Check for updates

Nutrient losses from global dairy production systems differ

The demand for dairy produce is growing alongside concerns about the impact of intensive dairying on water quality owing to nutrient loss. We found that nitrogen losses were greatest from all-grazed systems, but could be lowered by incorporating some housing.

The question

Increasing demand for dairy produce is accompanied by growing concerns about waste and the impact of dairying on water quality owing to annual nutrient (nitrogen and phosphorus) loss, with ranges of 5–200 kg nitrogen ha^{-1} and 0.5–10 kg phosphorus ha^{-1} (refs. [1,2]).

Some studies, and consumer marketing campaigns, have suggested that grazing systems perform better than confined systems by certain 'sustainability' metrics, including animal health and welfare, reduced labour demands, profitability, and nutrient losses to air and water[3,4]. These campaigns have been used to attract product premiums for grazed production[4], but little empirical data exist to support these claims from a nutrient loss perspective.

We aimed to determine whether differences in nutrient losses existed among three general types of dairy production systems that have developed around the globe based on varying durations of outdoor grazing: ≤2 months, 3–8 months, and ≥9 months, corresponding to confined, partially housed (hybrid), and grazed systems, respectively.

The observation

We contrasted global observational data ($n = 156$; Fig. 1) for losses of nitrogen and phosphorus from land to water among grazed, partially housed (hybrid) and confined systems. To support observational data, but avoid landscape-specific comparisons, we also modelled nitrogen and phosphorus losses in New Zealand, the United States and the Netherlands from the three systems using the same land area.

Observational nitrogen losses for confined systems were lowest on a productivity basis (g kg^{-1} fat and protein-corrected milk; FPCM) but not on an area basis. Grazed, hybrid, and confined systems lost 2.91 g kg^{-1} FPCM yr^{-1}, 2.70 g kg^{-1} FPCM yr^{-1}, and 0.94 g kg^{-1} FPCM yr^{-1}, respectively, but 35 kg ha^{-1} yr^{-1}, 31 kg ha^{-1} yr^{-1}, and 42 kg ha^{-1} yr^{-1}. Differences in nitrogen losses are largely driven by the duration and number of stock grazing pastures and the leaching of urinary-deposited nitrogen. No differences were noted for phosphorus losses among the systems. Variations in phosphorus losses are less obvious owing to the strong influence of spatially and temporally variable phosphorus loss processes such as soil sorption capacities, erosion and runoff.

Modelled nitrogen and phosphorus losses among systems generally behaved in a similar fashion to observed losses.

The implications

A link between nitrogen and phosphorus losses and nitrogen and phosphorus surpluses has been used to guide the Organisation for Economic Co-operation and Development and European Union water quality policy[5]. Our data support this link and the use of a nitrogen surplus in policy to reduce nitrogen losses; however, no such link was found for phosphorus. Based on first principles, a phosphorus surplus could evenly enrich soil phosphorus in a confined system owing to uniform manure spreading. However, the movement of livestock around grazed dairy systems means that farms with a high phosphorus surplus could have low phosphorus loss if animals are not grazed near streams or are grazed in a way to minimize soil erosion.

Based on observational and modelled data, the nutrient loss in systems when expressed on an area basis does not justify product premiums based on consumer perceptions of environmental claims. Moreover, on a productivity basis, we see evidence that nitrogen leaching losses are greatest from systems with ≥9 months of grazing, as milk production is generally lower.

Perhaps the best dairy system is the hybrid system that adopts partial housing during high-risk periods for nutrient loss. If used in winter and early spring, partial housing could provide improved animal welfare outcomes, and capture and store excreta before uniformly applying it to land when plants are growing, thus reducing the likelihood of nitrogen and phosphorus losses.

Although it is based on a combination of observational and modelled data, work to incorporate hybrid systems, rather than grazing or confined systems, has the greatest potential to reduce nutrient losses and improve water quality in regions where systems could change. However, before widespread shifts occur, systems must be tested locally, as the benefits may not accrue for all climates and landforms.

Rich McDowell
Lincoln University and AgResearch, Lincoln, New Zealand.

This is a summary of:
McDowell, R. W. et al. Limiting grazing periods combined with proper housing can reduce nutrient losses from dairy systems. *Nat. Food* https://doi.org/10.1038/s43016-022-00644-2 (2022).

