



HAL
open science

Implementing environmental labelling of food products in France

Arnaud Hélias, Hayo M. G. van Der Werf, Louis-Georges Soler, Franck Aggeri, Jean-Yves Dourmad, Chantal Julia, Lydiane Nabec, Sylvain Pellerin, Bernard Ruffieux, Gilles Trystram

► **To cite this version:**

Arnaud Hélias, Hayo M. G. van Der Werf, Louis-Georges Soler, Franck Aggeri, Jean-Yves Dourmad, et al.. Implementing environmental labelling of food products in France. *International Journal of Life Cycle Assessment*, 2022, 10.1007/s11367-022-02071-8 . hal-03697547

HAL Id: hal-03697547

<https://hal.science/hal-03697547v1>

Submitted on 17 Jun 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Implementing environmental labelling of food products in France

Arnaud Hélias¹ · Hayo M. G. van der Werf² · Louis-Georges Soler³ · Franck Aggeri⁴ · Jean-Yves Dourmad⁵ · Chantal Julia^{6,7} · Lydiane Nabec⁸ · Sylvain Pellerin⁹ · Bernard Ruffieux¹⁰ · Gilles Trystram¹¹

Received: 31 May 2022 / Accepted: 1 June 2022
© The Author(s) 2022

Abstract

Consumers increasingly demand information about the environmental impacts of their food. The French government is in the process of introducing environmental labelling for all food products. A scientific council was set up, and its main conclusions are presented in this article, through six questions: What environmental issues should be considered? What objective should be targeted? What data are needed, and for whom? What methods for assessing environmental impacts? Which environmental scores should be chosen? What label format should be proposed? By answering these questions and considering the context, the available data, the proposed methods and adjustments, and the knowledge of consumer perception of formats, the scientific council considers that a labelling scheme is feasible and relevant.

Keywords Data · Environmental labelling · Food · Operationalization · Public policy

1 Introduction

The French government has enacted legislation aiming to develop and implement an environmental labelling system for food products. During an experimentation phase in 2020–2021 involving numerous stakeholders, several of whom proposed labelling systems, an independent multidisciplinary scientific council (SC, composed of the authors of this article) was set up to support the process. The SC considered several issues related to the environmental impacts to be included, the data and methods to be used, and the label design to summarise all of the aforementioned aspects in a

simple, informative and useful way. As this type of initiative is obviously not limited to a French context, it seemed relevant to present here to a broader audience the main outcomes of the SC's work (Soler et al. 2021a, b). Overall, an operational environmental labelling applicable to all food products marketed in France is feasible and relevant.

The feasibility, stakeholder agreement and compliance with international recommendations were the basis for answering six questions structuring the work of the SC. We further identified several issues that would necessitate further reflexion and debate.

Communicated by Matthias Finkbeiner

✉ Arnaud Hélias
arnaud.helias@inrae.fr

¹ ITAP, Univ Montpellier, INRAE, Institut Agro, Montpellier, France

² UMR SAS, INRAE, Institut Agro, Rennes, France

³ Université Paris-Saclay, INRAE, UMR PSAE, Palaiseau, France

⁴ MINES ParisTech, Université PSL, Centre de Gestion Scientifique (CGS), i3 UMR CNRS, Paris, France

⁵ PEGASE, INRAE, Institut Agro, Saint Gilles, France

⁶ Sorbonne Paris Nord University, Inserm, INRAE, University of Paris, CRESS, Bobigny, France

⁷ Public Health Department, Avicenne Hospital – Assistance Publique Hôpitaux de Paris (APHP), Bobigny, France

⁸ Université Paris-Saclay, RITM, Sceaux, France

⁹ UMR ISPA, INRAE, Bordeaux Sciences Agro, Villenave d'Ornon, France

¹⁰ Grenoble INP, GAEL, INRAE, Univ. Grenoble Alpes, Grenoble, France

¹¹ Université Paris-Saclay, INRAE, AgroParisTech, UMR SayFood, Massy, France

2 What environmental issues should be considered?

Most environmental labelling systems implemented to date have focused on the impact of foods on climate change. However, other environmental issues (e.g. land use change, eutrophication, water scarcity) have become more acute, leading amongst others to a multicausal decline in biodiversity. This justifies not limiting the environmental labelling of food products to their impact on climate change. This position is reflected in the 2021 French law on environmental labelling of foods which established the need to consider not only climate change but also damage to biodiversity, impact on water consumption and other natural resources and, in general, “all the environmental externalities of the production systems of the goods and services in question”. This calls for a multi-criteria environmental assessment, in which life cycle assessment (LCA) is viewed as the most appropriate and legitimate methodological framework. However, to date, LCA obviously does not encompass all environmental and health issues.

