Accountability of livestock multinationals for global environmental impacts

Drotenko, C.; Taherzadeh, O.A.; Scherer, L.A.; Kortleve, A.J.; Hoekstra, R.; Behrens, P.A.

Accountability of livestock multinationals for global environmental impacts

Christina Drotenko

c.drotenko@cml.leidenuniv.nl

Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands
https://orcid.org/0009-0006-3861-6793

Oliver Taherzadeh

Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands
https://orcid.org/0000-0001-6144-9483

Laura Scherer

Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands
https://orcid.org/0000-0002-0194-9942

Anniek Kortleve

Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands
https://orcid.org/0000-0003-4617-2281

Rutger Hoekstra

Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands
https://orcid.org/0000-0001-6531-9782

Paul Behrens

Oxford Martin School, Oxford University, Oxford, United Kingdom; Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands https://orcid.org/0000-0002-2935-4799

Brief Communication

Keywords:

Posted Date: February 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8924723/v1

Additional Declarations: There is **NO** Competing Interest.

Accountability of livestock multinationals for global environmental impacts

Christina Drotenko
Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands

Oliver Taherzadeh
Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands

Laura Scherer
Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands

Anniek J. Kortleve
Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands

Rutger Hoekstra
Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands

Paul Behrens
Oxford Martin School, Oxford University, Oxford, United Kingdom
Institute of Environmental Sciences (CML), Leiden University, Leiden, The Netherlands

Abstract

Transnational livestock corporations are major contributors to environmental pressures, but rarely disclose their global impacts. To address this transparency gap, we integrate company-level production data (beef, poultry, pork, dairy) with a model that quantifies environmental impacts of 53 companies. These companies contribute substantially to land use (26%), water use (23%), and nitrogen application (28%) in the global livestock sector, highlighting the need for independent benchmarking and stronger sustainability disclosure requirements.

Main

Livestock is a significant driver of global environmental degradation.[1] A small number of transnational corporations (TNCs), such as JBS, Tyson, and Cargill, possess large leverage over global livestock supply chains and farmers.[2,3] However, the environmental impacts of these companies' supply chains are poorly documented, piecemeal in coverage, and rarely subject to the same level of rigorous independent assessment that is commonplace in financial reporting.[4,5] This is due, in part, to the voluntary nature of prominent environmental reporting frameworks, such as the Sustainability Accounting Standards Board and Global Reporting Initiative.[5]

Effective sustainability disclosure requires high-quality data that is publicly available, externally audited, and covers the full supply chain. Yet, these characteristics are regularly omitted from corporate reporting. TNCs lack incentives to disclose detailed supply chain information, as risks can outweigh benefits. For example, disclosing such information can establish future legal liability for environmental and human rights impacts, and reveal proprietary supply chain information.[6,7] Third-party modelling of supply chain impacts is also challenging due to heterogeneity across regions, production practices, and trade flows, requiring detailed product and trade flow data that are generally not made available by companies.[6] Some companies, such as JBS, have been criticised for under-reporting disclosure of scope 1, 2, and 3 emissions due to the exclusion of suppliers' agriculture and deforestation emissions when compared to independent assessments, further reducing the reliability of voluntary sustainability reporting.[8]

Independent analysis that links public company data from annual reports with corresponding supply chain environmental impacts can help to bridge this transparency gap. Previous work has explored high-quality data at the region- and sector-levels,[9–12] while enterprise-level models have also become available but use partially proprietary firm-level data.[13] Here, we systematically map global livestock TNC environmental impacts using publicly available data on production volumes, improving the spatial, sectoral, and impact coverage of previous assessments.

