SEGES INNOVATION

STØTTET AF
Promilleafgiftsfonden for landbrug

RAPPORT

[Opgørelse af klimaaftrykket fra dyrkning af afgrøder - delanalyse 2]

November 2022

Promilleafgiftsfonden for landbrug

Crop cultivation: multi-functionality and time representativeness

Alberto Maresca, SEGES Innovation P/S

Summary

This memo is written as part of the project “Fokus på klima- og bæredygtighedsopgørelser samt virkemidler, der understøtter landbrugsbedriftens grønne omstilling”, and it focuses on selected key topics identified as relevant for the ESGreen tool with respect to the carbon footprint of specific crop products. Typical allocation methods based on broadly used guidelines have been reported, with focus on crop production. Calculations examples have been provided (in the main text and in the supporting Excel file), showing how country specific allocation factors can be calculated, based on country yields, straw management practices and market prices. Recommendations for the ESGreen tool have been provided.

Table of Contents

Abbreviations

FAO: Food and Agriculture Organization; IPCC: Intergovernmental Panel on Climate Change; LCA: life cycle assessment; LEAP: Livestock Environmental Assessment and Performance; EF: environmental footprint; PEFCR: product environmental footprint category rule

Introduction

This memo is written as part of the “Klima- og bæredygtighedsopgørelser” project. This document focuses on selected key topics identified as relevant for the ESGreen tool with respect to assessment of climate change impacts (also referred to as “carbon footprint”) of specific crop products, starting from “bedrift” data.

Life Cycle Assessment (LCA) is a widely applied tool to evaluate the environmental impacts related to specific productions or management practices, over a wide range of “mid-point level” impact categories (e.g. climate change, eutrophication of freshwater, ecotoxicity freshwater and water scarcity) and “end-points levels” categories (e.g. damage to human health, damage to ecosystem, depletion of natural resources). The assessment of climate change impacts is part of a LCA, and sometime it is carried out as a stand-alone assessment, without being accompanied by other potential impacts. As for now, the ESGreen tool only focus on “climate change” impacts: therefore, this report only focuses on “climate change” (although the same discussions presented below are also valid for other this impact categories).

Depending on the focus of the LCA study, the choice of functional unit (e.g. the focus is on the production of 1 kg product), system boundary (e.g. the whole value chain is included in the assessment), system model (e.g. cut-off by classification), emission models (e.g. the ones recommended by the “The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories”), impact assessment method (e.g. the EF method (European Commission, 2021)), modelling approach (e.g. attributional LCA), etc… is likely to vary across different studies, despite the fact that they may all be compliant with the overarching ISO LCA standards (ISO, 2006a, 2006b). In the interest of harmonizing the LCA methodology and favor direct comparability across products or the same type, the European Commission has recommended the use of Environmental Footprint (EF) method (Commission Recommendation 2021/9332/EU, 2021). LCA is a dynamic tool, used for both research and environmental product declarations. In the interest of simplicity, this report only focuses on key aspects from widely used guidelines, i.e. the PEFCR Feed for food-producing animals (PEFCR: product environmental footprint category rule; (PEFCR Feed, 2020)), which is part of the European EF program, and the FAO guidelines for animal feeds supply chains (FAO, 2016).

The aim of this report is to support the further development of the ESGreen tool on the aspects of multi-functionality (with focus on cereal cultivation) and temporal representativeness (of the activity data and prices used for the economic allocation).

Discussion

Multifunctionality in crop cultivation

Agricultural processes and related activities often generate multiple products (so the name "multifunctional" processes). For example, the cultivation of cereals generates grains and straw, the production of dairy cattle generates milk, meat, manure and (in some parts of the world also) draft power, the pressing of rapeseeds generates rapeseed expeller and rapeseed oil, etc.… Specific guidelines, e.g. (FAO, 2016; PEFCR Feed, 2020), define how the impacts from multifunctional processes should be allocated across the individual products, based on specific criteria.

