IMPACTS OF FOOD

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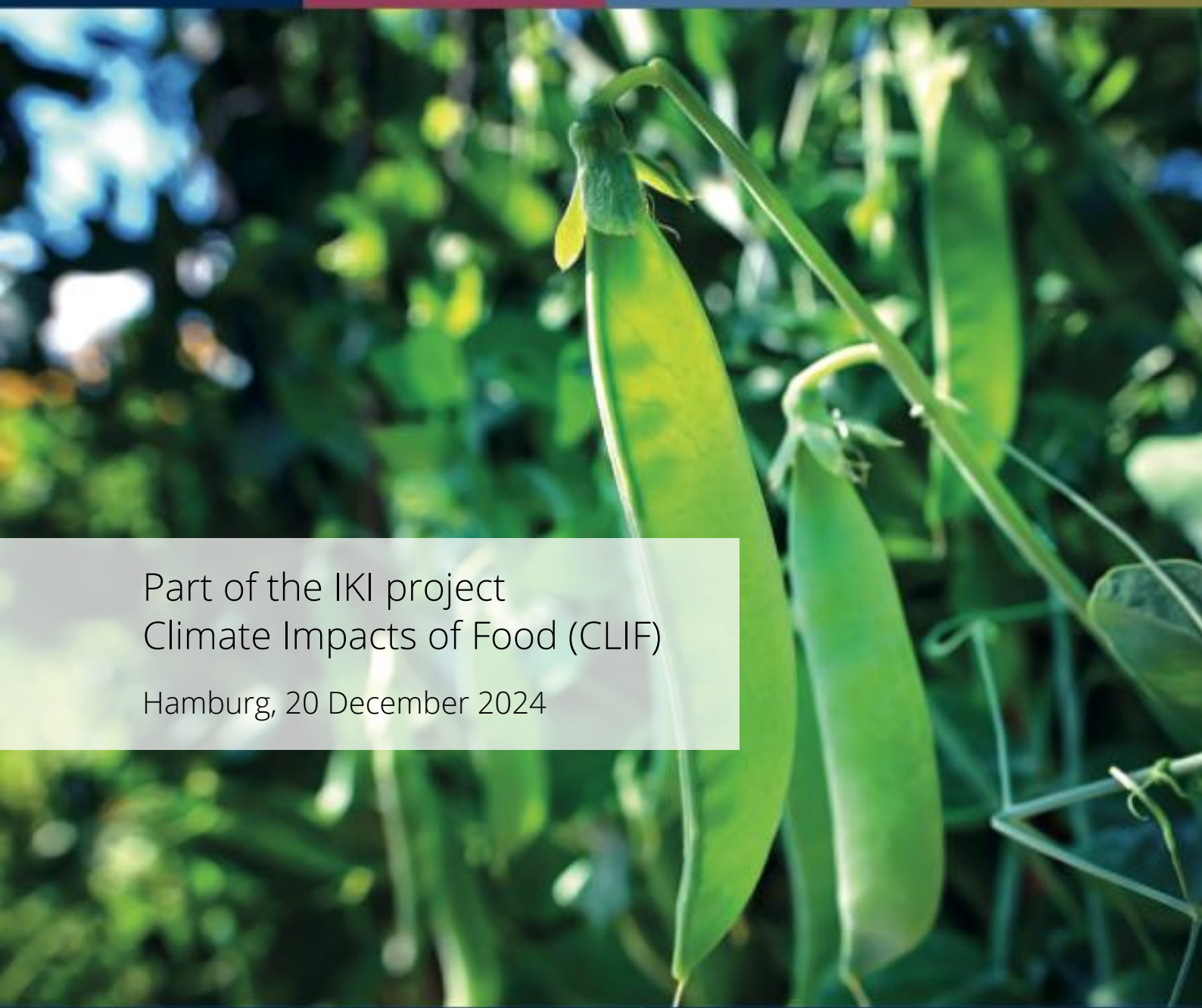
# White Paper: Most appropriate Life Cycle Impact Assessment Methods for communicating environmental impacts of food



Part of the IKI project
Climate Impacts of Food (CLIF)

Hamburg, 20 December 2024

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# Contents

# 1 Introduction

The aim of the 'CLIF - Climate Impacts of Food' project is to develop a prototype of a communication tool for food that can be used worldwide to communicate the environmental impact of food. For this purpose, it is necessary to base the information in the communication tool on valid and credible information and use a method that is accepted globally.