We assess the environmental impacts of 53 of the world's largest livestock TNCs, for which data is available, using production volumes derived from publicly accessible information on company accounts. Our analysis covers 18 beef, 18 poultry, 23 pork, and 16 dairy companies (several companies operate in multiple markets). We estimate that these companies globally produce 17%, 23%, 18%, and 41% of the world's beef, poultry, pork, and dairy products, respectively. We couple these company-level data with the Food, Agriculture, and Biomass Input-Output (FABIO) model,[14] a global biophysical model that captures food system resource flows in the livestock sector and their indirect crop feed impacts. We then quantify company-level impacts for land use, blue (ground and surface water) and green water (soil moisture

from precipitation) use, and nitrogen application (direct application of nitrogen fertilisers to crops and deposition from grazing animals).[15,16]

The companies in our sample are linked to the processing of 17.8 billion head of livestock per year, comprised of 54 million cattle, 267 million pigs, and 17.5 billion chickens, along with over 190 million tonnes of annual dairy production (**Fig. 1**). These companies are responsible for around one-quarter of the global land use (26%), water use (23%), and nitrogen application (28%) linked to global production of beef, poultry, pork, and dairy (**Fig. 1**, Supplementary Table 1). The shares of these impacts are larger than the relative livestock slaughter of analysed TNCs for beef (17%), poultry (23%), and pork (18%), indicating that TNC production is relatively more environmentally intensive (with the exception of dairy). Among the TNCs, JBS dominates in all impacts linked to the production of beef and poultry (22-45%, ranging across all three environmental impacts), WH Group for pork (18-19%), and Dairy Farmers of America for dairy (13-18%), highlighting these as actors to focus on to reduce environmental burdens (**Fig. 1**, Supplementary Table 2).

