How to AgBalance

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We create chemistry

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An AgBalance study starts with the so-call scoping phase in which all important background information as well as goal, scope and timeframe of the study is documented. Both customer as well as the AgBalance team agree on the document before the study is started. After this the analysis phase with collecting data and calculating the results leading to the generation of results in an easy to understand and visual way that is then presented to and discussed with the customer.

1. Scoping of an AgBalance® study

The definition of the goal and scope takes place in the planning phase of the sustainability analysis and serves as an outline for all the subsequent phases. The scope of the sustainability analysis for the analyzed case study is documented in the scoping document.

The scope of the sustainability analysis is leaned on the scope definition according to ISO 14040/44 guidelines for life cycle assessment. However, other scoping issues like time frame and geography, definition of the alternatives and scenarios are included into the scoping as well.

1.1 Background information

This section includes relevant information on the setup of the sustainability analysis.

1.2 Goal

The goal of the sustainability analysis describes the focus of the sustainability analysis, which defines the required input data.

1.3 Time frame and geography

In general, farming practices are determined by the time and geography, therefore, the time references of the sustainability analysis are defined.

As for the identified geographical characteristics, regional aspects are crucial for the selection of methods and background data.

1.4 Analyzed crops – object of the sustainability analysis

For the classification of the agricultural products in the AgBalance® Model, the Indicative Crop Classification (ICC 1.1) was used (FAO, 2017). In general, the ICC divides crops into groups, classes and subclasses. The ICC refers to the crops that are grown on farms and not to the products derived from them (FAO, 2017).

1.4.1 Functional unit

The functional unit (FU)1 serves as a meaningful unit in assessing the impact of agricultural products and provides a common basis for comparisons. In the AgBalance® Model, results are generally referred to as a quantified FU by

- mass e.g. 1 kilogram (kg) of the agricultural output (fresh matter) at field border
- area e.g. 1 hectare (ha) of agricultural land, to evaluate the productivity of evolving cultivation systems.

Other FUs can be used for the sustainability analyses with the AgBalance® Model. However, additional adjustments of the model are necessary.

1.4.2 Allocation

If the output consists of more than one agricultural product and the system boundaries are not expanded, an allocation of the considered environmental and economic impacts is necessary. By default, economic allocation, based on market or producer price, is used. However, allocation procedures based on mass, lower heating value, nitrogen or carbon content are also available.

1.5 System boundary

The AgBalance® Model depicts a generic cultivation system, so that the impact of the production of different agricultural products can be analyzed with the same model.

Taking the working input "fuel" as an example, the emissions and resource use from the extraction of crude oil, refining to diesel and transportation to the farm are considered. During farming practices like field preparation, planting, harvesting and other field operations, fuel is combusted in a machinery and results in various emissions like CO_2, NO_x, NMVOC, etc., which are considered as output of the cultivation system.

In general, the sustainability analysis in the context of the AgBalance® Model considers processes up to the field border. That means, the LCA performed with the AgBalance® Model follows a "Cradle-to-Gate" approach[2].

[1] The FU is described also as reference flow and customer benefit (CB) in the previous AgBalance® Technical Background Paper (Schöneboom, Saling, & Gipmans, 2012)

[2] Provision of infrastructure and further 'downstream' processes, such as post-harvest processes, distribution, consumption and end of life are excluded from the system in the AgBalance® Model. However, they can be incorporated if relevant for the goal and scope of the sustainability analysis. In that case, an expansion of the model is required.