Published online:
Published online: 12 December 2022

EXPERT OPINION

"As dairying is a very important economic sector among agriculture and its environmental effects are under heavy discussion, the study's conclusions will be of public interest and have a high impact for the development of more sustainable dairy systems — albeit each system has pros and cons." **Perttu Virkajärvi, Natural Resources Institute Finland (LUKE), Kuopio, Finland.**

FIGURE

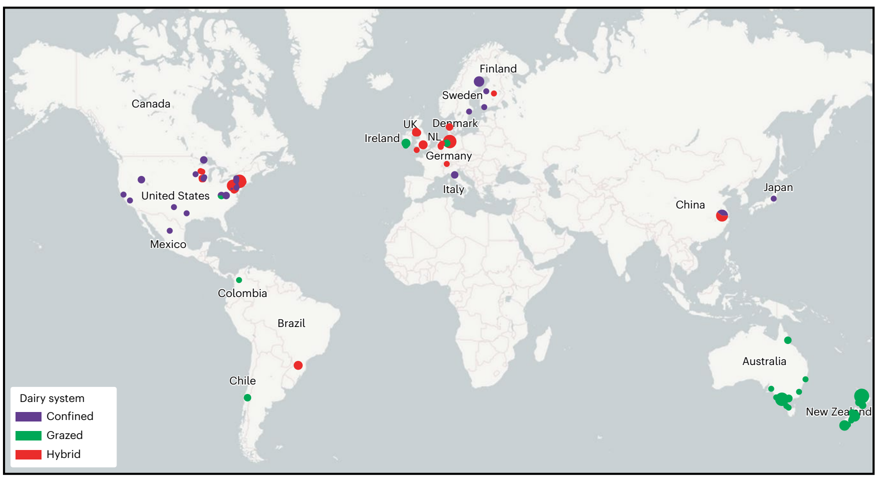

Fig. 1 | Location of the different dairy systems covered in the study. Observational data points used in the meta-analysis are indicated by coloured dots, including confined ($n = 32$), hybrid ($n = 49$) and grazed ($n = 75$) systems. Note that where data points are too close to be differentiated (<100 km), points are amalgamated, increasing the size of the mapped dots. The base map used data sourced from OpenStreetMap contributors available under an Open Database License (https://www.openstreetmap.org/copyright). © 2022, McDowell, R. W. et al., CC BY 4.0.

REFERENCES

1. Clark, M. et al. Estimating the environmental impacts of 57,000 food products. *Proc. Natl Acad. Sci. USA* **119**, e2120584119 (2022).
   An article highlighting the eutrophication risk associated with the production of different food products, including dairy.
2. McDowell, R. W. & Wilcock, R. J. Water quality and the effects of different pastoral animals. *NZ Vet. J.* **56**, 289–296 (2008).
   A review article summarizing contaminant losses from land to water from different livestock operations.
3. Gilker, R. E. & Weil, R. R. Inorganic nitrogen losses to groundwater are minimal from two management-intensive grazing farms in Maryland. *Renew. Agric. Food Syst.* **33**, 347–359 (2018).
   An article that measured lower nitrate losses to groundwater in grazed than in confined dairy systems.
4. Wong, J. et al. Consumer premiums for environmentally friendly grass-fed and organic milk in the Southeast. *J. Agribusiness* **28**, 75–88 (2010).
   An article outlining the magnitude and reasons behind consumer premiums for grass-fed milk.
5. Klages, S. et al. Nitrogen surplus—a unified indicator for water pollution in Europe?. *Water* **12**, 1197 (2020).
   An article outlining the case for using a nitrogen surplus to guide policy to improve water quality.

BEHIND THE PAPER

This research was developed from conversations with colleagues who were interested in comparing the greenhouse gas footprint of different dairy systems and those who were interested in global nutrient flows. My interest was sparked to combine and broaden the conversation to determine whether there was a system or systems that were likely to perform better than others. It is hoped that this study highlights the synergies or trade-offs for different dairy production systems and to guide which of those could be used to lower water quality impacts. This work was only possible through the support of colleagues overseas, and the academic freedom provided by our employers. **R.M.**

FROM THE EDITOR

"The topic is interesting and the modelling part of the study is well done (I worked with the Integrated Farm System Model (IFSM) in the past myself and I know it's a good, detailed model for this kind of assessment — especially for dairy systems)." **Juliana Gil, Senior Editor, *Nature Food*.**