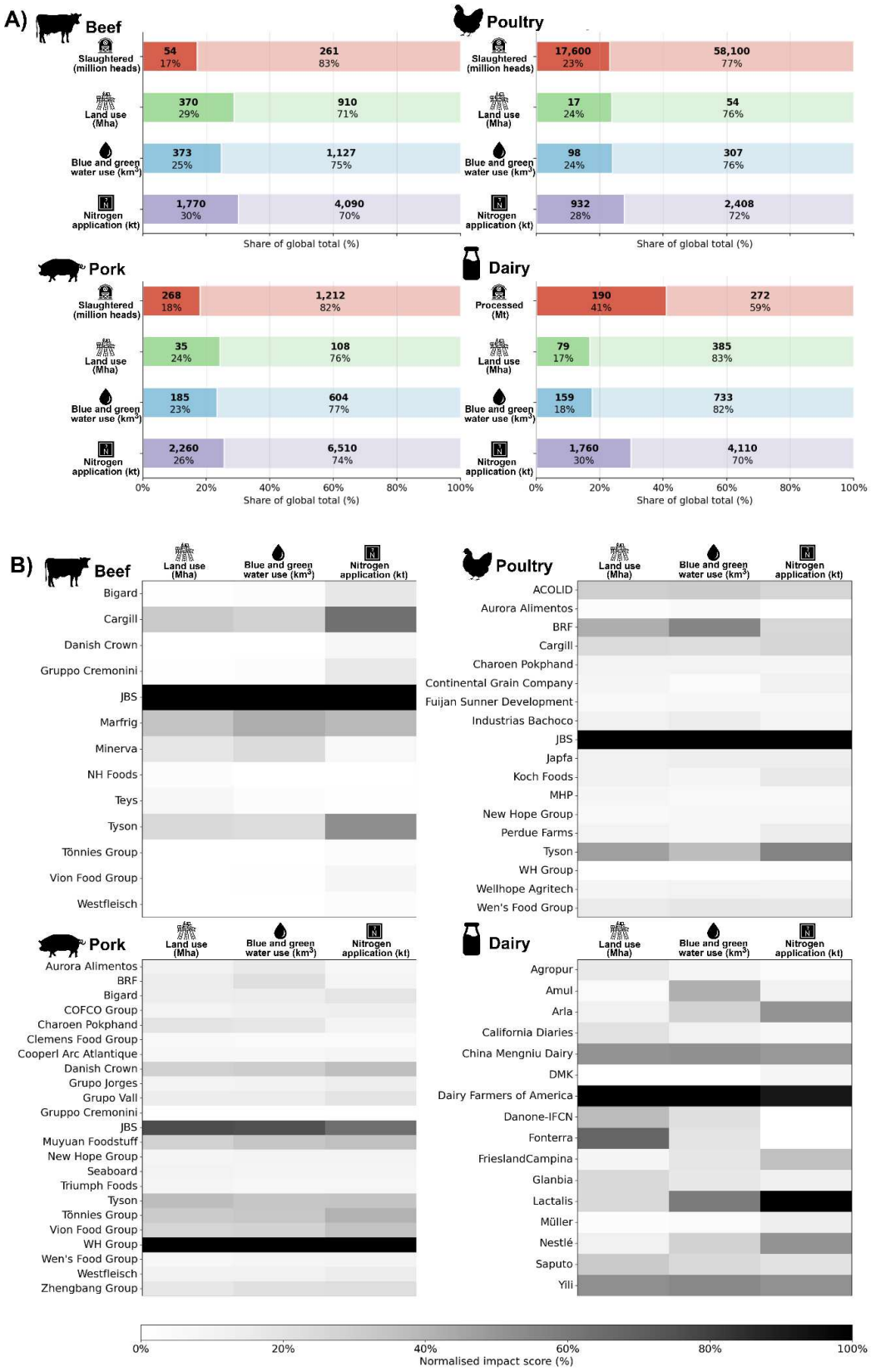

Fig. 1 | Contribution of analysed companies towards global slaughter and environmental impacts across four livestock products (beef, poultry, pork and dairy). **A)** Percentage share and absolute amount of global slaughtered livestock or processed dairy, land use, water use, and nitrogen application attributable to the analysed companies. **B)** Largest contributing TNC to each environmental impact category on a normalised scale (%) relative to each column (impact). See Supplementary Table 3 for all firms and Supplementary Table 4 supported by Supplementary Notes II for more information, including on green and blue water use reported separately.

By sector, beef production dominates in water (46%) and land use (74%), while pork production drives the largest share of nitrogen application (34%) (**Fig. 2**). Overall, the environmental impacts of these sectors are most commonly located in North America (40% land use, 38% water use, 45% nitrogen application), South America (31% land use, 34% water use), and Europe (30% nitrogen application), reflecting the global trend in large-scale livestock production in these regions (**Fig. 2**).[17,18] The Middle East and Africa see limited impacts as farming is less centralised and dominated by smallholders that are not generally integrated into TNC supply chains.[19]