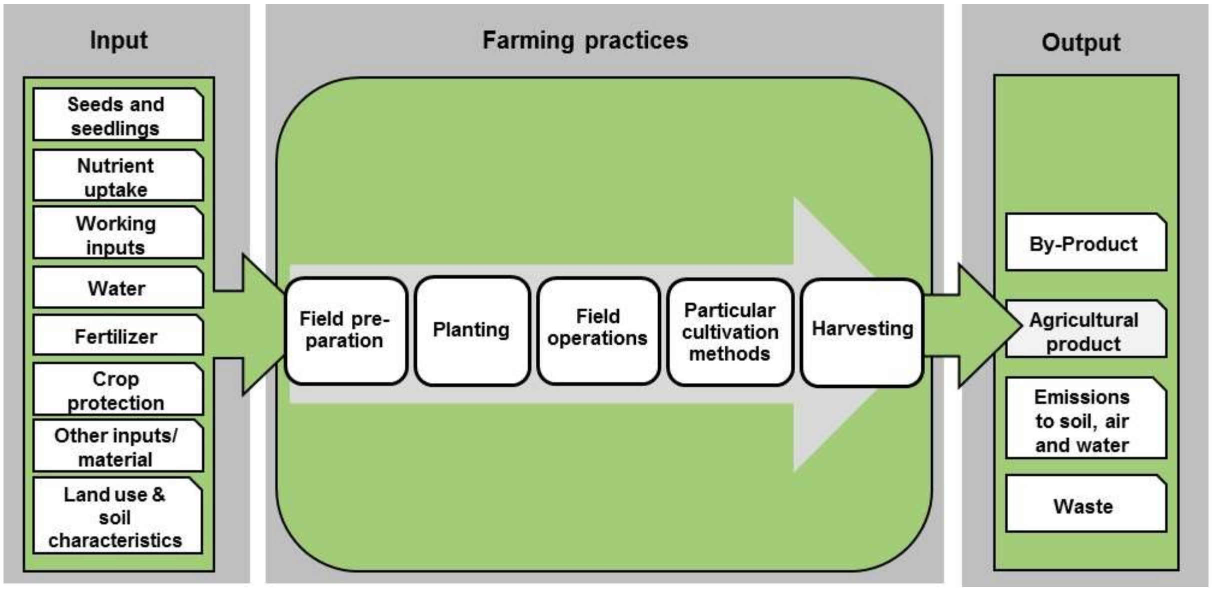

Figure 1 System boundaries of the generic cultivation system depicted in the AgBalance® Model

The cultivation system includes all ‘upstream’ processes related to the **provision of inputs** shown in Figure 1. These inputs are used for farming practices, which comprise all cultivation activities performed to produce the agricultural product and result in other outputs as well (e.g. emissions, waste and by-product). In general, labor is used as a working input in all farming practices during the growing season[3], while other farming practices may require different inputs such as seeds, fertilizers, etc.

Cut-off rules define the criteria for the exclusion of a material or energy flow. In AgBalance, all material must be included. In case of lacking datasets, an appropriate dataset is used as proxy. If none is available, a cut-off may be possible for the specific input, if the mass of the input makes up less than 1% of all inputs and the sum of all excluded inputs together is less than 5% of the total material input. However, a cut-off of energy flows is not applicable, following the PEFCR guidance (European Commission, 2017).

1.6 Definition of alternatives and scenarios

The alternatives are the references to be compared to, if applicable, the baseline for the scenario analysis. As a result, the defined alternatives have to be in line with other scoping issues. The definition of the alternatives is a key process step, because it determines the outcomes of each sustainability analysis within the AgBalance® Model. The alternative definition of farming practices usually includes the crop type and its specification (e.g. silage, corn, straw etc.), geographical (country and regional) and time specification (valid year/period for the defined alternatives) as well as applied farming practices.

Scenarios are also analyzed in the AgBalance® Model and represent theoretical predictions of the alternatives. Here, the relevant input data are varied to demonstrate their magnitude of environmental, economic and social impact as an outcome of the performed sustainability analysis.

1.7 Choice of impact categories and life cycle impact assessment methods

A predefined set of environmental impact categories is used within the AgBalance® Model. It is based on the guidance of the Product Environmental Footprint Category Rules (PEFCR) by the European Commission (European Commission, 2017).

[3] A growing season comprises the duration in which the crops are grown. It varies depending on the crop and region, influencing the time frame on the year in which crops are harvested.

Table 1 presents the predefined set of the environmental impact categories together with the respective method. An additional impact category is included for the assessment of **biodiversity**, due to its relevance in agricultural cultivation systems. On the contrary, one impact category of the PEFCR guidance document has been excluded (ionizing radiation), since the category is not significant in cultivation systems.