Life Cycle Assessment (LCA) is such a method. It is designed to assess environmental impacts of product systems. The method is standardized within the ISO 14040 series. However, there is no international agreement on which impact assessment methods should be used within LCA. In recent years, the European Commission has endeavoured to develop a generally accepted set of impact categories and associated impact assessment methodologies as part of the Environmental Footprinting (EF) process and corresponding impact assessment methods (EC, 2017). However, these efforts have been undertaken on a European level, and yet the process is not finished. On an international level leading experts assessed the pros and cons of different impact assessment methods for several impact categories (Frischknecht & Jolliet, 2017, 2019). But there is no process comparable to that at European level, at most for individual impact assessment methods, such as water use (Boulay et al., 2015, 2018, 2019).

Against this background, the aim of this white paper is to identify the most appropriate impact assessment methods for selected environmental impact categories in the context of CLIF, which have been identified as relevant for the environmental assessment of food.[1]

# 2 Methods

The Delphi method which was mainly developed by Dalkey and Helmer (1963) was chosen to answer the question. It is a method of choice to find consensus among different stakeholders and experts. A Delphi study is usually carried out in several stages and is widely used in various disciplines such as science, politics and governance (Clayton, 1997; Hsu & Sandford, 2007).

Within this white paper a Delphi study has been conducted to get a consensus on the question "Which life cycle impact assessment (LCIA) methods are most appropriate for assessing the most relevant environmental impacts?". The study was conducted with international food LCA experts (self-declared) and consisted of three steps. It started with an online survey, followed by three group discussions, and a second online survey (Figure 1).

[1] With respect to the selection of the chosen impact categories within the project CLIF a Delphi study has been carried out. The results of this work will be published soon.

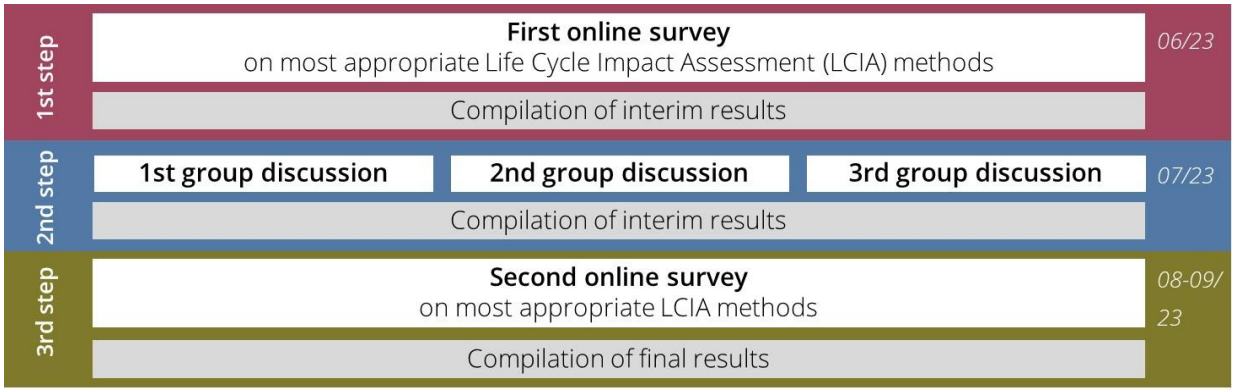


Figure 1. The three steps of the second Delphi study

In the study a set of selected impact categories have been included (Table 1).

