LUC impact
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2023

LUC Impact Tool – Full Dataset 2022

Documentation of the LUC Dataset:
Methodology and basic principles

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About us

Blonk is a leading international expert in food system sustainability, inspiring and enabling the agri-food sector to give shape to sustainability. Blonk's purpose is to create a sustainable and healthy planet for current and future generations. We support organizations in understanding their environmental impact in the agri-food value chain by offering advice and developing tailored software tools based on the latest scientific developments and data.

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1. Introduction

Through this document we share the methodology and data sources used to calculate land use change (LUC) emissions presented in the 2022 LUC Impact dataset. ***Tables and Appendices are deleted in this version of the methodology description. A full version (confidential) of this document is available for clients of the LUC impact tool or LUC impact dataset.***

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Deforestation is one of the major issues caused by the global agriculture production system, with as much as 8% of global CO_2 emissions being attributable to land use change. Many publications have focused on this issue and have provided solid global or country specific estimations of CO_2 emissions due to land use change based on available statistics and/or satellite imagery.

A big challenge for practitioners of Life Cycle Assessments (LCA) is to translate this impact of land use change to specific crops from specific countries when little primary data is available. Calculation methodologies are often not straightforward, even in the case when detailed information is available. The calculation becomes even more challenging when no specific information is available for the crop of interest. Our LUC Impact tool and dataset aim to provide insights into the impact of land use change of a wide variety of crop-country combinations and is specifically designed to support LCA practitioners and other professionals or academics.

Updated dLUC Excel-tool discontinued, web-tool in development

We transitioned from the Excel-based tool to a more extensive web-based tool, to provide the user with a reliable, complete, and well-maintained calculation application for different land use change accounting methodologies. We aim to provide the user with more freedom regarding calculation parameters (such as amortization method and amortization time), facilitate comparison of different results and result calculating following novel methodologies which are recommended in leading LCA and carbon footprint guidelines. As the development of the web-based tool is our priority, the updates of the Excel-based tool are discontinued.

2. Calculation methodology

New in 2022: Results with equal and linear amortization

Starting from 2022 there are two versions of the dLUC dataset: a result dataset calculated with linear amortization and a result dataset calculated using equal amortization. The choice for equal or linear amortization in the dLUC emission calculation is related to the guideline that the user wishes to comply to: the PAS2050-1 (and thus the European Commission's PEF guidance) prescribes the use of equal amortization; the recently published SBTi FLAG calculation guidance prescribes the use of linear amortization. The amortization method in direct Land Use Change defines how the impact of a land use change event (e.g., deforestation) is accounted for in the years following the event. In equal amortization, dLUC emissions are equal for each year after the land use change event, for the duration of the amortization period (in this case: 20 years). In linear amortization, dLUC emissions linearly decrease towards zero after the land use change event, for the duration of the amortization period (in this case: 20 years). Linear amortization thus implies that the years directly after a land use change event carry a larger burden compared to years further away from the land use change event. This implies that for the emission calculation not only the question *if* land use change in the last 20 years is related to a specific crop-country combination is relevant, but also *when* the land use changes took place.

2.1 Equal amortization

The Excel dataset gives the results of the three calculation methods from the 'country known, land use unknown' functionality of the tool. The weighted average takes into account relative differences in crop expansion at the expense of forest, grassland, annual/perennial. The normal average is a simple average of these options. All results are scaled to the relative amount of expansion of the crop. The worst case of the average and weighted average is used in the PAS2050-1 protocol. The Food SCP method requires the weighted average for the estimation of land use change emissions when previous land use is unknown. The GHG Protocol Product Standard requires that the method used to calculate land use change impacts, including the average approach, be included in the inventory report.

A summary of the procedure to calculate emissions from dLUC when country of cultivation is known and the previous land use is unknown, is provided below. The exact calculation method is described in the PAS 2050-1:2012 (horticulture), in section 5.2.3.3 "Assessment of average GHG emissions from land use change when the previous land use is not Known".