Human health was not explicitly mentioned in the 2021 French law but is now a major concern for consumers and citizens. Here, two domains may usefully be distinguished. The exposure of populations to pollutants emitted into the environment during the production process and impacting local or general population should be included in the environmental labelling scheme. These aspects have long been discussed in the LCA community and continue to be clarified and operationalised (Sala et al. 2022). On the other hand, health impacts associated with contaminants (e.g. pesticide residues) in foods absorbed by the sole eater relate to food safety issues, which are regulated by specific food legislations in the European Union (EU). Including these latter health impacts in environmental labelling could prove incompatible with EU regulations and raise significant risks of legal challenge. Before the integration of these health impacts (Fantke et al. 2011), regulatory constraints should therefore be addressed first.

3 What objectives should be targeted?

The main objectives of an environmental label are to draw attention of consumers to the environmental impacts of their foods and to encourage better choices. Environmental labelling can exhibit environmental impacts of foods at two levels: highlighting the environmental impacts of differentiated products within a given food category (e.g. local vs. imported) and highlighting the impact differences between food categories (e.g. animal- vs. plant-based foods). The environmental impact of foods within a category may differ substantially as it depends on the ways in which foods are produced, processed

and distributed. By informing consumers and inducing changes in their demand, labelling encourages strategic responses of the supply side, encouraging more environmentally friendly production, processing and distribution practices, as has been observed for nutritional labelling (Bablani et al. 2020). The reduction of the environmental impact of food consumption at the population level also depends on diet changes, i.e. changes in the relative amounts of each product category in the overall consumption. Changing dietary patterns, by increasing consumption of plant-based foods and substantially reducing consumption of animal source foods is imperative to considerably reduce the environmental impact of food consumption (Willet et al. 2019), as within-category substitutions will not be sufficient. Determining the extent to which environmental labelling should focus on one or the other, or on both of these levers is a major issue in the choice of a labelling system. We consider that both should be encompassed as much as possible, fostering potentially both differentiated product substitutions and larger diet changes.

The functions of food are multiple: from provision of energy, (micro)nutrients, hydration, to affordability, organoleptic pleasure, convenience or table-companionship. Depending on the type of product, some of these functions are more or less sought after and complicate the choice of functional units (McAuliffe et al. 2020). The choice of the functional unit is a key element of an environmental labelling system. Depending on the functional unit (which can be based on mass, nutritional characteristics, portion or economic value), significant differences occur in the ranking of products. For environmental labelling, impacts are usually expressed relative to product mass, for all food types. Other approaches have been proposed, in particular the expression of impacts relative to the nutritional value of foods (Hallström et al. 2018). Despite the importance of the nutritional function, implementing it for environmental labelling raises some difficulties. First, the future coexistence of the current nutritional label and the upcoming environmental label should inform consumers on both characteristics. Using multiple functional units for the environmental label, each specific to a food category (protein for meat products, calcium for dairy products, fibre for fruit and vegetables, etc.) while the nutritional label is expressed per product mass would complicate a balanced assessment of nutritional quality and environmental impact. Furthermore, and this is the most crucial aspect, a nutritional functional unit necessarily leads to environmental labelling by product category, which is undesirable if the environmental labelling aims to support product substitutions both within and between food categories. In the context of food labelling, with a double challenge of inter- and intra-category discrimination, this has direct consequences on the choice of functional unit: it has to be identical for all products and cannot be adapted for each product category. Therefore,

a standardized functional unit linked to the product mass appears to be the most appropriate generic option.