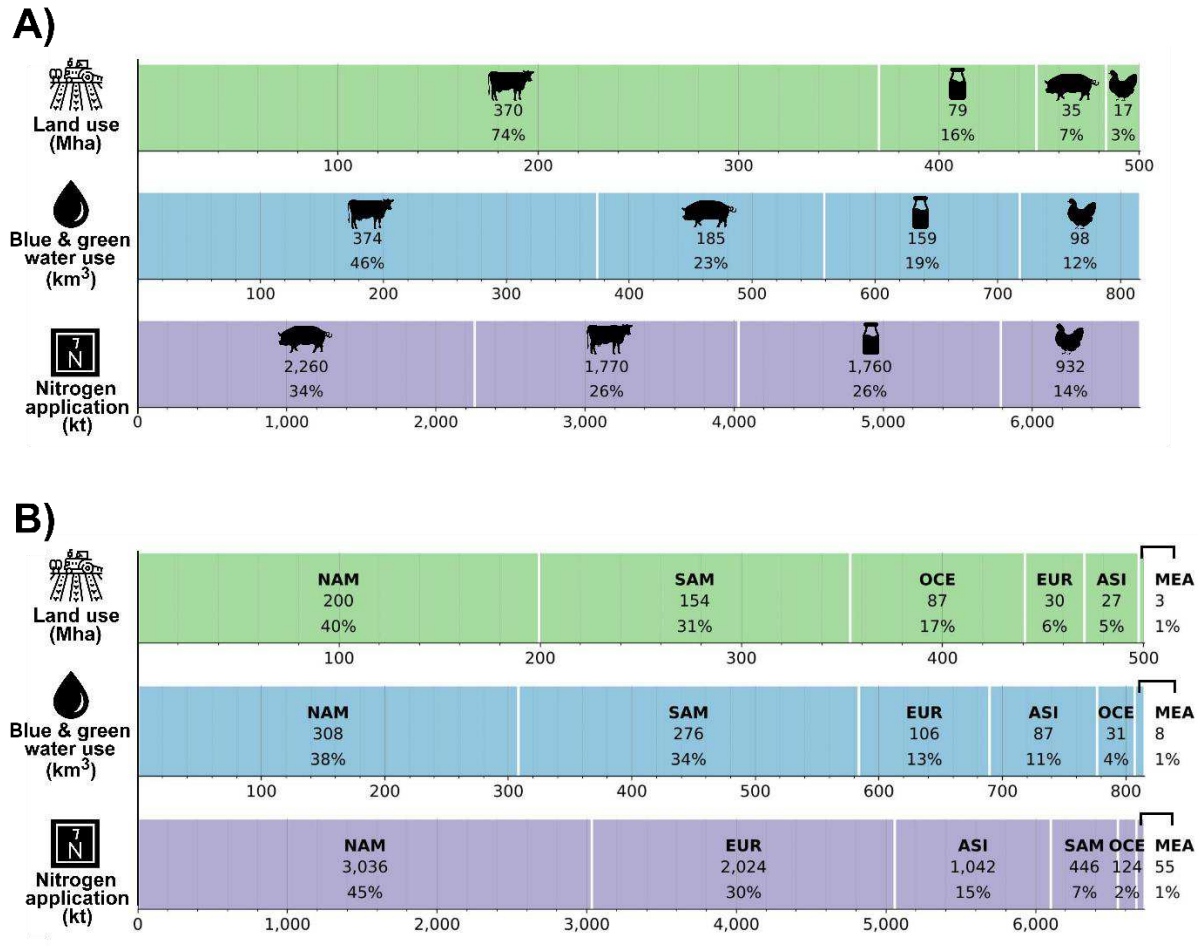

Fig. 2 | Analysed companies' environmental impacts disaggregated across livestock products and regions. A) Land use, water use, and nitrogen application across the companies analysed distributed by livestock product. B) The same impacts disaggregated by region across North America (NAM), South America (SAM), Europe (EUR), Asia (ASI), Oceania (OCE), and Middle East and Africa (MEA). See Supplementary Table 3 for full results, including on green and blue water reported separately.

Although the dataset used here contributes towards the mapping of major TNC impacts, some production remains underrepresented (see Supplementary Notes I for key assumptions). For example, China produces nearly half of the world's pork, which may not be captured fully in our analysis.[20] This dataset also does not map the production of potential subsidiary or shell companies.

Mandatory reporting could be a first step towards TNC accountability, leading to improvements upon transparency gaps. However, few countries globally outside of those within the European Union currently have legal requirements for sustainability reporting covering all companies under their jurisdiction.[5] Even with mandatory reporting the results are often less detailed than financial reporting, for instance in the case of the EU-mandated Corporate Sustainability Reporting Directive (CSRD). In the CSRD, auditor verification is only required to the level of 'limited assurance' rather than 'reasonable assurance', which means that significantly less evidence is required to achieve the standard.[21] The CSRD also omits full supply chain impacts as non-EU suppliers may not provide data, and smaller suppliers face no direct legal requirement to report these data after the 'simplification' of the EU's regulations in 2025.[6,22] Overall, raising requirements for mandatory reporting is an important step, but is still not a comprehensive solution to holding companies accountable.

In the absence of detailed, transparent reporting, top-down modelling approaches using publicly available data to independently benchmark firms and track progress is essential. This is not only necessary to provide insights into firm environmental performance, but also to hold livestock TNCs accountable for reducing their environmental impacts. Future work could combine additional subnational sourcing data that becomes available, which would also capture site-specific issues such as animal welfare, zoonotic disease risks, and manure run-off. Moreover, while we do not examine the structural barriers preventing corporate accountability, such as increasing market concentration or their contractual leverage over farmers, improved transparency through external modelling can support future research investigating the role of livestock TNC power in shaping environmental performance and governance.[2,23]

In the long-term, raising public awareness of opaque environmental impacts across the livestock supply chain can guide policymakers in setting disclosure standards and detailed reporting requirements. These could include data on subsidiaries and shell companies, supplier names, sourcing and purchasing practices, and production conditions.[24,25] Public awareness could also empower civil society groups to advocate for other issues, such as mitigation of these companies' impacts and requirements for stronger auditing of sustainability claims, as called for by the EU Green Claims Directive.[26]

The vacuum of corporate accountability within food supply chains highlights the need for research that increases transparency of livestock TNC environmental impacts and clarifies priorities for reforms required to make such accountability possible. It prompts a discussion about the responsibility of livestock corporations for their roles in environmental damage.

