The Journal of Open Source Software

cowfootR: An R Package for Dairy Farm Carbon Footprint Assessment

Juan M. Moreno [1¶]

1 Conaprole, Uruguay ¶ Corresponding author

DOI: 10.21105/joss.09572

Software

- Review
- Repository
- Archive

Editor: Kalyn Dorheim

Reviewers:

- @tscheypidi
- @kendalynnm

Submitted: 20 September 2025
Published: 07 May 2026

Summary

The cowfootR package is an open-source R package designed for comprehensive carbon footprint assessment of dairy farms, implementing internationally recognized methodologies including Intergovernmental Panel on Climate Change (IPCC) Guidelines and International Dairy Federation (IDF) standards. The package enables transparent and reproducible estimation of carbon emissions from dairy production systems through modular functions that estimate emissions from five key sources: enteric fermentation, manure management, soil nitrogen dynamics, energy consumption, and purchased inputs, supporting both Tier 1 and Tier 2 IPCC methodologies. Key features include standardized intensity metrics (kg CO eq per kg of fat-protein corrected milk, per hectare), batch processing capabilities for multiple farms, and regional benchmarking tools. Unless otherwise stated, absolute greenhouse gas emissions reported by cowfootR are annual emissions expressed as kg CO -equivalent per year at the farm (system) level, consistent with IPCC and IDF accounting frameworks. By transforming complex carbon accounting into accessible workflows, cowfootR empowers researchers, agricultural consultants, and policymakers to evaluate mitigation strategies, monitor environmental progress, and enhance the sustainability of dairy operations while addressing the critical need for standardized, reproducible carbon assessment in agricultural systems.

Statement of need

The environmental impact of milk production is a subject of growing global concern due to the sector's contribution to anthropogenic greenhouse gas (GHG) emissions. Global analyses of food systems indicate that livestock production is a major contributor to agricultural emissions and environmental impacts (Poore & Nemecek, 2018). One of the key indicators in environmental impact assessment is the carbon footprint (CF), which quantifies the total greenhouse gas emissions associated with a product or process and expresses them as carbon dioxide equivalents (CO e or CO eq). In dairy systems, these emissions arise from multiple sources including enteric fermentation, manure management, feed production, fertilizer use, energy consumption, and other external inputs (Stolarski et al., 2025).

The dairy sector is estimated to contribute approximately 4% of global greenhouse gas emissions, with reported carbon footprint values ranging from approximately 0.78 to 3.20 kg CO eq per kilogram of milk depending on production system characteristics and regional conditions (Flysjö et al., 2011; Stolarski et al., 2025). Accurate quantification of emissions from livestock systems is therefore essential for evaluating mitigation strategies, supporting policy development, and enabling consistent environmental reporting (IPCC, 2019).

Several methodological frameworks are currently used to estimate greenhouse gas emissions from dairy systems. The Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories define tiered methodologies (Tier 1, Tier 2 and Tier 3) that differ in complexity and data requirements for estimating emissions such as enteric methane

and manure management emissions (IPCC, 2019). In parallel, sector-specific standards such as the International Dairy Federation (IDF) Global Carbon Footprint Standard for the Dairy Sector provide guidance for applying life cycle assessment (LCA) principles to dairy supply chains, ensuring methodological consistency and comparability across production systems (International Dairy Federation, 2022).

Despite the availability of these methodological frameworks, practical tools for implementing them remain limited. Many existing LCA platforms are proprietary software requiring specialized training, while advisory services often rely on spreadsheet-based calculators that can be difficult to audit, reproduce, or integrate with statistical workflows. Methodological inconsistencies and lack of transparency in these tools can limit the comparability of results across farms, regions, and research studies (Pirlo, 2012).

The cowfootR package addresses these challenges by providing an open-source, fully scriptable implementation of dairy carbon footprint methodologies within the R ecosystem. The package implements emission calculations following IPCC and IDF frameworks using a modular structure that estimates emissions from five key sources: enteric fermentation, manure management, soil nitrogen dynamics, energy consumption, and purchased inputs. In addition to total emissions, cowfootR provides standardized intensity metrics (e.g., kg CO eq per kg of fat-protein corrected milk or per hectare), batch processing functions for multi-farm analyses, and flexible system boundary definitions. By enabling transparent, reproducible and programmable carbon footprint calculations, cowfootR facilitates the integration of dairy environmental assessments with modern data-science and research workflows.

Usage

With cowfootR, users can estimate emissions for dairy farms using a systematic, modular approach based on annual production and management data. Total emissions correspond to one accounting year, while intensity metrics are calculated per unit of product or per unit of managed area. The package follows a standard workflow: defining system boundaries, calculating emissions by source, aggregating total emissions, and computing intensity metrics.