4 What data are needed, and for whom?

Environmental labelling initiatives experimented by companies in different countries since the late 2000s have remained limited. This is mainly due to the complexity of implementing the LCA method, which is data-intensive and can be costly, especially for small and medium-sized enterprises. In France, the public life cycle inventory database AGRIBALYSE (2020) describes 2500 generic food products, to represent the diversity of foods on the market. Having this type of database is a prerequisite in implementing environmental labelling.

For each of these representative products, an average environmental impact value based on the Product Environmental Footprint (PEF) method proposed by the European Commission is available: this provides an overall “generic” value. Such generic data may reduce the cost of environmental labelling. However, the number of representative products in AGRIBALYSE is limited, compared to the several hundreds of product variants on the market that may correspond to each of them. Considering within-category food discrimination, more accurate data is necessary.

An intermediate pathway is possible between relatively low-cost creation of generic data and the creation of more specific datasets at higher cost. Implementing such a “semi-specific” approach would involve complementing the generic data with data for a range of high-impact action levers, e.g. product recipe, transport or packaging. This can be done by using either publicly available data (list of ingredients, type of packaging, origin of the product, see for example Coste and Hélias (2022)), or by using company data. In both cases, an impact value closer to the specific value of a given food can be obtained. Tests conducted during the experimentation phase have shown that this semi-specific level can capture a significant part of impact variability due to product variants.

Different types of stakeholders — agribusinesses and third parties, including digital app providers — can then attribute environmental impact values to products on the market. Collective rules must however be agreed upon for this. In all cases, impact calculations should be part of a coherent and compatible methodological framework and be transparent and traceable to allow external verification or an institutional validation process.

5 What methods for assessing environmental impacts?

The European Commission has proposed the Environmental Footprint (EF) 3.0 life cycle impact assessment method (Fazio et al. 2018), for assessing the PEF. LCA is mainly

used in multicriteria comparative approaches, but for environmental labelling, the 16 mid-point impact categories should be aggregated in a single score. The PEF and the EF method have certain limitations, which are the subject of research. Points under debate are the weighting of impact categories, impact allocation to co-products and the choice of a functional unit (Pedersen and Remmen 2022). Nevertheless, the EF method offers a structured, well thought-out and institutionally validated framework for French environmental labelling.

The LCA framework as such is sometimes contested because it would penalise extensive systems and agro-ecological practices as it ignores some of their environmental benefits (van der Werf et al. 2020). For example, although several factors that impact biodiversity are well considered by the EF method (such as climate change or eutrophication), the variations in biodiversity observed in the field, directly linked to agricultural practices, are not estimated. For environmental labelling of food products, where agricultural production specificities are a lever to reduce environmental impacts and an argument for highlighting certain products, it is legitimate to point out this limitation of the EF method. Similarly, difficulties relating to the quantification of impacts in terms of toxicity and ecotoxicity, threatened or invasive species, have been clearly identified (Crenna et al. 2020) and justify improvements in the EF method.

For food labelling, improvements to the method and associated current data can be proposed. (1) Variations in soil carbon (C) stocks in agro-ecosystems should be taken into account. These variations can correspond to an observed trend, or result from a change in practices or in land use. Taking these stock variations into account is legitimate and desirable in an environmental label, and data for France are available. Trend changes in soil C stocks are simple to consider, as a product can be relatively easily associated with a land use (such as permanent grassland or arable land). Required data are available for France in Pellerin et al. (2020) and could be integrated in the AGRIBALYSE database. (2) Toxicity and ecotoxicity indicators are the subject of numerous debates by stakeholders. EF uses an infinite time horizon, which results in very high ecotoxicity impact values for metals. Modulating the EF with a 100-year horizon would allow a better balance between the impacts of organic molecules and trace metals. This alternative is already provided in several life cycle impact assessment methods (e.g. Bulle et al. 2019; Verones et al. 2020). (3) The relations between agricultural practices and biodiversity are complex. Several proposals have been made but have not yet been included in the EF. A potential and interim approach is to identify agricultural production systems that favourably impact field-level biodiversity. This can be done, initially, by focussing on labels

and certifications available for foods. Organic agriculture supports 30% higher biodiversity levels than conventional agriculture (Tuck et al. 2014). Organic certification thus signals products favourable to field-level biodiversity. On this basis, a rapidly operational solution would be to add a new impact category “field-level biodiversity” in the LCA framework in addition to the EF method. It would require defining two parameters: (1) coefficients expressing biodiversity benefit associated with various types of labels and corresponding agricultural practices and (2) the weight given to this impact category, which is a matter of societal arbitration that needs to be made explicit.

