indices

Kc values

Root depth

N-fixation

Transpiration reduction factors (FAO)

Amount of crop residues

N and P content of crops and residues

Height in relation to pesticide interception

Humification coefficient of crop residues

Dry matter content

Fertilizer and manure

Farm activity data and related emission (e.g. from manure application)

Country or region specific emissions of inputs

Composition of organic manures and fertilizers

Humification coefficient of manure

Pesticides

Basic characteristics of pesticides: % active ingredient, metabolites, toxicity, persistence, adsorption etc

Further characteristics of pesticides combined with appliction circumstances (soil and surface water types, application methods, weather)

Maximum Acceptable Concentration (MAC) per active ingredient

Predicted concentrations in groundwater at different circumstances and MAC's

Predicted concentrations in soil at different circumstances and MAC's

Spray drift emission factors per application method (possible simplification to 10 types)

Run-off emission factors per slope ratio (may be simplified into 4 classes)

Environment and landscape
Surface water types
Surface water characteristics (3 types depending on width and depth of water bodies)
Slope ratio (may be simplified in 4 types)
Region specific N in surface water

Livestock characteristics
Composition of feed concentrates (ingredients)
Dry matter content of feed ingredients
Average share of country of origin in feed ingredients (from import/export stats)
Average country specific yields of crops used as feed ingredients
N and P content of: eggs, milk, meat, feeds, animals

Annex 2: Steering Committee and external experts

Steering committee

Ernesto Brovelli	-	Coca Cola
Richard Burkinshaw	-	Kellogg
Kimberley Crewther	-	Fonterra
Hal Hamilton	-	Sustainable Food Lab
Richard Heathcote	-	Heineken
Selwyn Heilbron	-	SAI Platform Australia
Ian Hope-Johnstone	-	Pepsico
Don Jansen	-	Wageningen University and Sara Lee
Yves Leclerc	-	McCain
Sarah Lewis	-	The Sustainability Consortium
Daniella Malin	-	Sustainable Food Lab
Sikke Meerman	-	Unilever
Nathalie Ritchie	-	Kraft
Gail Smith	-	Unilever
Frederika Somers	-	Novus
Jolanda Soons	-	Lamb Weston

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External experts who provided input

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Tobias Bandel	-	Soil&More International, Netherlands
Sarah Collier	-	University of Wisconsin, USA
Sjaak Duinhouwer	-	MozaID, arable expert, Netherlands
Dana Gunders	-	Natural Resources Defence Council, USA
Anton Haverkort	-	Wageningen University & Research Center, Netherlands
Molly Jahn	-	Center for Sustainability and the Global Environment, University of Wisconsin, USA
Bianca Moebius Clune	-	Cornell University, USA
Amanda Raster	-	University of Wisconsin, USA
Debbie Reed	-	Coalition on Agricultural Greenhouse Gases (C-AGG), USA
Marlies Zonderland-Thomassen	-	AgResearch, New Zealand

Annex 3: About SAI Platform and CLM

SAI Platform

The Sustainable Agriculture Initiative (SAI) Platform is a platform created by the food industry to support the development of sustainable agriculture worldwide. Founded in 2002 by Nestlé, Unilever and Danone, SAI Platform in 2012 counts 40 members, including one fifth of the top 100 world food industries. All members share the same view on sustainable agriculture seen as a "productive, competitive and efficient way to produce agricultural products, while at the same time protecting and improving the natural environment and social/economic conditions of local communities". They cooperate in a pre-competitive manner to develop and identify strategies and tools facilitating the adoption of sustainable agriculture.

The latest services and deliverables produced include: Principles and Practices for the Sustainable production of Arable and Vegetable Crops, Coffee, Dairy, Fruit and Water; a Benchmark Study of Agriculture Standards and a Short Guide to Sustainable Agriculture. The Platform also partnered-up with one of the top Business Schools in the World – IMD – to develop the first and only training for Executives on Sustainable Sourcing. Furthermore, seminars and webinars are proposed to members throughout the year on a wide range of subjects related to sustainability, such as water management, certification schemes, the use of videos for farmer training etc.

www.saiplatform.org

CLM (Centre for Agriculture and Environment)

CLM is an independent consultancy working in the field of sustainable food and farming and rural development. CLM provides advice to governments at all levels- from the European to the local level. In addition, CLM works for and with companies such as Heineken and Unilever, and for environmental and farmer's organizations. Its expertise is rooted in professional practice, supported by CLM's network of 250 farmers and other rural entrepreneurs. In addition, the organization has extensive experience and expertise in communication and process facilitation.

One specialty of CLM is developing user-friendly tools and methodologies for measuring sustainable farming, most of them online and free to use. Some examples are: the Climate Yardstick, the Environmental Yardstick for Pesticides, the Gaia Biodiversity Yardstick and the Ammonia-Yardstick for dairy. CLM also built more integrated systems, like the "Kringloopkompas" covering six environmental themes, used for the milk production for Ben&Jerry's.

CLM was established in 1981 and is based in Culemborg, Netherlands.

www.clm.nl