In general, the outputs of a multi-functional process have to be classified into either co-products, residuals or waste. This is just a convention (and some variations exist, depending on the specific guideline used), but it is practical to categorize the outputs into these groups:

- co-products: carry the burdens of the multi-functional process
- residues: are regarded as residual without allocation of any upstream burden (a typical example is manure), and the emissions related to their management are allocated to the other farm outputs (i.e. the co-products) where the residue is produced; the downstream user of the residues can use them free of any upstream production burden (e.g. the crop producer using manure).
- waste: "*are materials with no economic value and no interest in their collection without compensation. The producer therefore generally has to pay to dispose of these materials; thus, he consumes the service of disposing of these materials*" (https://ecoinvent.org/the-ecoinvent-database/system-models/). In practice, and according to the broadly used "*allocation, cut-off by classification*" (Ecoinvent terminology) system model (other models are though also possible), the emissions related to their management / disposal are allocated to the other farm outputs (i.e. the co-products) where the residue is produced.

Case grain-straw

The PEFCR feed (PEFCR Feed, 2020) are rich in requirements and clarifications, which is not possible to reproduce in this very short document. In general, however, "*cultivation data shall be collected over a period of time sufficient to provide an average assessment of the life cycle inventory associated with the inputs and outputs of cultivation that will offset fluctuations due to seasonal differences: For annual crops, an assessment period of at least three years shall be used (to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests and diseases, et cetera). Where data covering a three-year period is not available i.e. due to starting up a new production system (e.g. new greenhouse, newly cleared land, shift to other crop), the assessment may be conducted over a shorter period, but shall be not less than 1 year*". This is agreement with the FAO guidelines for animal feeds supply chains (FAO, 2016).

The cultivation of cereals generates grains and straw, and the PEFCR feed (PEFCR Feed, 2020) requires that the impacts of the cultivation process should be allocated following the economic allocation method, with the default allocation factors defined in the guidelines (e.g. barley cultivation: 75% to the grains, 25% to the straw; wheat cultivation: 79% to the grains, 21% to the straw) – which are seemingly the same as the ones proposed by the FAO guidelines for animal feeds supply chains (Table 8 in (FAO, 2016)) after a global assessment over the period 2007-2011.

The PEFCR feed further specifies that "*if primary data are collected for feed ingredients economic allocation shall be done according to the procedure described in the LEAP feed guidelines*" (PEFCR Feed, 2020). It is not uniquely defined the section of the guidelines it refers to, but (probably) it is the "*input/output analysis at factory level*": "*…the total inputs and related LCI data at the factory and upstream are divided among the products on the basis of their relative contribution to over- all revenue (in the case of economic allocation)* (page 81-82 in (FAO, 2016)).

Overall, and according to the (FAO, 2016; PEFCR Feed, 2020) guidelines, the life cycle impact assessment impacts related cereal cultivation shall be economically allocated to grains and straw. In this context, general datasets shall use default economic allocation values, while more specific input/output analyses based on farm primary data may adapt the allocation factors to specific conditions.

Depending on local practices, the entire straw may be left on the field (as part of the crop residues) and incorporated into the soil. In this very specific case, it may be debated whether the unharvested straw has any economic value, as it is not sold – but it is part of the crop residues. In this specific example, it could be argued that the only product having a market value is the grains, and therefore 100% of the impacts should be allocated to the grains. **Box 1** show the effect of different allocation factors on the final products: example 1 represents the default PEFCR feed economic allocation factors, while example 2 represents the case of 100% allocation to the grains. Note that the impacts per ha of soil remain the same, regardless of which allocation factors used.

Box 2 reports the calculations behind the extrapolation of specific economic allocation factors, given the market prices and products' yields.

Box 1. Economic allocation examples, from "kg CO2eq / ha" to "kg CO2eq / kg product". Example 1 reports the allocation factors used in PEFCR feed, whereas example 2 represents the case of 100% allocation to the grains.