6 Which environmental scores should be chosen?

The EF method provides a single score expressed in a linear way. To make the environmental labelling more understandable and meaningful, this scale can be changed for two reasons: (1) to express the impact of a food product relative to other foods and not in absolute terms, in order to facilitate comparison between products; (2) to introduce a nonlinearity between the single score scale and the labelling scale, so that the latter can be fully used (with values all along the variation range and not only at the extremes). When changing scale, special attention must be paid to the equation (introduction of non-linearity) and to the bounds used (construction of the reference), scale changes must be transparent and argued.

During the experimentation phase, some stakeholders proposed to include additional non-LCA indicators in order to complement the environmental assessment based on the amended PEF framework. In general, these additional indicators were included after a change of scale (conversion of the PEF score to a 0–100 log-based scale), through a bonus/malus system, i.e. adding or subtracting points based on additional criteria (e.g. product label, transport distance), e.g. Itab (2021).

These additional indicators may aim to integrate additional corrections for topics that are still poorly described, such as the end-of-life of packaging, or the effects of land-use changes on soil C stocks. This may be significant from an environmental point of view, but the inclusion of these effects by a bonus/malus system after a change of scale lacks rigour. Indeed, these adjustments are not directly commensurable with the impact values of the LCA indicators they are supposed to correct. This obscures the effect of the correction, both in terms of the modulation of the impact factor considered and the weight assigned to it. Provided that they are scientifically based, some adjustments can be made, but they must be applied before the change of scale, to guarantee transparency.

Modifying the environmental scores by introducing additional indicators may distort the food-environment relationship established in the basic framework, and thus risks losing scientific rigour in order to gain on other dimensions such as increasing discrimination between different variants of foods. However, this may be acceptable to better highlight the benefits of actions that are consistent with public policy priorities (like in the EU “Farm-to-Fork” strategy). These elements raise important questions to be considered when thinking about complementary indicators, as their justifications may not only be based on science but rather stem from policy and regulatory perspectives.

7 What label format should be proposed?

Label format refers to the graphical design that is actually presented to the consumer, for instance as a front-of-pack label. Considering the research undertaken in the field of front-of-pack nutrition labelling, elements of effectiveness from a graphical design perspective appear relevant to be transposed to environmental labelling. In France, the Nutri-Score appears as the natural frame of reference for environmental labelling of foods. Overall, an effective format must raise awareness and have salience. For this, it is preferable that it be standardised, hence the importance of having a unique, immediately recognisable format. For salience, colour-coded schemes have shown to be more easily identified than monochrome systems (Talati et al. 2019). Similar to Nutri-Score for nutrition labelling, a five-level ordinal scale, based on a summary environmental indicator, would allow discrimination between food categories and guide consumers in product comparisons (“diet” effect). However, it may not always be sufficient to guide consumers in product comparisons within food categories should the distance between different types of foods within categories be limited. Some options may address this limitation. First, the number of levels in the ordinal labelling scale would be expanded, which may reduce effectiveness with respect to consumer choices, but would increase the visibility of supply-side action levers. Second, an ordinal scale may be complemented by a numerical value expressing the overall environmental score on a scale of 0 to 100. This finer granularity would facilitate comparisons between products in the same category, revealing the effects of supply-side policy levers. Third, the ordinal scale could be complemented by a breakdown of the overall score into sub-scores expressing the main environmental issues (climate, biodiversity, etc.). Supply-side actions would be made more visible by the variations they induce in the sub-scores. The decomposition would also increase the information given to the consumer, without necessarily losing overall efficiency thanks to the presence of the aggregate score. However, considering the elements

of information for which the front-of-package is already the vector (quality labels, nutrition labels, marketing elements etc.), the additional information needs to be carefully weighed against detrimental effects, and in particular the loss of consumer attention through the multiplication of elements of arbitration to take into account. In this case, the balance between front-of-pack and back-of-pack information needs to be taken into consideration.