## 2.1 First online survey

Aim of the first online survey was to get a first consensus on suitable impact assessment methods as impact for the group discussions (section 2.2). In this online survey, participants were therefore asked to indicate which LCIA methods they were already familiar with for each impact category and which LCIA method they could recommend. For the latter, they were asked to state their reasons for the recommendation (optional free text). If they knew more methods than those on the list, they could add them as free text and also recommend them. All LCIA methods were given with the following information: reference for the respective LCIA method, link, and name of the method, if existent. Table 1 shows the impact categories and LCIA methods included in the first survey.

The results were used as input to the group discussions.

## 2.2 Group discussions

In July 2023, three online group discussions were held with a total of seven LCA experts. The results of the previous online survey were presented in the discussions. The results were then discussed in the workshop with the aim of identifying the most suitable LCIA method for the respective impact category from the participants' perspective.

The results from the three workshops were summarized and used as input for the second online survey.

## 2.3 Second online survey

The aim of the second online survey was to reach a consensus on the most suitable LCIA methods. It was conducted in August and September 2023. Again, the participants were international food LCA experts. The recommended LCIA methods were rated in terms of their appropriateness on a numerical scale from 0 to 10 (0 not suitable, 10 most suitable).

# 3 Results

In the following the results of the two online surveys and the workshops are presented.

## 3.1 First online survey

The link to the questionnaire was sent out to more than 50 food LCA experts worldwide. Eight experts from six countries (Australia, France, Germany, Spain, Switzerland, Thailand) participated in the survey. Five of them stated that they have more than ten years of experience in LCA research.

The knowledge about LCIA methods differs very much among the different impact categories. Thus, the LCIA methods GWP 100 (climate change), AWARE (water use) are the best known LCIA methods as all eight experts participating in the survey knew them. They were followed by the Chaudary & Brooks (2018) method for land use (terrestrial biodiversity), the LANCA method (Bos et al., 2016), (Horn & Maier, 2018), (De Laurentiis et al., 2019) for land use (soil health), and USEtox (Fantke et al., 2017) which have been known by seven of the eight experts. At least half of the experts knew (Brandão & i Canals, 2013) for land use (soil health) (5), accumulated exceedance (Seppälä et al., 2006, Posch et al., 2008) for terrestrial eutrophication (4), and ReCiPe (Goedkopp et al., 2009) for freshwater and marine eutrophication (4). The other LCIA method have been known by less than the half of the experts. Some of the methods have been totally unknown. However, in total 14 LCIA methods have been added, of which one was also recommended by the expert that added the method. Most methods have been added in the impact category climate change (4), followed by marine biodiversity (3), land use (terrestrial biodiversity) (2) and water use (2). For land use (soil health), terrestrial eutrophication and freshwater and marine eutrophication one further LCIA method has been added for each category.

The highest consensus was reached for the LCIA methods for the impact assessment terrestrial eutrophication (Seppälä et al., 2006, Posch et al., 2008) and ocean acidification (Bach et al., 2016) (100%). However, only 50% (terrestrial eutrophication) resp. 25% (ocean acidification) of the experts knew the method (4 resp. 2 experts). The next best consensus was achieved regarding GWP 100 - the method was recommended by seven of the eight experts and was known by all experts. The next method in the consensus ranking of recommended methods is Fantke et al. (2015) for particulate matter. Four of five experts who kew the method recommended it (80%). This was followed by USEtox (Fantke et al., 2017), where five from seven experts recommended the method (71%), Lindner et al. (2019) and Hélias et al (2018) resp. Hélias et al. (2023) where the methods were recommended by two thirds of the experts who knew the method (2 of 3 experts). Also AWARE (Boulay et al., 2018) is recommended by more than the half of the experts (62,5%) as is USEtox (Fantke et al., 2017), Chaudary & Brooks (2018), and LANCA, which are recommended by four of seven experts (57%). At least half of the experts (2 of 4) recommended ReCiPe (Goedkopp et al, 2009) for freshwater and marine eutrophication. The results are shown in Table 1.