Table 1 Impact Categories for the sustainability analysis in the AgBalance® Model

Impact Category	Methodology of assessment	Unit
Climate change	Baseline model of 100 years of the IPCC (Myhre, et al., 2013)	kg of CO_2 equivalent
Acidification	Accumulated Exceedance (Seppälä, Posch, Johansson, & Hettelingh, 2006)	moles of H^+ ions equivalent.
Eutrophication: marine	EUTREND model (Struijs, Beusen, van Jaarsveld, & Huijbregts, 2009)	kg of N equivalent
Eutrophication: freshwater	EUTREND model (Struijs, Beusen, van Jaarsveld, & Huijbregts, 2009)	kg of P equivalent
Eutrophication: terrestrial	Accumulated Exceedance (Seppälä, Posch, Johansson, & Hettelingh, 2006)	moles of N equivalent
Human toxicity: cancer	USEtox® model (Rosenbaum, et al., 2008)	CTU_h
Human toxicity: non-cancer	USEtox® model (Rosenbaum, et al., 2008)	CTU_h
Freshwater ecotoxicity	USEtox® model (Rosenbaum, et al., 2008)	CTU_e
Land use	SOM (Milà i Canals, Romanyà, & Cowell, 2007) **(default method)** LANCA (Beck, et al., 2016) **(optional method)**	kg of C (deficit) Points
Ozone depletion	(World Meterological Organisation (WMO), 1999)	kg CFC-11 equivalent
Particulate matter	(Fantke, et al., 2016)	deaths
Photochemical ozone formation	LOTOS-EUROS model (Van Zelm, et al., 2008)	kg NMVOC equivalent
Resource use: minerals and metals	CML (Guinée & Heijungs, 1995) (van Oers, de Koning, Guinée, & Huppes, 2002)	kg Sb equivalent
Resource use: energy carriers	CML (Guinée & Heijungs, 1995) (van Oers, de Koning, Guinée, & Huppes, 2002)	MJ
Water scarcity	AWARE (Boulay, et al., 2018)	m^3
Biodiversity	(Chaudhary & Brooks, 2018)	Species loss

For the economic analysis following economic impact categories can be selected: Profit, Gross Margin, Net Value Added, Total Cost of production. Only one impact category is chosen per study and defined in the scoping document.

The social analysis is performed according the BASF's SEEbalance® methodology if relevant for the goal and scope of the sustainability analysis and defined in the scoping document.

Additional environmental, economic and social impact categories can be selected, if these are relevant for the specific goal and scope of the sustainability analysis. This procedure must be documented in the scoping document for the specific case study.

Finally, the aggregation procedure for the analyzed case study is stated in the scoping document. If aggregation is applied for the specific sustainability analysis, normalization and weighting scheme have to be specified in the scope of the sustainability analysis. Likewise, if aggregation is not performed, it is stated in the scoping document as well.

1.8 Main data sources for the AgBalance® Input Data

The main data sources consider primary or/and secondary data sources, required for the definition of the alternatives.

2. Analysis Phase with the AgBalance® Model

The sustainability analysis with the AgBalance® Model consists of four main phases: Planning Phase, Analysis Phase, Application Specific Analysis (if relevant) and Application Setup in which different experts are involved.

The aim of the Analysis Phase is generation of the AgBalance® Modelling Results. As a result, the focus of this phase is data collection and subsequent calculations in the AgBalance® Model.

First, the necessary input data in an AgBalance® Data Sheet is collected. Next, the input data is transferred to the model by manually copying the data from AgB Data Sheet. During the AgBalance® Analysis, the model calculations are performed. As a result, the AgBalance® Modelling Results of economic and environmental impacts are retrieved and copied back to an excel spreadsheet and subsequently processed depending on the chosen AgBalance® Application. In the next step the AgBalance® Modelling Results are aggregated and visualized. Finally, the internal review of the input data and generated AgBalance® Modelling Results is performed.

2.1 Data collection

The relevant agronomic and economic AgBalance® input data is collected and revised. If the social analysis is performed, the selected agronomic and economic data are used as data input for this analysis. Furthermore, the input data for the Biodiversity Calculator is collected in this step, if the biodiversity assessment is anticipated in the goal and scope of the analyzed case study. The data is then transferred into the AgBalance Model.

2.2 Processing of AgBalance® Modelling Results

The results are evaluated in terms of their plausibility. The evaluation of LCIA results is done in terms of the contribution of each individual impact category in relation to the aggregated results. Impact categories dominating the aggregated environmental score are analyzed further in detail, while the economic results are reviewed by comparing with literature data, if applicable. If the LCIA results for one or more selected impact categories are not plausible, the AgBalance® input data is revised and corrected accordingly. This process is iterative and is repeated until all inconsistencies are removed. As a final evaluation step, the LCIA results are compared to literature values concerning the analyzed agricultural product and system, if literature sources are available and are in line with the goal and scope of the sustainability analysis.

