Environmental Impact Categories

Technical documentation

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The environmental impact in BASF AgBalance® Model is assessed using the impact categories which are recommended by the (European Commission, 2017), except for biodiversity, which is an additional impact category.
All impact categories may be aggregated to a total environmental impact with the normalization and weighting scheme.

1. Climate Change

In the AgBalance® Model, the assessment of climate change is performed with the baseline model adjusted for the 100-year global warming potential (GWP), as defined by the Intergovernmental Panel on Climate Change (Myhre, et al., 2013). The greenhouse gas effect of one kilogram of each substance is assessed as a relative measure, using the radiative forcing of one kilogram of carbon dioxide (CO_2) as a reference.

The EU Product Environmental Footprint (PEF) recommends biogenic carbon assimilations and emissions to be considered only if they are stored for more than 100 years (European Commission, 2017). In the case of the agricultural products, these rarely store carbon longer than 100 years, therefore, the biogenic CO_2 storage in the crop is, by default, not accounted the calculations in the AgBalance® Model. If relevant for the goal and scope of the sustainability analysis it is possible to account for the biogenic CO_2 storage in the crop.

2. Eutrophication

Marine: The EUTREND model of (Struijs, Beusen, van Jaarsveld, & Huijbregts, 2009) is used in the AgBalance® Model to measure the extent to which a substance causes the proliferation of algae in marine water, damaging the aquatic ecosystem (Anderson & Thornback, 2012), using an equivalency of the substances in kilograms of nitrogen.

Freshwater: The assessment of freshwater eutrophication in AgBalance® Model is performed with the EUTREND model, also used for the marine eutrophication impact category. The model assesses the extent to which a substance causes the proliferation of algae in freshwater.

Terrestrial: The model of Accumulated Exceedance (Seppälä, Posch, Johansson, & Hettelingh, 2006) reflects the potential of a substance to cause terrestrial eutrophication in its equivalent to mols of nitrogen (N). This model is used in AgBalance® Model not only for the assessment of acidification but also for terrestrial eutrophication of all emissions.

3. Biodiversity

It is important to mention that the European Commission favors addressing biodiversity separately (European Commission, 2017). In the context of conservation in agricultural systems, an assessment of the biodiversity on farm level and possible improvements is fundamental. Hence, biodiversity is a relevant impact category for the impact assessment evaluation of the agricultural cultivation systems for BASF. Resulting from this need, a biodiversity impact category was developed by BASF and applied in AgBalance® Model (Ulrich, et al., 2020). Currently, the analysis is performed in a separate tool.

With the intention to estimate the impact of agri-environmental strategies on biodiversity on farm, BASF developed a tool, combining two approaches:

1. In order to assess the biodiversity footprint in LCA, a characterization model (Chaudhary & Brooks, 2018) was used, which predicts the global potential species loss of 5 taxa[1] per unit of area of 804 ecoregions, for occupation and transformation of 5 land use types and three levels of intensity.

2. The University of Cambridge has summarized evidence from scientific literature about the effects of conservation interventions (Dicks & Ashpole, 2014) to support decisions on how to maintain and restore global biodiversity. Furthermore, an assessment of effectiveness and certainty of these interventions is available in the Conservation Evidence free-access database.

The output of this tool consists of a biodiversity score (in percent) and adapted characterization factors of global potential species loss due to land use, based on the interventions taking place on the farm. Detailed information on the methodological aspects of the tool can be found in the publication of the Biodiversity Calculator (Ulrich, et al., 2020).

In order to include the biodiversity assessment in the agricultural model, the results from the Biodiversity Calculator will serve as inputs to adjust the global potential species loss per hectare.

4. Land use

In the current PEFCR (European Commission, 2017) the LANCA method (Beck, et al., 2016) is recommended to assess land use impact. This method consists of various indicator values based on ecosystem functions: erosion, infiltration reduction, physicochemical filtration reduction, groundwater regeneration reduction and biotic production loss, given the land use type, time of use, area and site-specific conditions. The Joint Research Center has aggregated four of these indicators into a dimensionless soil quality index and recommends this method for the land use assessment under the new Environmental Footprint scheme (Fazio, et al., 2018). To avoid redundancy, only the indicators with lowest correlation coefficients were included. In this case, the physicochemical filtration and the mechanical filtration indicators were highly correlated. The physicochemical filtration was therefore not considered for the aggregation. The complexity of this method and the degree of aggregation makes the results difficult to trace.

In case not all data is accessible a SOM methodology is chosen for analysis in the AgBalance® Model due to its simplicity proposed by (Milà i Canals, Romanyà, & Cowell, 2007) and recommended for the European Context (European Commission, 2011). However, in this method other soil functions, such as resistance to erosion, are not taken into account (Vidal-Legaz, et al., 2016).

[1] The taxa covered by (Chaudhary & Brooks, 2018) include mammals, birds, amphibians, reptiles and plants.