In the following the reasons (when given) for the recommendation of a method are summarised:

- Climate change
  - The reasons to recommended **GWP 100** were that it is an "established indicator, great consensus, points in the right direction, though not perfect" and that GWP 100 "[…] is the most commonly one used in LCA for a long time. So I recommend it in terms of maturity of use. However, short term impacts have also been recommended in recent years."
  - The reasons to recommend the **Radiative Forcing footprint** were the "transparency of impacts of short- and long-lived forcers".
- Land use – terrestrial biodiversity
  - The reasons to recommend **Chaudary & Brooks (2018)** were that the method is "recommended by the UN life cycle initiative", that the method "has limitations, but to my knowledge is the best currently available", and that "This is the one we have used in our research as has been quite widely used and has recently been updated as well".
  - The reasons to recommend the **BVI-method** (Lindner et al. 2019) were that is in a "meaningful aggregation, points in the right direction, transparency and openness regarding normative aspects, universal applicability to different land use types, ongoing development with further improvements to be expected" and "For the inclusion of agricultural practices, a key to analyse loss of terrestrial biodiversity."
- Land use – soil health

  The reasons to recommend **LANCA** (Bos et al., 2016, Horn & Maier, 2018, De Laurentiis et al., 2019) were, that it "includes more aspects than only SOC, background data available", and that it is "recommended by the UN life cycle initiative".

- Water use

  The reasons to recommend **AWARE** (Boulay et al, 2018) were that the method is "recommended by the UN life cycle initiative", that "Most water scarcity models are highly correlated but vary in absolute magnitude. It can be beneficial to use an ensemble model, depending on the purpose.", and that "this method has been adopted by international consensus via the UNEP Life Cycle Initiative".

- Terrestrial eutrophication

  The reasons to recommend **Accumulated exceedance** (Seppälä et al., 2006, Posch et al., 2008) were that it "can be regionalised, recommended by PEF-CR".

- Freshwater & marine eutrophication

  The reason to recommend **ReCiPe** (Goedkopp et al., 2009) was the method is "recommended by PEF-CR".

- Marine biodiversity

  The reasons to recommend **Hélias et al. (2018)** were "Hélias et al. (2023) (following Hélias et al., 2018) enables the quantification of marine biodiversity loss due to biomass extraction. Others lose aspects of the issue. Woods and Verones 2019 is about Seabed Impact. The future Hoiberg et al., and Stanford-Clarke et al. will be important, too (respectively the impact of entanglement and at ecosystem level)"

- Novel entities
  - The reasons to recommend **USEtox** (Fantke et al., 2017) were that the method is an "universal consensus model, incorporates very different impact pathways", that it is a "consensus methodology, recommended by the UN life cycle initiative", that it is "State-of-Art to my understanding", and that "this is a widely used method for ecotoxicity."
  - For the recommendation of **CML (2002)** no reason was given.
- Ocean acidification
  For the recommendation of **Bach et al. (2016)** no reason was given.
- Atmospheric aerosol loading
  The reason for recommending **Particulate Matter** (Fantke et al., 2015) was that the respective expert said "I think it has been used quite widely."

## 3.2 Expert workshops

In July 2023, three expert workshops were held with a total of seven LCA experts on the LCIA methods.

In the first workshop, the impact assessment methods GWP100 (IPCC, 2013 IPCC, 2021) for climate change, AWARE for water use and Bach et al. (2016) for ocean acidification were clearly recommended. The impact assessment methods for terrestrial biodiversity (Chaudhary & Brooks (2018) or Lindner et al. (2019) and the methods for soil health were much discussed. No clear recommendation was made here.

In the second workshop, GWP* was discussed with different time horizons for short or long-term effects. There was also a discussion about LANCA and SALCA for soil health impact assessment. The participants recommended LANCA for the background of the CLIF project, as SALCA would require too detailed specific information. It was said that the CLIF project would generally have to decide which impact assessment methods would be most suitable in each impact category.

