Science-Based And Interest-Driven? Harmonising Agricultural Carbon Footprint (CF) Methods – The Case Of Manure

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1 Abstract

The demand for carbon footprint (CF) studies of agricultural products is increasing, but the calculation methods differ. At the example of manure, we compare two methodological options: the 'cut-off approach' outlined in the International Dairy Federation's (IDF) LCA guidelines, whereby all emissions of manure application are excluded from the animal and assigned to the plant system; and the approach outlined in the FAO-LEAP guidelines, whereby the share of manure which is applied in excess of plant nutrient requirements ("over-fertilisation") is attributed to the animal system. We find that the choice of methodological approach has a significant impact on the carbon footprint (CF) of winter wheat and cow milk, with the FAO-LEAP method resulting in an increase of nearly 3% of cow milk CF. We then analyse how the consideration of manure in CF studies is linked to scientific and normative principles, which are intertwined with interests and incentives. We argue that in order to facilitate harmonization and reach widespread acceptance, a normative concept for decision making would need to be developed that considers stakeholder views.

Keywords: Agricultural carbon footprints, climate change mitigation, environmental impact reporting, harmonization and standardization, allocation

2 Problem statement

The recent decade witnessed a "fast and furious" rise of carbon footprints (CF) of agricultural products (Deconinck, Jansen and Barisone, 2023). Consumers, civil society, and businesses are calling for greater transparency regarding the climate impacts of food. But the methods, as often expressed in standards and guidelines, differ and general recommendations may be interpreted in different ways which can lead to inconsistent and potentially misleading results. As a result, these discrepancies can invite "cherry-picking" of solutions that are most suitable for individual stakeholder groups, leading to inconsistent results. However, there is a lack of information on the different impacts of methodological choices, both on the carbon footprint outcomes and other interests, incentives and public goals involved (OECD 2025). This lack of knowledge may be problematic in terms of reaching wider public acceptance of carbon footprint methods. Fertilization practices are a major mitigation potential for agriculture and methodological guidelines provide different ways of considering over-fertilisation.

3 Research question(s) and objectives

Research questions

- Which methodological choices, expressed in standards and guidelines, are used to consider the fertilizer application of manure, including over-fertilisation?
- How do methodological choices affect the results of CF assessments?
- Which normative principles, incentives and interests are relevant when choosing between the two methodological options?

Objective

This research contributes to the ongoing debate on harmonizing carbon footprint standards in the agri-food sector. The case study shall be used for developing a model for decision-making in cases of underdetermined regulations on methodological issues.

4 Methods

This research project explores the potential of Germany's National Inventory Reports to the UNFCCC as a reference for harmonizing carbon footprint calculations. To this end, a comprehensive literature review was conducted to examine which methodological choices are left open by standards, norms, and guidelines and how these influence carbon footprint calculations.

We selected the consideration of manure in plant production systems as a case study because it illustrates the complexity and ambiguity of methodological standards, offers significant mitigation potential, and is relevant to various production systems. The choice between two methodological options is being analysed in more detail: In the first option, over-fertilisation is assigned entirely to the wheat carbon footprint, according to the IDF Dairy default recommendation ("cut-off approach)" (IDF 2022); and the second option, the emissions due to overfertilization are assigned to the milk production system ("waste-share approach"), according to FAO LEAP (FAO 2016).

We first analyze the impacts of each option on the carbon footprints of milk and winter wheat, focusing on N2O emissions from N fertilization. We assumed a wheat producer applied 50 kg of excess nitrogen fertilizer, exceeding the level of good practices defined in the German fertilizer regulation, to represent over-fertilization

We then qualitatively analyze the broader implications of each option, considering the scientific and normative principles of product-level environmental impact assessments outlined in relevant standards and guidelines. These principles encompass relevance, completeness, consistency, accuracy, consequence, and operational feasibility

5 Data

We used the formulas and emission factors from Germany's National Inventory Reports to the UNFCCC to calculate the impacts of the methodological choice on the carbon footprint. This approach provides a peer-reviewed scientific basis and allows for comparability with future case studies. Emissions due to over-fertilisation were divided into two sources, direct N2O emissions during application of manure on the field, and indirect emissions (deposition and leaching) N2O emissions. The emission factors are taken from the submission 2025 of the German National Inventory Report, as published by the Federal Environmental Agency (UBA 2025). Also conversion factors in N2O and CO2e are taken from Submission 2025.

Our assessment of impacts is based on a literature review of LCA standards and guidelines, which provides a foundation for evaluating methodological principles. We analyzed the impacts in relation to normative principles of product-level assessments, using principles from ISO 14067 (ISO 2018) and GHG Protocol (2011). We also drew on the methodology developed under the Food Data Transparency Partnership (FDTP) of the United Kingdom, which provides guidance on combining methodological choices to achieve consistent application across food sectors (WRAP 2025, p. 12). It is further planned to confirm the relevance of the normative principles in expert interviews.

6 Results and discussion

Our results consist of both quantitative and qualitative components. In terms of quantitative impacts, the calculated emissions were compared with peer-reviewed carbon footprints of winter wheat and milk. Using the German Inventory Report formula, we calculated N2O emissions of 191.35 kg CO2e per hectare due to 50 kg N input above good practices. Direct N2O emissions of 138.88 kg / ha CO2e have the highest share, followed by 36.09 kg CO2e / ha by deposition and 16.38 kg CO2e per run-off and leaching. Our results show that N2O emissions from over-fertilization can have a significant impact on both winter wheat and milk carbon footprints. Over-fertilization can make up to roughly 7 % of the carbon footprint of winter wheat and roughly 4 % of raw cow's milk.

According to the FAO LEAP waste-share approach, 7% of the wheat carbon footprint would be reallocated to the cow milk footprint, equivalent to 4% of the cow milk carbon footprint. However, the significant impact of over-fertilization on carbon footprint results may not be the primary driver for choosing one of the two methodological options. The main problem with the waste-share approach is that for animal farmers, data on manure application in other farms will be difficult to get. Additionally, even if data is available, the waste-share approach would require more administrative effort from both animal and plant farmers compared to the cut-off approach. In terms of incentives, the two approaches have different effects. When manure is used for feed production that reenters the animal system, the incentives to reduce over-fertilization are aligned, as a higher wheat carbon footprint directly affects the milk carbon footprint. However, if human food products are produced or feed is sold to external markets, the animal sector has no incentive to address over-fertilization. Emissions of disposing redundant manure would not affect the animal systems carbon footprint, despite the fact that areas with high nitrogen over-fertilization often coincide with high animal production densities. The waste-share approach would create incentives for the animal sector to seek solutions to mitigate over-fertilization, e.g. requiring from purchasers to apply adequate fertilizer practices. However, a major obstacle to implementing the waste-share approach is that over-fertilization is often not reported or accounted for. Farms that intentionally over-fertilize are unlikely to participate in climate measures that penalize this practice. The cut-off approach avoids this conflict, but shifts the responsibility for over-fertilization to plant production, overlooking the role of animal production in this system.

Overall, deciding on the methodological choice involves several distinctive rationales:

- Incentives to achieve public goals, such as climate change mitigation,
- Practicability, including data availability and administrative costs,
- Causation, e.g. allocating emissions to the practices or conditions deemed responsible for over-fertilization.

Developing a widely accepted methodological choice requires a normative concept that integrates these rationales. This concept should be accepted by all stakeholders that are affected by the

decision. Public intervention can enable or facilitate a neutral platform of exchange, including exchange on conflicting arguments and interests.

7 References

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