5. Water Scarcity

The AgBalance® Model uses the Water Use in Life Cycle Assessment (WULCA), a consensus of the UNEP-SETAC Life Cycle Initiative working group for a method of water scarcity footprint assessments (WULCA, 2018). The outcome of this consensus is the available water remaining (AWARE) method, which assesses the available water remaining per unit of surface in a given watershed relative to the world average, after human and aquatic ecosystem demands have been met, in m^3 world eq.

6. Toxicity

Human Toxicity: The toxicity impact of agricultural chemicals on humans is assessed in AgBalance® Model with the USEtox® model release version 2.12, using characterization factors developed by (Rosenbaum, et al., 2008), based on environmental fate, exposure and effects. The characterization factor is assessed in comparative toxic units (CTUh), which represents the estimated increase in morbidity in the total human population, per unit mass of a chemical emitted. Human effect factors relate the quantity a population is exposed to via ingestion and inhalation to the likelihood of detrimental effects of the chemical in humans. It is grounded on the results of laboratory studies on toxicity data and cancer as well as non-cancer effects. Human toxicity non-cancer assesses the risk potential of chemicals intake for cases of non-cancer diseases in comparative toxic units (CTUh), and the human toxicity cancer assesses the increase of morbidity with cancer effects, also in CTUh (European Commission, 2013).

Freshwater ecotoxicity: The USEtox® model assesses the ecotoxicity impact using the freshwater ecotoxicity as an indicator. This decision was based on the fact that most of the data needed for the calculation of CFs, such as the bioconcentration factor, is widely available with regards to water organisms (Klöpffer & Grahl, 2009) (Rosenbaum, et al., 2008). This assessment method is included in all the emission flows in the AgBalance® Model for which the USEtox® values (release version 2.12) are available. It measures the impact of chemicals on the health of water organisms and ecosystems (European Commission, 2013) in comparative toxic units (CTU_e), which refers to the potentially affected fraction of species, integrated over time and volume per kilogram of substance emitted (Rosenbaum, et al., 2008).

7. Other Impact Categories

7.1 Acidification

The model of Accumulated Exceedance (Seppälä, Posch, Johansson, & Hettelingh, 2006) reflects the potential of a substance to cause the acid deposition or “acid rain” (Anderson & Thornback, 2012) as its equivalent charge in mols of hydrogen ions (H^+). This model is used in AgBalance® Model, for the assessment of acidification of all emissions.

7.2 Ozone depletion

Some farming practices analyzed in the AgBalance® Model, such as burning of crop residues or biomass for field clearance causes emissions of halogenated organic compounds that contribute to the destruction of the ozone layer.

The chosen methodology considers the entire atmospheric lifetime, a substance can be characterized by the amount of ozone it can destroy. This characterization follows the assessment of the (World Meterological Organisation (WMO), 1999), which assess the impact of gaseous substances in the destruction of the stratospheric ozone layer as the equivalent mass of trichlorofluoromethane (CFC-11), that is, the impact of a no longer used chlorofluorocarbon refrigerant.

7.3 Particulate matter

A model developed by UNEP-SETAC Task Force on PM (Fantke, et al., 2016) is used AgBalance® Model for the assessment of the impact of particulate matter. It quantifies the damage to human health caused by primary and secondary $PM_{2,5}$ [2], as a change in the mortality due to the exposure to these emissions in terms of deaths per kilogram of $PM_{2,5}$ (Fantke, et al., 2015).

7.4 Photochemical ozone formation

In AgBalance® Model, gaseous substances are characterized by their potential of photochemical ozone formation using the model of (Van Zelm, et al., 2008), based on the mass of non-methane volatile organic compounds (NMVOC) as a reference.

7.5 Resource use: minerals and metals

The CML method is applied in AgBalance® Model, which considers the natural reserves of resources and their rates of extraction, using the depletion of the element antimony (Sb) as a reference, to derive characterization factors for the depletion of minerals and metals (Guinée & Heijungs, 1995) (van Oers, de Koning, Guinée, & Huppes, 2002). Thus, it indicates the decreasing availability of non-renewable resources as a relation between the consumption and scarcity of minerals and metals (Anderson & Thornback, 2012).

7.6 Resource use: energy carriers

Similar to the resource use of minerals and metals, it indicates the decreasing availability of energy-bearing materials as a relation between the consumption and scarcity of fossil fuels and uranium, based on the ultimate reserve of fossil carbon in the earth's crust and uranium, respectively (Guinée & Heijungs, 1995) (van Oers, de Koning, Guinée, & Huppes, 2002).

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[2] Primary $PM_{2,5}$ refers to direct emissions of $PM_{2,5}$ into the atmosphere, while secondary $PM_{2,5}$ are those emissions generated from gas or vapor phase precursors (e.g. NO_x, SO_x, NH_3) through chemical and/or physical processes. (Fantke, et al., 2016)

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