At the third workshop, the participants agreed that soil health can be assessed very differently from region to region and that the inclusion would therefore be very important but difficult. In addition, USEtox was recommended for assessing the effects of pesticide use. However, it was pointed out that the existing uncertainty of the modelling must be taken into account.

The results of the three workshops were summarised in preparation for the next online survey[2].

## 3.3 Third online survey

Again, the link to the questionnaire was sent out to more than 50 food LCA experts worldwide. In the final online survey, eleven experts from ten countries answered the questionnaire (response rate 14.3

[2] Table 2 shows the questionnaire of the final survey.

%). Eight of them have more than ten years of LCA experience. Two thirds of the experts came from Europe, one third from various countries around the world (South America, Asia and Australia).

In the survey the experts ranked the appropriateness of the LCIA methods within a scale from 0 (not suitable) to 10 (most suitable). The results were analysed for four value ranges: 0-<= 2.5; >2.5 to <=5.0; >5.0 to <=7.5; >7.5. Figure 2 shows the value ranges (the bluer the greater the consensus for the LCIA method), the achieved average points (black stitched line) and the median points (turquoise line).

The results clearly show that the two LCIA methods GWP 100 (climate change) and AWARE (water use) receive a high level of approval from the impact assessment methods surveyed. Approval is slightly lower for GWP100 (IPCC, 2013) than for AWARE. The method by Fantke et al. (2015) for particulate matter achieved the next highest level of agreement. The picture varies somewhat more for the other methods. However, if the upper two value ranges are taken together, Chaudary & Brooks (2018) for terrestrial biodiversity, Accumulated exceedance (Seppälä et al., 2006; Posch et al., 2008) for terrestrial eutrophication and ReciPe (Goedkopp et al., 2009) for freshwater and marine eutrophication also achieve over 50% agreement. There are also impact assessment methods that score no less than 2.5 points (no opposing experts) and no less than 5.5 points on average (Cosme et al., 2017; ReCiPe (Goedkopp et al., 2009), and Hélias et al., 2018 and 2023). This shows that there is as yet no consensus among the experts involved as to which impact assessment is most suitable for assessing freshwater and marine impacts. It seems that both fit somehow. However, Cosme et al. (2017) is a method for assessing marine eutrophication, while ReCiPe includes both freshwater and marine eutrophication. In relation to Hélias et al. (2018; 2023), it seems that the method is generally pointing in the right direction as there are no disagreements, but that there is still room for further development. In contrast, CML is clearly rejected as a method for novel entities. In Figure 2 the results of the survey are shown.