1. Expansion and contraction of forest and grassland per country (as defined in PAS 2050) are based on FAO land occupation change in 20 years.
2. Expansion and contraction of specific crop is based on FAO harvested area change in 20 years. Cropland is either classified as perennial or annual cropland.
3. For each crop: transformation in hectares from forest, grassland, perennial crop and annual crop is calculated.
    a. The weighted average takes into account relative differences in crop expansion at the expense of forest, grassland, annual/perennial based on the expansion/contraction of forest, grassland and cropland.
    b. The normal average is a simple average of these options (all 1/3).
    c. All results are scaled to the relative amount of expansion of the crop. This is described in the PAS2050.
4. Based on worldwide climate and soil types provided by EU, climate zone and soil types are selected which are representable for the country. With this, carbon stock can be calculated. For forest land, specific biomass is obtained per country from the Global forest resources assessment 2020. For grassland, biomass is derived from continent and climate condition (based on European commission data and IPCC values). Soil carbon content is based on IPCC 2019 soil carbon defaults for climate regions and soil types, stock change factors from IPCC 2019 are used to calculate the soil carbon stock for different land use and land management practices. Biomass of crops is obtained from either the IPCC or PAS 2050, one value represents all annual crops and another all perennial crops.
5. Change in carbon stock between previous and current land use is multiplied with 44/12 to obtain kg CO_2. This is divided equally over 20 years (multiplied with 1/20).
6. The crop yield is derived from FAOSTAT and determines impact per kg of product.

Following this calculation method, as described in the PAS2050-1 protocol, implies that emissions are calculated over the net expansion of a specific crop-country combination over the last 20 years. In case the crop area expanded first, and then contracted to equal to, or less than the area 20 years ago, the net expansion is zero.

2.2 Linear amortization

For the calculation of dLUC emissions through linear amortization, the exact same steps are takes as described in section 2.1, with the important difference that the calculation is made 20 times over a 1-year period (although still with a three-year average). The results found for the most recent year (difference 2018-2020 compared to 2017-2019) will be multiplied by the highest percentage, and the results found for the most historic years (difference 1997-1999 compared to 1998-2000) is multiplied with the lowest percentage. The percentage of each year is calculated as: amortization percentage = (1 / amortization time (= 20 years)) + (((amortization time / 2) - ((conversion year + 1) - (1 / 2))) * (2 / amortization time^2)).

Following this calculation method implies that emissions are calculated for all (yearly) expansions which occurred of a specific crop-country combination in the last 20 years. In case the crop area expanded first, and then contracted to equal to, or less than the area 20 years ago, the total expansion is considered larger than zero.

Due to fluctuations in cultivated area for crops in FAO statistics, most of the crop-country combinations are associated with some total expansion. For this reason, many crop-country combinations which lead to zero expansion (and thus zero emissions) when using equal amortization will be associated with some expansion (and thus emissions) when using linear amortization.

2.3 LUC calculation in standards

The different standards are transparently summarized in the table below.

	FLAG	Draft GHG protocol	PAS 2050
Amortization period	20 years	20 years	20 years
Amortization method	Linear amortization	Linear or equal amortization	Equal amortization
Approach	Shared responsibility or Product specific	Shared responsibility and/or Product specific	Product specific
Separately report GHG	Not mentioned	Should be separately reported	Not mentioned
Emissions from biomass burning	Not mentioned	Should be included	Not mentioned
Emissions from peatland drainage	Not mentioned	Should be included	Not mentioned

2.4 Methodological remarks

Our LUC calculation methodology is under constant development. Several important aspects to know about the current methodology, used to calculate the LUC emissions for the 2022 dataset are summarized in the table below.