Barley, at farm - example

	climate change
	kg CO2eq / ha
Barley cultivation /DK	2252.2

example 1: Economic allocation, based on default PEFCR feed factors

	allocation in AFP5		climate change	yield FAOstat		climate change
	-		kg CO2eq / ha	kg /ha		kg CO2eq / kg
Barley grain, at farm/DK Economic	75%	2252.2 x 75% =	1689.1	5781	1689.1 ÷ 5781 =	0.2922
Barley straw, at farm/DK Economic	25%	2252.2 x 25% =	563.0	2155	563.0 ÷ 2155 =	0.2613
		sum	2252.2			

example 2: Economic allocation, with no economic value of straw

	allocation 100% to grains		climate change	yield FAOstat		climate change
	-		kg CO2eq / ha	kg /ha		kg CO2eq / kg
Barley grain, at farm/DK Economic	100%	2252.2 x 100% =	2252.2	5781	2252.2 ÷ 5781 =	0.3896
Barley straw, at farm/DK Economic	0%	2252.2 x 0% =	0.0	2155	0 ÷ 2155 =	0
		sum	2252.2			

Box 2. Calculation of economic allocation factors, based on market prices and yields.

Calculation of economic allocation factors based on market prices

	market prices	yield FAOstat		calc.		allocation factors
	€ /kg	kg /ha		kg * €		-
Barley grain, at farm/DK Economic	0.16	5781	5781 x 0.16 =	924.96	924.96 ÷ 1054.26 =	87.74%
Barley straw, at farm/DK Economic	0.06	2155	2155 x 0.06 =	129.30	129.30 ÷ 1054.26 =	12.26%
			sum	1054.26		

<u>Practical challenges, and possible solution</u>

Case example.

Two Danish neighbor famers, X and Y, share the same yields and 2000 kg CO2eq / ha of barley cultivation. The 2000 kg CO2eq / ha includes all the emissions related to the cultivation process (from cradle to gate), but it excludes the field emissions due to crop residues (which in the interest of simplicity are here excluded). Farm X sells the straw to a biomass combustion plant, whereas farm Y does not harvest the straw and prefers to incorporate it into the soil. Both farmers sell the grains to the same animal producer.

Application of allocation factors.

a. Case a. "default economic allocation" factors (e.g. 75% to the grains, 25% to the straw):
   - <u>Grains</u>: the climate change impacts of the grains from both farm X and farm Y are the same, and equal to 75% of the cultivation impacts
   - <u>Straw</u>: the climate change impacts of both harvested and unharvested straw is the same, and equal to 25% of the cultivation impacts
   - <u>Discussion</u>: the limitation of this approach may appear* that the unharvested straw carries 25% of the cultivation impacts, but there is no downstream actor in the value chain that will use this material. In other words, the 25% of the cultivation impacts may appear* be lost in the system, because the value chain is interrupted [may appear*: see the explanation in the suggested practical solutions, which clarifies the reason of the apparent lost]. In reality, all emissions are still being considered from a national perspective, assuming that the default allocation factors are representative for assessed country

b. Case b. "100% allocation to the grains" (i.e. straw is implicitly seen as a residue, regardless of its possible economic value):
   - <u>Grains:</u> the climate change impacts of the grains from both farm X and farm Y are the same, and equal to 100% of the cultivation impacts
   - <u>Straw:</u> the climate change impacts of the unharvested straw from both farm X and farm Y are the same, and equal to zero
   - <u>Discussion:</u> The limitation of this approach is that the straw that is sold on the market carries no upstream cultivation impacts, meaning that it can be used by the next user free of any upstream impacts despite its economic value (this is convenient for biomass combustions plants or the animal farm that uses it as bedding material). It will not be meaningful to compare local farm impacts for grains with other LCA

databases that apply any kind of default allocation to grains and straw (e.g. the GFLI database and the Agri-footprint database)[1].

c. Case c. "site specific economic allocation factors", depending on what happens to the straw:

   - Grains: the climate change impacts of the grains from the two farmers are different (i.e. higher impacts on the grains coming from farm Y)
   - Straw: the climate change impacts of the unharvested straw (farm Y) is equal to zero, whereas the straw from farm X carries 25% of the cultivation impacts
   - Discussion: the limitation of this approach is that the impacts on the grains are different and affected by a practice (harvesting vs non-harvesting) that has little to do with the grains themselves. It will be difficult to argue that the ranking of farmers based on the environmental performance of their grains is affected by what they do with the straw.