Methodology

Here, we use environmentally extended input-output analysis (EEIOA) to quantify environmental pressures occurring across the entire supply chain, thereby capturing the indirect impacts for each product input across each step of the chain.[10] We integrate company-level data from investor reports with the global food supply chain model FABIO to enable environmental impact analysis at the company scale (Error! Reference source not found.).

FABIO covers 191 countries and one Rest of World region (n^r), 123 commodities (n^c), and five final demand categories of which we utilise one category titled 'food' (n^y), all with data from the year 2020. We use the Leontief model to calculate the environmental impacts of 53 companies for land use, blue and green water use, and nitrogen application across four commodity categories of beef, poultry, pork, and dairy production. Some companies are represented in more than one category depending on their operations and data availability.

In EEIOA, the standard analysis to calculate E, environmental impacts, uses the equation:

$$E = b' \cdot L \cdot y \tag{1}$$

where b' is a row vector with dimensions ($1 \times n^r n^c$) representing environmental impact intensity as a per unit factor for each of the environmental impacts. This is obtained by dividing each of the environmental extension vectors e by the total output vector x, given as $b' = e'\hat{x}^{-1}$. We then construct the technical coefficients matrix A from inter-sector flows of physical units matrix Z and total output vector x. There we derive the Leontief inverse $L = (I - A)^{-1}$ where I is an identity matrix and the resulting L has the dimensions ($n^r n^c \times n^r n^c$). The y vector, dimensions ($n^r n^c \times n^y$), represents the region-commodity pairing with the production of each company in the year 2022. Different years for FABIO (2020) and production data (2021-2023) are used due to data availability at the time of analysis. Here, we construct a final demand vector that represents each company's output for every selected commodity by attributing TNC production to final demand. This calculation is repeated for 53 companies across four commodities. Additional details on specific assumptions that are required, such as the regionalisation of country-level data with a concordance table, can be found in the Supplementary Notes I.