8 Discussion and conclusions

The scientific council delivered its report on the national experimentation on environmental labelling to the French government on December 2021. The government now has to decide on the contours of the environmental labelling scheme that could be recommended in France. This means that an arbitration will be made with respect to the six issues discussed in this paper. These choices will hopefully be made based on the recommendations of the scientific council, but they will also depend on political choices and considerations of practical feasibility.

To encourage relevant and far-reaching changes commensurate with current environmental challenges, an environmental label must provide information to consumers allowing them to compare products within food categories (varying according to production-processing-distribution methods) and between food categories (to change diet structure more profoundly).

Controlling the costs of implementing environmental labelling, as well as the completeness and accuracy of the data to be used, justifies the joint use of generic publicly available data (provided by the AGRIBALYSE database) and specific private or publicly available data. The way in which these data are used for labelling, by both companies and independent third party platform actors, must be subject to collectively agreed rules in order to guarantee the quality and consistency of the information across outlets. The deployment of environmental labelling also requires the development of tools for calculating semi-specific values, to be made available to stakeholders to facilitate evaluations, as well as the development of a platform for centralising the values to be used for labelling.

An important issue will no doubt be to what extent signals delivered by an environmental label will contradict other public policy objectives. In particular, a major subject of debate (Brimont and Saujot 2021) is the question whether an environmental label should be favourable to products of organic farming, the development of which is an objective of the European Commission (2020) “Farm to Fork” strategy. Tests during the experimentation period have shown that an environmental label based uniquely on the EF method will encourage a shift from animal

foods to plant foods rather than a shift from conventional to organic foods. Introducing a bonus/malus approach to favour organic foods will come at a cost, as it will be less supportive of the needed shift to plant-based nutrition.

The environmental information to be provided to consumers should be developed based on the LCA methodology and within the PEF reference framework, recognised scientifically and institutionally at European level. However, given certain current limitations in the available data and models, in particular in the capacity to take into account the environmental benefits of agroecological production methods, amendments to this reference framework may be considered. In this perspective, we proposed several corrective measures, which can be implemented rapidly, to improve the consideration of issues related to carbon sequestration in soils, field-level biodiversity and toxicities. These proposed modifications remain interim solutions, necessary to meet the French labelling timeline, but which will have to be amended according to the evolution of the PEF.

Through the existence of the PEF, the life cycle inventory data in the AGRIBALYSE database and the answers to the above questions, the LCA framework can be operationalized and adapted for environmental labelling. Informing consumers about the environmental impacts of food products is therefore possible and is certainly a step forward in minimising human impact on nature.

Declarations

Conflict of interest The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- AGRIBALYSE (2020) Database v3.0, France: ADEME. <https://agribalyse.ademe.fr>. Accessed 3 May 2022
- Bablani L, Ni Mhurchu C, Neal B, Skeels CL, Staub KE, Blakely T (2020) The impact of voluntary front-of-pack nutrition labelling on packaged food reformulation: a difference-in-differences analysis of the Australasian Health Star Rating scheme. *PLoS Med.* 17(11):e1003427. <https://doi.org/10.1371/journal.pmed.1003427>. PMID: 33216747; PMCID: PMC7679009