The discussion of N_2O emissions (and C stocks) coming from field crop residues were excluded from the examples above only for simplicity reasons, but they can be included in the climate change impacts and allocated to the products just as any other impact (note for C stocks: currently, there is no scientific agreement on whether C stocks from crop residues should be accounted for, because of the labile nature of this C). In both cases b) and c), N_2O emissions and C stocks coming from field crop residues could be modelled using farm-specific practices (the values will change from farm to farm), or national averages (the same value will apply on all Danish farms). Case b) considers a 100% allocation factor to the grains, which is independent of the amounts of straw incorporated in the soil and harvested. Case c) follows is based on national average practices, which means that "the sum of all the farm-specific practices" is equal to the national average. In practice, both cases can calculate their N_2O emissions and C stocks based on the actual amounts of straw being incorporated into the soil and harvested, regardless of whether this is by using farm-specific conditions or national averages. On the contrary, the allocation factors of case a) are not specific for Denmark, which also means that they are not based on actual Danish (straw) practices. From a consistency point of view, N_2O emissions and C stocks should be calculated based on the same amounts and practices used to generate the default (global) allocation factors. However, this is not optimal if seen from a Danish perspective, where different practices occur.

Suggested solution for the ESGreen tool.

Assessing the environmental impacts of specific Danish farmers and rank them according to their environmental performance could be done according to any of the methods above, acknowledging the presented limitations. The most practical solutions would however be to

- calculate Danish crop-specific economic allocation values (which depends on average practices and prices) and apply these factors, regardless of specific farmer practices. This method is not meant to accurately describe farm-specific straw cases. However, if

[1] at least not before a back-calculation that redistributes the impacts (to grains and straw). It is however noteworthy that the Ecoinvent database contains two types of cultivation of cereals processes: one calculated with country based economic allocation factors (similar to case a.; available only for Swizz cereals and organic cereals – note that Ecoinvent is based in Switzerland), and one with the 100% allocation to grains (case b.; available for all other countries). On the other hand, the Ecoinvent database does not yet contain any Danish cereal cultivation process.

the method is applied on all the farms in Denmark, it will still result in 100% of the climate change impacts being accounted for.

A practical example on how to calculate these allocation factors is presented in **Box 3**, which reports an Ecoiveint 3.8 example for Switzerland. The same approach was used by FAO guidelines, when estimating their default values (which was however based on a global assessment) – see page 72 in (FAO, 2016). Note that the relative price difference between grains and straw have a strong effect on the calculated allocation factors, and that prices are different across countries.

- the alternative possibility of using the 100% allocation to grains would imply the acceptance of the limitations listed in case b.

Box 3. Calculation of economic allocation factors, based on the Ecoinvent process "barley production, Swiss integrated production, intensive, CH" and considering that only ~49% Swiss straw will in practice be harvested.

Calculation of economic allocation factors considering that 49% of the country's barley straw will be harvested

	yield	prices		revenue		allocation
	kg /ha	€ /kg		kg * €		-
barley grain	6828	0.117	6828 x 0.117 =	798.82	798.82 ÷ 842.08 =	94.9%
straw - harvested	3605	0.012	3625 x 0.012 =	43.26	43.26 ÷ 842.08 =	5.1%
straw - unharvested	3792	0		0.00		0.0%
TOT				842.08		
	7397	kg straw / ha				
	48.7%	of the straw is harvested in conventional systems				

Temporal representativeness

In general, LCA processes are described using steady-state or average conditions (with possible adjustments that can aim to, for example, represent all production stages of a permanent crop). Annual crops may be characterized by large fluctuations in terms of yields and prices depending on the year considered. These fluctuations would have a large effect on the impacts associated to a cultivation process, and therefore on its outputs (see the effects of prices and yields on the allocation factors in **Box 3**), if the carbon footprint would be made using data for a single year only. For this reason, it is advised by multiple guidelines (e.g. (FAO, 2016; PEFCR Feed, 2020)) that a few-year average data (e.g. for fertilizer use, yields, market prices, diesel consumption, irrigation, …) should be used when making a carbon footprint, or more generally a LCA, of a cultivation process.