Methodological aspect	Methodology in 2022 dataset	Consideration for future version
Soil nitrogen mineralization, related to soil carbon losses	Included, characterized using IPCC AR5 GWP 100 factors (incl. climate carbon feedback): 298 kg CO_2eq./kg N_2O.	In 2023 version of tool, it will be possible to select other GWP factors for characterization of N_2O.
Emissions from peat oxidation and mineralization	Not included. The tool is applicable for mineral soils only.	No direct plans to include in 2023 version of tool or dataset.
Emissions from biomass burning	Not included	Plan to include in 2023 tool and dataset.
Double cropping	No correction is made for double cropping. This results in an overestimation of the total harvested area for certain crops in certain countries. In case the total harvested area of crop-country combinations expanded in the last 20 years due to increased implementation of double cropping, the emissions from land use change are overestimated. This situation is, among others, applicable for the cultivation of soybeans in Brazil.	Plan to include in 2023 tool and dataset. (We recognize that accounting for double cropping in our dLUC tool and dataset is required to best represent the land transformation situation in the results. Internal research is ongoing to find a suitable way to account for double cropping correctly and consistently for all crop-country combinations.)

3. Data sources

The current results are based on the average FAO statistics (harvested area) of 2018-2020 and 1998-2000.

3.1 Areas

Forest and grassland area

Forest and grassland area for all countries are obtained from FAOstat. The item definitions are:

- Item: Land under perm. meadows and pastures, FAO item: 6655, FAO element: 5110
- Item: Forest land, FAO item: 6646, FAO element: 5110

Data is downloaded in August 2022 and contains data up to and including 2020.

Harvested area

For each crop and country, we use FAO data from "Crops and livestock products", obtained from FAOstat in August 2022. The area harvested over the last 20 years is downloaded and contains data up to and including 2020.

3.2 Carbon stocks

Soil carbon stock

The carbon stock will depend on the country under study. Soil carbon content is based on IPCC 2019 soil carbon defaults for climate regions and soil types: From IPCC 2006 (no refinements in IPCC 2019 refinements) Volume 4, Table 2.3. stock change factors from IPCC 2019 are used to calculate the soil carbon stock for different land use and land management practices: From IPCC 2019 refinements, Volume 4, Table 5.5. The climate in a country is often described by a combination of multiple climate types, just as the soil is described by a combination of different soil types. We take into account the 2 most prevalent climate types and soil types to calculate the climate- and soil-specific soil carbon stock.

Tables are deleted in this version of the methodology description. A full version of this document is available for clients of the LUC impact tool or LUC impact dataset.

Forest vegetation carbon stock

Forest carbon stocks include above and below-ground biomass carbon stock and carbon stock in dead matter and litter. All of these carbon stocks are considered in the total vegetation carbon stock obtained from the Forest Resource Assessment (FRA) 2020, published by the FAO. This assessment is updated every 5 years.

Grassland and vegetation carbon stock

For the calculation of the LUC dataset results, grassland carbon stocks of IPCC are used. For crops, values are obtained from the European Commission. The vegetation carbon stock for annual crops is taken to be 0 tonne C/ha, for perennials this value depends on the climate type. In specific, values are obtained from C(2010) 3751: COMMISSION DECISION of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC, Official Journal of the European Union, L 151/19.

Tables are deleted in this version of the methodology description. A full version of this document is available for clients of the LUC impact tool or LUC impact dataset.

3.3 Definitions

Weighted average, normal average and worst case

Definitions of the three results are provided below:

- **Weighted average:** conversions of forestland to cropland and grassland to cropland and conversions between annual and perennial cropland are based on statistics of expansion/contraction of forestland, grassland and annual/perennial cropland. This is the methodology as described in chapter 2 of this document. The exact calculation method is described in the PAS 2050-1:2012 (horticulture), in section 5.2.3.3 "Assessment of average GHG emissions from land use change when the previous land use is not Known".

- **Normal average**: conversion of forestland to cropland and grassland to cropland and conversions between annual and perennial cropland are all set to 1/3rd of the converted area. This means that a normal average of the emissions related to each of the three types of conversions is taken. This is also described in the PAS 2050.
- **Worst case** is the highest of the two above. It is prescribed by the PAS 2050 to take the highest of these two calculation methods.