- Brimont L, Saujot M (2021) Révéler les visions derrière l’affichage environnemental pour construire un compromis politique. Étude N°08/21, Iddri, Paris, France, 44. https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Etude/202110-ST0821-AE_1.pdf. Accessed 31 May 2022
- Bulle C, Margni M, Patouillard L et al (2019) IMPACT World+: a globally regionalized life cycle impact assessment method. *Int J Life Cycle Assess* 24:1653–1674. <https://doi.org/10.1007/s11367-019-01583-0>
- Coste G, Hélias A (2022) PEFAP : Estimating the environmental footprint of food products from packaging data. *J Open Source Softw* 7:3329. <https://doi.org/10.21105/joss.03329>
- Crenna E, Marques A, La Notte A, Sala S (2020) Biodiversity assessment of value chains: state of the art and emerging challenges. *Environ Sci Technol* 54:9715–9728. <https://doi.org/10.1021/acs.est.9b05153>
- European Commission (2020) Farm to fork strategy. European commission, Brussels. https://ec.europa.eu/food/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf. Accessed 31 May 2022
- Fantke P, Juraske R, Antón A et al (2011) Dynamic multicrop model to characterize impacts of pesticides in food. *Environ Sci Technol* 45:8842–8849. <https://doi.org/10.1021/es201989d>
- Fazio S, Castellani V, Sala S et al (2018) Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment method. EUR 28888 EN, European Commission, JRC109369, Ispra. https://eplca.jrc.ec.europa.eu/permalink/TR_SupportingCF_FINAL.pdf. Accessed 31 May 2022
- Hallström E, Davis J, Woodhouse A, Sonesson U (2018) Using dietary quality scores to assess sustainability of food products and human diets: a systematic review. *Ecol Indic* 93:219–230. <https://doi.org/10.1016/j.ecolind.2018.04.071>
- Itab (2021) Affichage environnemental, rapport d’expérimentation. Planet-score. Available at : http://itab.asso.fr/downloads/affichage-environnemental/rapport__planet-score__itab-sayari-verygoodfuture_29juillet2021_vf.pdf. Accessed 31 May 2022
- McAuliffe GA, Takahashi T, Lee MRF (2020) Applications of nutritional functional units in commodity-level life cycle assessment (LCA) of agri-food systems. *Int J Life Cycle Assess* 25:208–221. <https://doi.org/10.1007/s11367-019-01679-7>
- Pedersen E, Remmen A (2022) Challenges with product environmental footprint: a systematic review. *Int J Life Cycle Assess* 27:342–352. <https://doi.org/10.1007/s11367-022-02022-3>
- Pellerin S, Bamière L et al (2020) Stocker du carbone dans les sols français, Quel potentiel au regard de l’objectif 4 pour 1000 et à quel coût ? Rapport scientifique de l’étude, INRA, 540 p. https://www.inrae.fr/sites/default/files/pdf/etude-4-pour-1000-resume-en-francais-pdf-1_0.pdf. Accessed 31 May 2022
- Sala S, Biganzoli F, Mengual ES, Saouter E (2022) Toxicity impacts in the environmental footprint method: calculation principles. *Int J Life Cycle Assess* 27:587–602. <https://doi.org/10.1007/s11367-022-02033-0>
- Soler LG, Aggeri F, Dourmad JY, Hélias A, Julia C, Nabec L, Pellerin S, Ruffieux B, Trystram G, van der Werf HMG (2021a) L’Affichage environnemental des produits alimentaires. Rapport du conseil scientifique. <https://expertises.ademe.fr/sites/default/files/assets/documents/affichage-environnemental-produits-alimentaires-rapport-final-conseil-scientifique.pdf>. Accessed 31 May 2022
- Soler LG, Aggeri F, Dourmad JY, Hélias A, Julia C, Nabec L, Pellerin S, Ruffieux B, Trystram G, van der Werf HMG (2021b) Environmental labelling for food – assessment report by the Scientific Council. <https://expertises.ademe.fr/sites/default/files/assets/documents/environmental-labelling-food-assessment-report-scientific-council.pdf>. Accessed 31 May 2022
- Talati Z, Egnell M, Hercberg S, Julia C, Pettigrew S (2019) Consumers’ perceptions of five front-of-package nutrition labels: an experimental study across 12 countries. *Nutrients* 16;11(8):1934. <https://doi.org/10.3390/nu11081934>. PMID: 31426450; PMCID: PMC6723043
- Tuck SL, Winqvist C, Mota F, Ahnström J, Turnbull LA, Bengtsson J (2014) Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. *J Appl Ecol* 51:746–755. <https://doi.org/10.1111/1365-2664.12219>
- van der Werf HMG, Knudsen MT, Cederberg C (2020) Towards better representation of organic agriculture in life cycle assessment. *Nature Sust* 3:419–425. <https://doi.org/10.1038/s41893-020-0489-6>
- Veronesi F, Hellweg S, Antón A et al (2020) LC-IMPACT: a regionalized life cycle damage assessment method. *J Ind Ecol* 24:1201–1219. <https://doi.org/10.1111/jiec.13018>
- Willett W, Rockström J, Loken B et al (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet* 393:447–492. [https://doi.org/10.1016/S0140-6736\(18\)31788-4](https://doi.org/10.1016/S0140-6736(18)31788-4)

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.