In a practical example, let's assume a very dry cultivation season (year Z), accompanied by very poor yields in all Danish crops. The carbon footprint of products based purely on year Z will result in very poor environmental performances, in contrast to the case where a few-year average was to be used. The first assessment method would be characterized by more pronounced yearly fluctuations compared to the second method, but the long-term average impacts would be the same between the methods.

Activity data, temporal representativeness

The ESGreen tool supports the farmer to calculate the climate footprint of their farm as a whole ("bedrift" in Danish), and soon also products. The farmer can see his/her own impacts on climate change, as a function of its operating conditions (and future change in practices). The tool is based on yearly data, which the farmer updates regularly. Any farmer can decide to cultivate a different crop compared to the year before, which generate immediate challenges if the carbon footprint assessment would need to be generated based a recent few-year average. How should the ESGreen tool handle these cases? Multiple options are available:

a. If available, the ESGreen tool can calculate the climate change impacts of the cultivation outputs (e.g. barley grain) based on a recent few-year average. If the recent few-year average is not available (e.g. because of changes in crop cultivation), the ESGreen tool can calculate the impacts based on the available data (e.g. a single year). The approach would be in line with PEFCR feed guidelines: "*For annual crops, an assessment period of at least three years shall be used (to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests and diseases, et cetera). Where data covering a three-year period is not available i.e. due to starting up a new production system (e.g. new greenhouse, newly cleared land, shift to other crop), the assessment may be conducted over a shorter period, but shall be not less than 1 year.*"
b. The ESGreen tool can calculate the climate change impacts based on a single year only, regardless of the farmer's crop history. However, large fluctuations can be expected, for example in the case of very dry seasons, which will reduce the comparability with other studies and LCA databases. Furthermore, the impacts of all downstream products linked to these crops will be subject to fluctuations (e.g. the barley flour sold at the supermarket, the pork meat sold at supermarket, …).

Option a. would be preferable.

Prices, temporal representativeness

Crop prices fluctuate largely over the year, and across years. These large fluctuations can result into potentially large fluctuations in the calculated economic allocation factors, if these were to be based on short-period (e.g. weekly or monthly) averages. For this reason, it is generally recommended to take a few-year market averages, when calculating the economic allocation factors (e.g. the GFLI database requests that "*Prices needed for economic allocation shall be representative for the region in scope and shall be average prices for a recent 3 year-period*"). It is advisable that the ESGreen tool follows a similar approach.

Conclusions

Typical allocation methods based on broadly used guidelines have been reported, with focus on crop production. Calculations examples have been provided, showing how country specific allocation factors can be calculated, based on country yields, straw management practices and market prices. Recommendations for the ESGreen tool have been provided.

References

Commission Recommendation 2021/9332/EU, 2021. Commission Recommendation of 16.12.2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations.

European Commission, 2021. ANNEXES 1 to 2. Commission recommendation of 16.12.2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations.

FAO, 2016. Environmental performance of animal feeds supply chains: Guidelines for assessment., Draft for public review. Rome, Italy.

ISO, 2006a. DS/EN ISO 14044. Environmental management – Life cycle assessment – Requirements and guidelines.

ISO, 2006b. DS/EN ISO 14040. Environmental management - Life cycle assessment - Principles and framework.

PEFCR Feed, 2020. PEFCR Feed for food-producing animals. Version 4.2. February 2020 (original publication date: April 2018). Date of expiration: 31stDecember 2021.