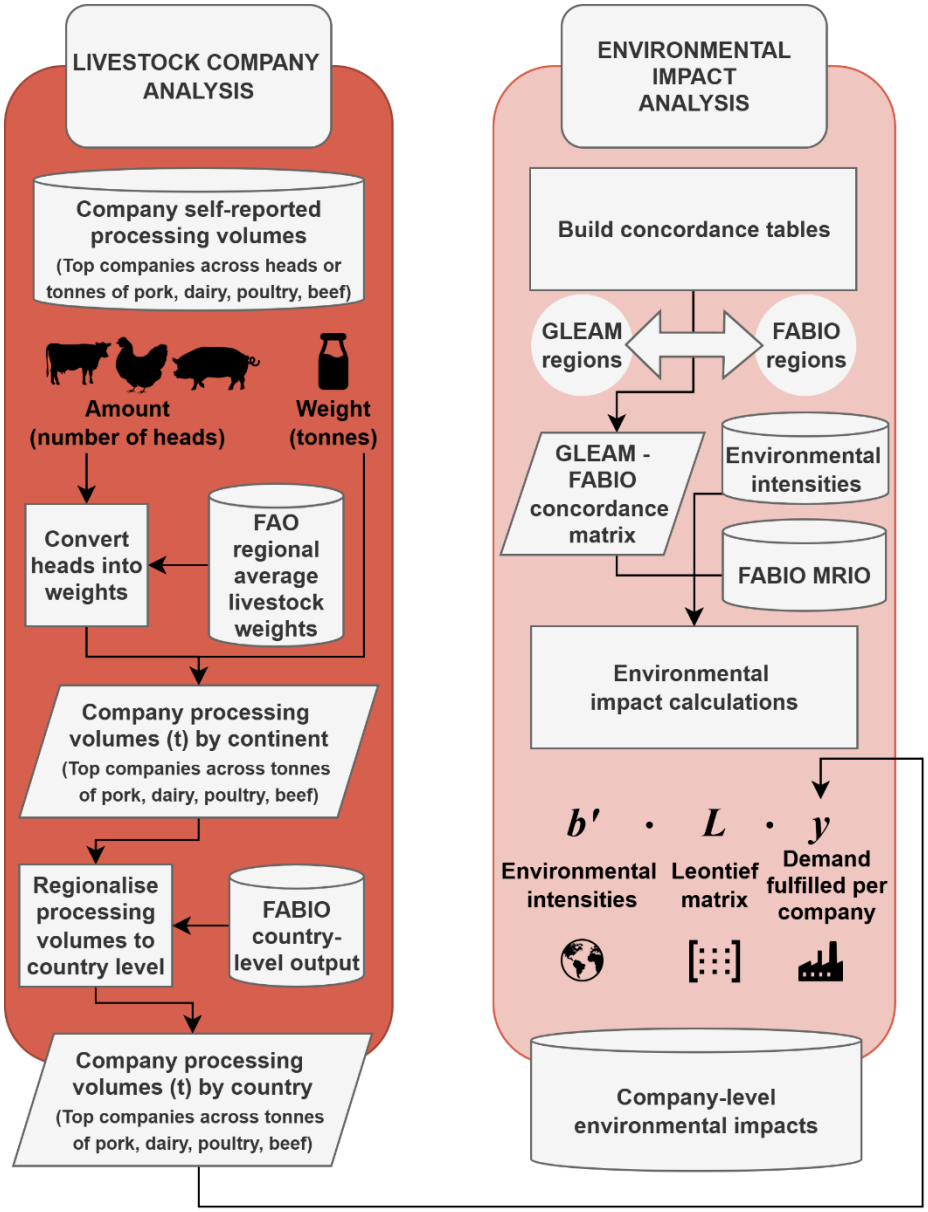

Fig. 3 | Overview of the method consisting of livestock company analysis and environmental impact analysis. Left panel: Derivation of company-level livestock processing volumes by country, based on self-reported company data, FAO regional livestock weights, and FABIO country-level outputs. Right panel: Environmental impact analysis linking company-level demand to environmental impacts using region concordance tables, FABIO, and environmental Leontief accounting, resulting in company-level environmental impacts.

Data availability

We used three main data sources: (1) land use spatial mapping from Liu et al.,[27] (2) the Food and Agriculture Biomass Input-Output (FABIO) database for global multi-regional input-output tables in physical units and related impacts (blue water use, green water use, nitrogen application),[14] and (3) company data, based on self-reported company data from sources such as investor reports, available here: https://doi.org/10.5281/zenodo.18709709. Results and related data which are directly referenced in the text are available in the Supplementary Tables.

Code availability

Code and an explanation of how to reproduce the results is available via Zenodo at: https://doi.org/10.5281/zenodo.18709709 and in Supplementary Notes C).

Author contributions

C.D., P.B., O.T., L.S., and A.J.K. designed the study. C.D. adjusted data collected by Profundo, an independent research consultancy, and performed the analysis with the support of O.T., P.B., L.S., and A.J.K. C.D. prepared figures with substantial feedback from O.T., P.B., L.S. and R.H. The writing was led by C.D. with significant contributions by O.T., P.B., L.S., A.J.K, and R.H. All authors approved the final manuscript.

Acknowledgements

Thank you to Arthur Schoorlemmer and Nils Pauliks for their editing assistance and invaluable feedback. All icons used in the figures are designed by Freepik and can be found here: https://www.freepik.com/.

Corresponding authors

Christina Drotenko, Paul Behrens

Funding

This work was supported by funding from the Frontiers Planet Prize and Foodrise.