Workflow

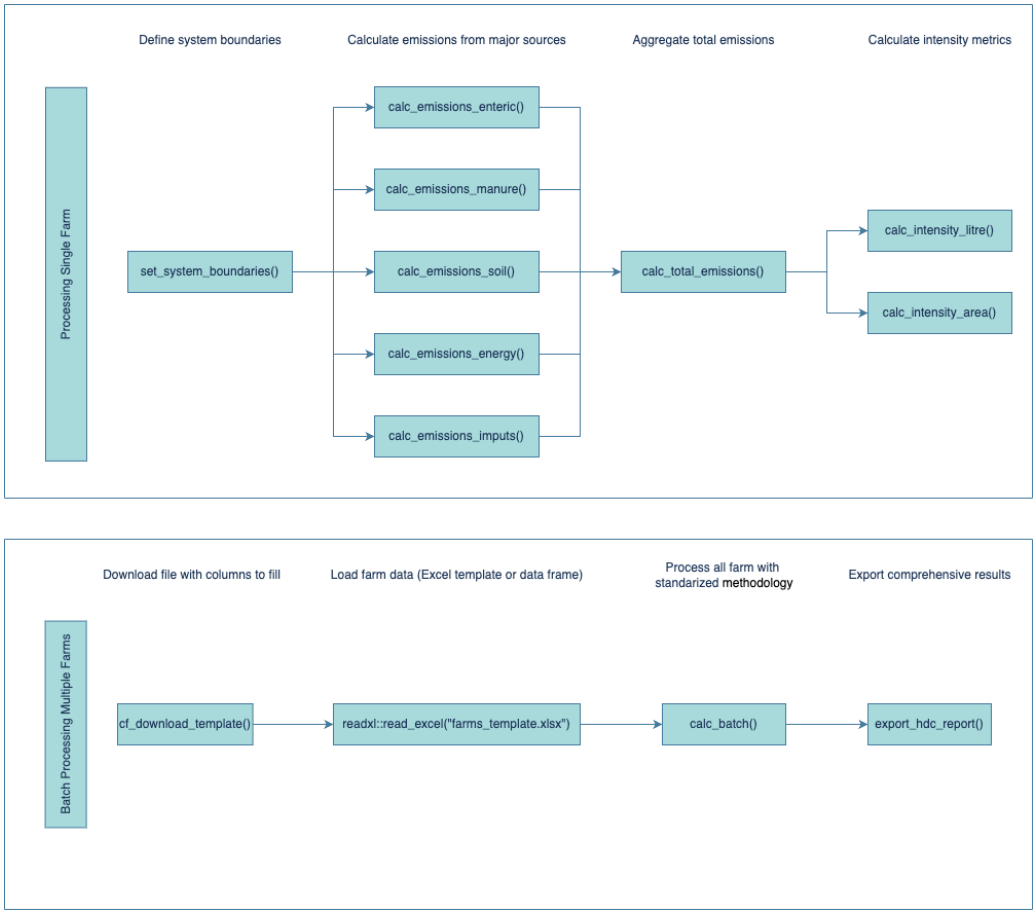

Figure 1: Workflow of the cowfootR package.

Availability

The cowfootR package is freely available on both CRAN and GitHub. Comprehensive documentation, including vignettes and reproducible examples, is provided to facilitate adoption and integration into research and sustainability assessment workflows. cowfootR package is available on GitHub (https://github.com/juanmarcosmoreno-arch/cowfootR). Documentation, including vignettes and examples, is provided to facilitate adoption.

Acknowledgements

The author would like to thank the Sustainability Team at CONAPROLE for their valuable input and collaboration in the development and validation of this software. Their expertise in dairy farm operations and environmental assessment has been instrumental in ensuring the practical applicability and accuracy of the cowfootR package.

References

Flysjö, A., Cederberg, C., Henriksson, M., & Ledgard, S. (2011). How does co-product handling affect the carbon footprint of milk? Case study of milk production in new

zealand and sweden. *International Journal of Life Cycle Assessment*, *16*, 420–430. https://doi.org/10.1007/s11367-011-0283-9

International Dairy Federation. (2022). *A common carbon footprint approach for the dairy sector: The IDF guide to standard lifecycle assessment methodology*. International Dairy Federation.

IPCC. (2019). *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories* (E. Calvo Buendia, K. Tanabe, A. Kranjc, J. Baasansuren, M. Fukuda, S. Ngarize, A. Osako, Y. Pyrozhenko, P. Shermanau, & S. Federici, Eds.). Intergovernmental Panel on Climate Change; IPCC.

Pirlo, G. (2012). Cradle-to-farmgate analysis of milk carbon footprint: A descriptive review. *Italian Journal of Animal Science*, *11*, 109–118. https://doi.org/10.4081/ijas.2012.e20

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Stolarski, M. J., Warmiński, K., Krzyżaniak, M., Olba-Zięty, E., & Dudziec, P. (2025). The carbon footprint of milk production on a farm. *Applied Sciences*, *15*, 8446. https://doi.org/10.3390/app15158446