Additional (intermediate) parameters

In the datasets where equal amortization is applied, additional parameters are provided. These parameters provide the user with insights into the main intermediate calculation parameters for the emissions from land use change, the additional parameters can also be used as an input for other calculations or other applications. The parameters which are included, in addition to the normal average and weighted average emissions from land use change, are the following:

- Crop expansion (%): Percentage of current harvested area of the crop under study which was not in use for cultivation of this crop 20 years ago.
- Expansion at expense of forest to analyzed crop (%): Percentage of current harvested area of the crop under study, which was forest 20 years ago.
- Expansion at expense of grassland to analyzed crop (%): Percentage of current harvested area of the crop under study, which was grassland 20 years ago.
- Expansion at expense of perennials to analyzed crop (%): Percentage of current harvested area of the crop under study, which was perennial cropland 20 years ago.
- Expansion at expense of annuals to analyzed crop (%): Percentage of current harvested area of the crop under study, which was annual cropland 20 years ago.
- Emissions from conversion of forest (tonne CO2 eq per hectare): Emissions related to the conversion of a hectare forest to the type of cropland under study (annual or perennial), for the selected country.
- Emissions from conversion of grassland (tonne CO2 eq per hectare): Emissions related to the conversion of a hectare grassland to the type of cropland under study (annual or perennial), for the selected country.
- Emissions from conversion of perennials (tonne CO2 eq per hectare): Emissions related to the conversion of a hectare perennial cropland to the type of cropland under study (annual or perennial), for the selected country.
- Emissions from conversion of annuals (tonne CO2 eq per hectare): Emissions related to the conversion of a hectare annual cropland to the type of cropland under study (annual or perennial), for the selected country.

3.4 Differences compared to previous years

Appendix I and II show the main differences in results between the 2021 and 2022 version of the LUC dataset (Appendix I) and main differences for between the 2018 and 2021 version of the LUC dataset (Appendix II). In general, main drivers for differences are the following:

Main drivers for change

When interpreting the data (differences), it is important to realize where (changes in) dLUC emissions originate from. The changes in direct land use change emissions compared to previous years for a crop-country combination are mainly driven by three questions:

- *Did the total forest area in a country contract over the last 20 years?*
  Conversion from forest area to cropland results in the largest loss of carbon stock, compared to conversion from grassland or changes between annual and perennial croplands. Therefore, if the total forest area in a country did not reduce compared to 20 years ago, the emissions factors due to direct land use change will generally be low.
- *Did the total area for crop cultivation increase in a country?*

If there is no increase in the total area used for crop cultivation, according to the PAS-2050-1, it can be assumed that no contractions of forest or grass land are caused by an increase of cropland. Therefore, the emissions factors for that country will generally be low.

- *Did the total area harvested for the crop under investigation expand?*
  If the area harvested for a crop under investigation did not increase over the last 20 years, there is no land use change. If there is an increase, the emissions due to land use change will be mainly driven by the factors mentioned above. For crops that are rapidly expanding, this can result in large changes in emissions factors between the chosen 20 year interval.

Differences between 2021 and 2022

For the difference between 2021 and 2022 the same timeframe is considered. Due to the update from an Excel based tool to the web-based tool, some differences occur. Also, the FAO data which is downloaded in 2022 contains deviations from the FAO data downloaded in 2021, also for historic data. Main reasons for deviations between the 2021 and 2022 dataset, when calculated over the same period of time are:

- Change in historic grassland and/or forest data for country in new FAO download (download in August 2022 compared to March 2021)
- Change in historic cropland data (harvested area) for crop country combination, in new FAO download (download in August 2022 compared to March 2021)
- Resolved small issue with lookup of climate and soil type in the Excel-based tool (effects only three countries).
- Difference in methodology compared to Excel tool: difference in carbon stock between perennial cropland and this crop is not set to 0, as carbon stock for vegetation has a non-standard value for this crop.
- Due to changes in historic data for harvested area on other crops cultivated in this country in the new FAO download (August 2022 instead of March 2021), the total expansion/contraction of cropland is different and thus conversions are different.
- A small error occurs due to rounding of values in the 2022 dataset to 2 decimals.

For all results, differences between the 2021 and 2022 dataset occur due to the availability of two additional years in the FAO data, and thus emission calculation for 2020, instead of for 2018.

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