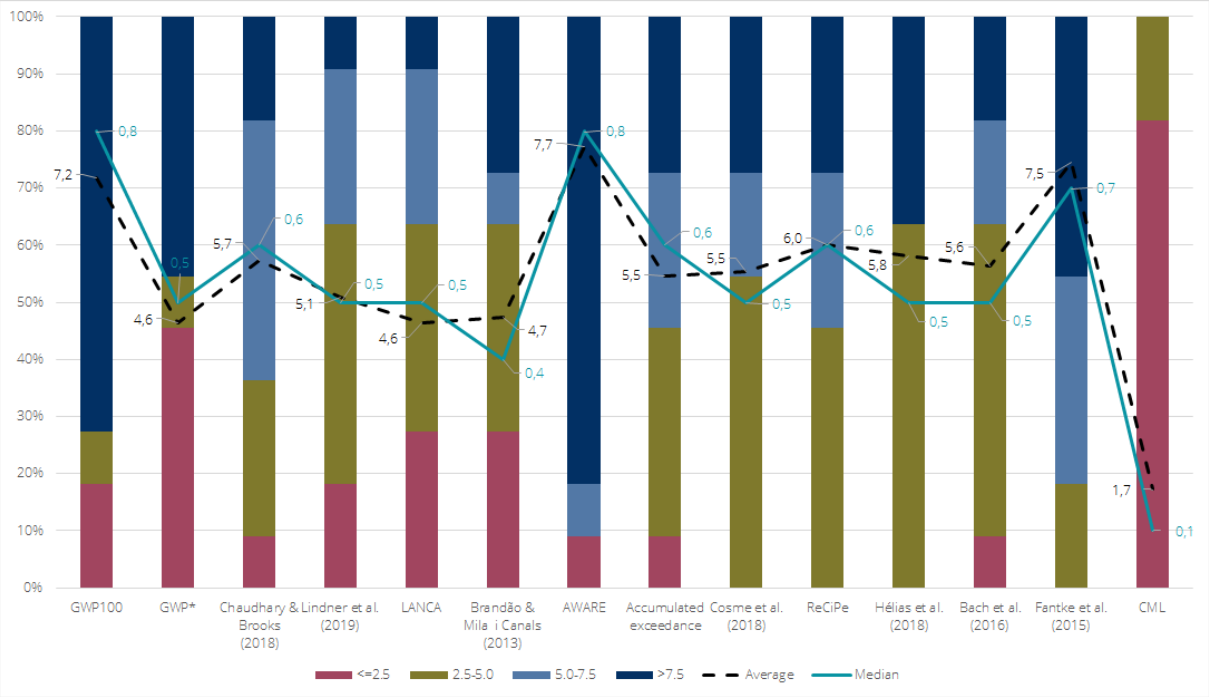


Figure 2: Share of experts per value range for the LCIA methods under survey in the second online survey

# 4 Conclusion

The results clearly show that some LCIA methods are more generally accepted than others, like GWP100 and AWARE. However, even with these LCIA methods, there are experts who disagree with these methods. Interesting are the findings for impact assessment methods for freshwater and marine eutrophication (Cosme et al. (2017) and Goedkopp et al. (2009) – ReCiPe), which are both rated in the same range and thus showing that both are suitable, but none is better than the other. Although it should be kept in mind that the method of Cosme et al. (2017) only takes marine eutrophication into account.

However, it must be noted that the results are only based on a small number of experts and are therefore limited. Furthermore, the workshops have shown that even LCA experts cannot be experts in every LCIA method. In addition, the LCIA methods differ in their level of awareness among experts, e.g. due to the fact that they are quite 'young' methods that are not yet known worldwide (e.g. Lindner et al., 2019) or that it is difficult to introduce other methods when there are already well established LCIA methods (e.g. GWP*)[3]. Obviously, unknown methods cannot be recommended.

[3] However, there are also quite controversial discussions about the method.

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# 7 Annex

Table 1: Results of the first online survey on most appropriate LCIA methods

| **Impact category** | **LCIA methods included in the survey (name, reference)** | **Method known** | **Method recom-mended** | **Additional methods mentioned** | **Recommen-dation of other methods** |
|---|---|---|---|---|---|
| Climate change | GWP 100 (IPCC, 2013) | 8 | 7 | *GWP** (Lynch et al., 2020) | 0 |
| | | | | *Radiative Forcing (RF) footprints*[4] | 1 |
| | | | | GTP | *0* |
| | | | | GWP 20, 50 | *0* |
| Land use, terrestrial biodiversity | Chaudhary & Brooks (2018) | *7* | *4* | Michelsen (2008) | *0* |
| | BVI-method (Lindner et al. (2019) | *3* | *2* | Maier et al. (2019) | *0* |
| | de Baan et al. (2013) | *3* | *0* | | |
| | de Souza et al. (2013) | *3* | *0* | | |
| | Kuipers et al. (2021) | *1* | *0* | | |
| | None | 1 | 2 | | |
| Land use, Soil | LANCA (Bos et al., 2016; Horn & Maier, 2018; De Laurentiis et al., 2019) | 7 | 4 | SALCA [5] (Jeanneret et al., 2014) | 0 |
| | Brandão & Mila i Canals (2013) | 5 | 0 | | |
| | Alvarenga et al. (2015) | 0 | 0 | | |
| | None | 1 | 4 | | |

[4] No further reference was given.