2.3 Sustainability results generation

The aggregation step is an optional step in the Analysis Phase and corresponds to the aggregation of the AgBalance® Modelling Results with respect to the environmental impact categories. If the aggregation is performed for the analyzed case study, usually, the default aggregation scheme is used. However, other schemes can be used as well if the default scheme is not suitable with the goal and scope of the sustainability analysis. For the economic analysis, the aggregation is not performed, since only one indicator is chosen within the scope of the analyzed case study, which is subsequently normalized.

3. Result generation

3.1 Normalization

The normalization step helps to understand the relative magnitude of the impact associated with a product, when compared to a reference value per impact category (ISO, 2006b). Taking the climate change impact category as an example, the normalization scheme used is applied to the climate change AgBalance® Modelling Results of the analyzed farming practices compared to the average climate change per person at global scale as a reference value.

3.1.1 Environmental normalization

The PEFCR normalization scheme recommended by the European Commission (European Commission, 2017) summarized in **Table 1** is used as the basis for the normalization scheme of environmental impacts in AgBalance® Model. As for the land use normalization value, it is based on the global normalization factor reported in (Benini, Sala, & Pant, 2015) and (GreenDelta GmbH, 2017). To account for the biodiversity impact, a yearly average of number of species[4] gone extinct (IUCN, 2019) is used as normalization factor and is integrated in the normalization scheme of the AgBalance® Model.

Table 1 Default global and person normalization factors in AgBalance® Model

Impact category	Unit	Global normalization factors	Person normalization factors
Climate Change	kg CO_2 eq	5,35E+13	7,76E+03
Acidification	mol H^+ eq	3,83E+11	5,56E+01

[4] The list of extinct species was filtered to include the same taxa covered by (Chaudhary & Brooks, 2018): mammals, birds, amphibians, reptiles and plants.

Impact category	Unit	Global normalization factors	Person normalization factors
Eutrophication: marine	kg N eq	1,95E+11	2,83E+01
Eutrophication: freshwater	kg P eq	1,76E+10	2,55E+00
Eutrophication: terrestrial	mol N eq	1,22E+12	1,77E+02
Human toxicity: cancer	CTU_h	2,66E+05	3,86E-05
Human toxicity: non-cancer	CTU_h	3,27E+06	4,74E-04
Freshwater ecotoxicity	CTU_e	8,15E+13	1,18E+04
Land use	kg C deficit eq	3,74E+16 [a)]	5,42E+06
Ozone depletion	kg CFC-11 eq	1,61E+08	2,34E-02
Particulate matter	deaths	4,39E+06	6,37E-04
Photochemical ozone formation	kg NMVOC eq	2,80E+11	4,06E+01
Resource use: minerals and metals	kg Sb eq	3,99E+08	5,79E-02
Resource use: energy carriers	MJ	4,50E+14	6,53E+04
Water scarcity	m^3 world eq	7,91E+13	1,15E+04
Biodiversity	species loss	2,54E+00 [b)]	3,68E-10

Legend:
a) Normalization factor from (Benini, Sala, & Pant, 2015) and (GreenDelta GmbH, 2017)
b) Normalization factor from (IUCN, 2019).

The normalization scheme of environmental impacts is applied to the AgBalance® Modelling Results, where lower normalized environmental results reflect a lower impact on the environment.

3.1.2 Economic normalization

As for the normalization of economic LCIA results, a similar approach is applied. The profit or other economic impact category is normalized with the global gross domestic product (GDP) per capita from the Word Bank Database of year 2018, equivalent to 8207,75 €[5]. The normalization factor with the latest available GDP per capita is yearly updated. If the total production costs are chosen, lower normalized economic results indicate a better performance in cost reduction similar to the environmental normalization scheme. On the contrary, if profit, gross margin or net added value are chosen, a higher normalized economic result indicates a better performance.

3.1.3 Social normalization scheme

A social normalization scheme is not applied in the AgBalance® Model due to qualitative or semi-quantitative character of the SEEBalance® methodology.

3.2 Weighting

The environmental and economic scores are useful for the interpretation and visualization of the results. Here, a graphic representation including simultaneous visualization of economic and environmental scores is performed. The social analysis is performed independently, and the results of this analysis are not aggregated to a single score due to methodological limitations.