References

1. Poore, J. & Nemecek, T. Reducing food's environmental impacts through producers and consumers. *Science* 360, 987–992 (2018).
2. Clapp, J. The problem with growing corporate concentration and power in the global food system. *Nat Food* 2, 404–408 (2021).
3. Heinrich Böll Stiftung. *Meat Atlas 2021*. https://eu.boell.org/en/MeatAtlas2021-PDF (2021).
4. Flores-Martínez, P., Heron, T., West, C. & Prado, P. Power and sustainability governance in the soy-animal protein global value chain. *Review of International Political Economy* 0, 1–30 (2025).
5. OECD. *Global Corporate Sustainability Report 2025*. (OECD Publishing, 2025). doi:10.1787/bc25ce1e-en.
6. Stenzel, A. & Waichman, I. Supply-chain data sharing for scope 3 emissions. *npj Clim. Action* 2, 7 (2023).
7. Mateska, I., Wagner, S. M. & Stienen, L. Media Reporting of Environmental Supply Chain Sustainability Risks: Contextual and Moderating Factors. *J Bus Ethics* 199, 285–308 (2025).
8. New Climate Institute & Carbon Market Watch. *Corporate Climate Responsibility Monitor 2022*. (2022).
9. Trase - Insights and analysis on commodity trade sustainability - Trase. *trase.earth* https://trase.earth/.
10. Green, J. M. H. *et al.* Linking global drivers of agricultural trade to on-the-ground impacts on biodiversity. *Proceedings of the National Academy of Sciences* 116, 23202–23208 (2019).

11. Flach, R., Fader, M., Folberth, C., Skalský, R. & Jantke, K. The effects of cropping intensity and cropland expansion of Brazilian soybean production on green water flows. *Environ. Res. Commun.* **2**, 071001 (2020).

12. Escobar, N. *et al.* Spatially-explicit footprints of agricultural commodities: Mapping carbon emissions embodied in Brazil's soy exports. *Global Environmental Change* **62**, 102067 (2020).

13. Katafuchi, Y. *et al.* Construction of an enterprise-level global supply chain database. *Nat Commun* **16**, 11158 (2025).

14. Bruckner, M. *et al.* FABIO—The Construction of the Food and Agriculture Biomass Input–Output Model. *Environ. Sci. Technol.* **53**, 11302–11312 (2019).

15. Harrison, M. T. *et al.* Carbon myopia: The urgent need for integrated social, economic and environmental action in the livestock sector. *Global Change Biology* **27**, 5726–5761 (2021).

16. Hoekstra, A. Y. Green-blue water accounting in a soil water balance. *Advances in Water Resources* **129**, 112–117 (2019).

17. *World Food and Agriculture – Statistical Yearbook 2022*. (FAO, 2022). doi:10.4060/cc2211en.

18. Herrero, M. *et al.* Farming and the geography of nutrient production for human use: a transdisciplinary analysis. *The Lancet Planetary Health* **1**, e33–e42 (2017).

19. IFAD Livestock Stocktake 2010-2024. https://www.ifad.org/en/w/publications/ifad-livestock-stocktake-2010-2024?.

20. USDA Foreign Agricultural Service. Production - Pork. https://www.fas.usda.gov/data/production/0113000.

21. Committee of European Auditing Oversight Bodies. CEAOB guidelines on limited assurance on sustainability reporting. (2024).

22. Legislative Observatory European Parliament. Certain corporate sustainability reporting and due diligence requirements. (2025).

23. Béné, C. Why the Great Food Transformation may not happen – A deep-dive into our food systems' political economy, controversies and politics of evidence. *World Development* 154, 105881 (2022).

24. Grabs, J. *et al.* The role of midstream actors in advancing the sustainability of agri-food supply chains. *Nat Sustain* 7, 527–535 (2024).

25. Gardner, T. A. *et al.* Transparency and sustainability in global commodity supply chains. *World Dev* 121, 163–177 (2019).

26. European Commission. Green claims. https://environment.ec.europa.eu/topics/circular-economy-topics/green-claims_en (2026).

27. Liu, B., Behrens, P., Sun, Z. & Scherer, L. Two-thirds of agricultural carbon and biodiversity loss occurs on one-third of the agricultural area. Preprint at https://doi.org/10.21203/rs.3.rs-5527595/v1 (2025).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTables.xlsx
- SupplementaryNotes.docx