[5] Swiss Agricultural Life Cycle Assessment (SALCA)

| Impact category | LCIA methods included in the survey (name, reference) | Method known | Method recom-mended | Additional methods mentioned | Recommen-dation of other methods |
|---|---|---|---|---|---|
| Water use | AWARE (Boulay et al., 2018) | 8 | 5 | Pfister et al. (2009) | 0 |
| | None | 0 | 3 | Ridoutt and Pfister (2010) | 0 |
| Freshwater / marine eutrophication | Cosme et al. (2017) | 2 | 1 | CML[6] | 0 |
| | ReCiPe (Goedkoop et al., 2009) | 4 | 2 | | |
| | Helmes et al. (2012) | 0 | 0 | | |
| | None | 1 | 5 | | |
| Marine biodiversity | Langlois et al. (2014) | 1 | 0 | Hélias et al. (2023) | 0 |
| | Farmery et al. (2017) | 0 | 0 | Woods & Verones (2019) | 0 |
| | Hélias et al. (2018) | 3 | 2 | Emanuelsson et al. (2014) | 0 |
| | None | 5 | 6 | | |
| Novel entities | CML (2002); van Oers et al. (2018) | 3 | 1 | | |
| | USEtox (Fantke et al., 2017) | 7 | 5 | | |
| | Woods et al. (2016) | 1 | 0 | | |
| | Persson et al. (2022) | 0 | 0 | | |
| | None | 2 | | | |
| Ocean acidification | Bach et al. (2016) | 2 | 2 | | |
| | None | 6 | 6 | | |
| Atmospheric aerosol loading | Particulate matter (Fantke et al., 2015) | 5 | 4 | | |
| | None | 3 | 4 | | |
| Terrestrial eutrophication | Accumulated exceedance (Seppälä et al., 2006; Posch et al., 2008) | 4 | 4 | CML[7] | 0 |
| | None | 3 | 4 | | |

Table 2: Questionnaire of the final online survey in August 2023

| LCIA Methods (August 2023) | Answer |
|---|---|
| **Questions** | **Possible answers** |
| How appropriate is GWP100 (Global Warming Potential over a 100 year time horizon) to inform on climate change impacts? | Numeric scale: 0-10 (0 not appropriate, 10 most appropriate) |
| How appropriate is GWP* to inform on climate change impacts? | 0 to 10 |
| How appropriate is Chaudhary and Brooks (2018) to inform on impacts of the loss of terrestrial biodiversity due to land use change? | 0 to 10 |
| How appropriate is Lindner et al. (2019) to inform on impacts of the loss of terrestrial biodiversity due to land use change? | 0 to 10 |
| How appropriate is LANCA (Bos et al., 2016; Horn and Meier, 2018; de Laurentiis et al., 2019) to inform on impacts of the degradation of soil health? | 0 to 10 |
| How appropriate is AWARE (Boulay et al., 2018) to inform on impacts of water scarcity due to freshwater use? | 0 to 10 |
| How appropriate is accumulated exceedance (Seppälä et al., 2006; Posch et al., 2008) to inform on terrestrial eutrophication impacts? | 0 to 10 |
| How appropriate is Cosme et al. (2017) to inform on freshwater or marine eutrophication impacts? | 0 to 10 |
| How appropriate is ReCiPe (Goedkoop et al., 2009) to inform on freshwater or marine eutrophication impacts? | 0 to 10 |
| How appropriate is Hélias et al. (2018, 2023) to inform on impacts of the loss of marine biodiversity due to sea use change? | 0 to 10 |
| How appropriate is Bach et al. 2016 to inform on ocean acidification impacts? | 0 to 10 |
| How appropriate is particulate matter (Fantke et al., 2015) to inform on atmospheric aerosol loading impacts? | 0 to 10 |
| How appropriate is CML 2002 (van Oers et al., 2002) to inform on novel entities impacts? | 0 to 10 |
| How appropriate is USEtox (Fantke et al., 2016) to inform on novel entities impacts? | 0 to 10 |

6 No further reference was given.

7 No further reference was given.

# 8 Imprint


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