A weighting scheme is used to define the relative importance of the impact categories among each other. In this context, it is important to mention, that on the one hand, the definition of appropriate weighting methods inherently involves value choices, based on policy, cultural and other preferences and value systems (Sala, Cerutti, & Pant, 2018). As a result, the weighting method is a matter of scientific consensus that can be argued about. On the other hand, it is seen as crucial to aid the aggregation of complex information and enhance the practical utility of LCAs in complex decision situations.

3.2.1 Environmental weighting scheme

The environmental impact weighting scheme is based on the aggregated weighting set and the robustness factors of scientifically approved weighting scheme for environmental categories of the PEFCR (European Commission, 2017) (Sala, Cerutti, & Pant, 2018)). It was adapted to include the biodiversity impact category and exclude the ionizing radiation impact category.

[5] Global GDP of 2018 (10.881,139 USD) is expressed in USD value of 2010 (The World Bank, 2019). Conversion rate of 2010 taken from Finance Portal of the BASF equivalent to 1,326 USD/€.

3.2.2 Economic weighting scheme

An economic weighting scheme is not applied in the AgBalance® Model. Here, one economic indicator is chosen for the assessment of the economic impact of the analyzed alternatives and scenarios depending on the scope of the study. In most of the cases, the profit indicator is chosen from the available economic impact indicators in the AgBalance® Model, since this indicator is usually of highest relevance to the target audience (Schöneboom, Saling, & Gipmans, 2012), as it considers the total income and total costs.

3.2.3 Social weighting scheme

A social weighting scheme is not applied in the AgBalance® Model due to the qualitative and semi-quantitative character of the SEEBalance® methodology.

3.3 AgBalance® Modelling Results: environmental and economic scores

Depending on the goal and scope of the sustainability analysis, a graphic representation of environmental and economic LCIA results can be useful. In this case, an environmental and economic score for each alternative is calculated. The scores enable a relative comparison between different alternatives. Here, the normalized and weighted environmental LCIA results are used to calculate the environmental score, while the normalized economic LCIA results (usually profit) are used to calculate the economic score.

The environmental score of each alternative is plotted against their corresponding economic score, as shown in **Figure 1** below. The scale of the axes is simplified for better visualization, showing the results as a high and low environmental and economic score. The vertical axis is used to plot the environmental score, where low environmental burden (high environmental score) is shown in the upper area of the graphic. The horizontal axis is used to plot the economic score, where high economic result (high profit) is shown in the right area of the graphic (see labels of the axes in **Figure 1**). This way, the alternatives with better overall sustainability performances (high environmental and economic score) will locate closer to the area of the upper right corner of the graph. It is important to mention, that the scores are a relative indication of performance among the analyzed alternatives and not a measurement of the environmental impact or the economic results in absolute terms.

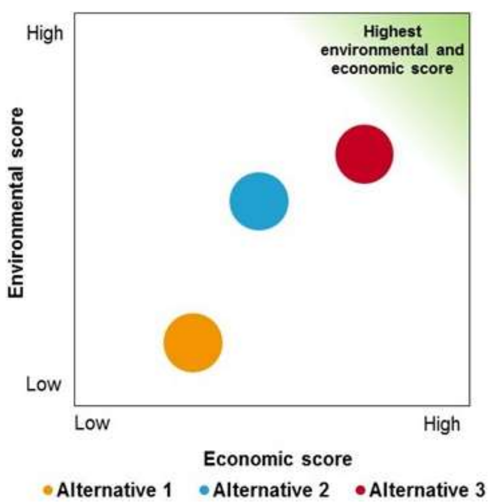

Figure 1 AgBalance® environmental and economic scores

This graphical representation is similar to the Eco-Efficiency Analysis Portfolio of BASF's Eco-Efficiency methodology (Uhlman, et al., 2016). The main difference is that the Eco-Efficiency Analysis shows the normalized costs in person years as an economic impact in the axis, whereas the graphical representation of the economic AgBalance® Modelling Results usually shows the normalized profit.

3.4 Presentation and discussion of the results to the customer

The discussion with customer has the purpose of getting feedback on the results and to discuss the relevance of the input data for the environmental, economic and social impact for the defined alternatives and scenarios as well as next steps.

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