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LIVESTOCK

The value of improving manure management

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Standfirst: Manure management and land application can improve soil health and nutrient recycling but can also be a major source of air pollutant emissions and regional eutrophication. A high-resolution, regional framework can now facilitate assessment of current and future manure management policies in a representative livestock-dense region of Europe.

The Flemish region of Belgium has a high concentration of livestock, and its farms often produce more manure than the surrounding lands can absorb. West-Vlaanderen, a region in Flanders, has the third-highest livestock density in the European Union (EU), and of the top three EU regions, it has been the only region to increase its livestock density since 2010.[1] The majority of the region's livestock are swine, accounting for 64% of total head, followed by 23% bovine and 13% poultry.[2] In Flanders, all swine are confined within barns and deposit manure through slatted floors into a pit below.[2] Storing this manure, which is typically more than 80% water by weight, creates anaerobic conditions, leading to significant emissions, primarily in the form of methane (CH_4).

Writing in Nature Food, Vingerhoets et al.[3] explore the societal cost tradeoffs of different manure management strategies by developing a high-resolution geospatial model of Flanders that optimizes manure management to minimize total societal costs while meeting policy requirements. The impact of nutrient pollution and air pollutant emissions from manure varies across fine spatial scales, so the model accounts for important local factors such as ecosystem sensitivity, proximity to water bodies, and human population density. The authors focused their analysis on three policy levers: an existing 170 kg N ha^{-1} manure application limit (EU Nitrates Directive), a recent amendment to the Directive that excludes refined manure-based fertilizers from the application limit (RENURE), and a hypothetical internalization of environmental and health externalities. The model meets policy and economic objectives by optimizing decision making for manure storage, transportation, processing (solid-liquid separation, nitrification-denitrification, and composting) and refinement to concentrated fertilizer products (NH_3 stripping to produce ammonium sulfate).

While the Directive and RENURE scenarios slightly reduced overall societal cost (private + external) relative to no legislation, their net impacts were modest (3-5% reduction) due to the large increase in private cost from additional manure processing and transport. The greatest societal cost reduction (28%) was achieved by combining these policies and including external costs within the objective function. With external costs considered, the model directs mitigation efforts toward the most vulnerable regions, resulting in external cost savings that far exceed the increase in private costs.

Developing an accurate representation of current practices can be challenging, particularly if manure management plans are not routinely aggregated into accessible, machine-readable datasets. Vingerhoets et al.[3] set a baseline using the EU Nitrates Directive scenario, which was implemented in 1991.[4] However, instead of drawing from an existing inventory of manure management practices across Flanders, the authors use their model to estimate current practices, assuming manure is stored and processed in ways that minimize cost while meeting policy requirements and technical constraints.[2,5] While this ensures fair cross-comparisons between the scenarios, their modeled results for current practices may not align with what is actually being done. Relying on reported data or at least comparing and validating these modeled results to reported real-world practices, would be a useful exercise for future studies.[2,5]

It is also critical that assumptions made about manure characteristics and management strategies reflect the modeled region as much as possible. For example, Vingerhoets et al.[3] do not distinguish between dairy and beef cattle manure, even though these manure streams are currently managed very differently in Flanders.[2] Additionally, excluding swine and cattle, all other livestock and poultry manure are aggregated into one category, and the authors assume that all manure (cattle, swine, and other) is available for processing. However, much of this manure is likely not practical to collect and process, especially in the case of cattle manure excreted in pastures.[6] Furthermore, anaerobic digestion, one of the primary CH_4 mitigation strategies for manure, was not included as a treatment option in the model, despite the existence of active projects in Flanders and a high potential for manure biogas production in the region.[2,6] While localized assessments of manure management have the potential to play a key role in shaping policy, their impact will largely be determined by the degree to which they are tailored to their specific region. Future work could build on the high-resolution, regional framework developed by Vingerhoets et al.[3] by comparing scenario results to a baseline that captures how manure is currently managed locally.

At a broader scale, the modeling framework developed by Vingerhoets et al.[3] is an improvement over other high-resolution regional manure management models, such as the Regional Manure Utilization Chain, which optimize private costs only.[7] As they demonstrate, external costs from manure management are substantial and can account for the majority of total societal cost within a particular region. Internalizing these externalities will likely play a key role in maximizing the net societal benefit of manure management policies. By accounting for environmental and health externalities, modelers can use the approach presented by Vingerhoets et al.[3] to evaluate the total societal cost of current and future policies – and design regional manure management plans that prioritize the most affected regions for tailored manure impact mitigation.

References

1. Eurostat. (2023). *Agri-Environmental Indicator - Livestock Patterns.* Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_
2. Belgian Interregional Environmental Agency. (2026). *Belgium's Greenhouse Gas Inventory (1990-2024).* Retrieved from https://climat.be/doc/nid2026-def.pdf
3. Vingerhoets, R., Spiller, M., Ravi, R., De Pue, D., Vlaerminck, S., Buysse, J., & Meers, E. (in press). Spatially optimized manure management and nutrient recovery can reduce societal costs in a European livestock production hotspot. *Nat Food*. https://doi.org/10.1038/s43016-026-01329-w
4. European Commission. (2026). Commission Directive Amending the Nitrates Directive as Regards the Use of Certain Fertilising Materials from Livestock Manure. Retrieved from https://environment.ec.europa.eu/publications/commission-directive-amending-nitrates-directive-regards-use-certain-fertilising-materials-livestock_en
5. Vlaams Coördinatiecentrum Mestverwerking. (2021). *VCM Survey Operational State of Affairs of Manure Processing in Flanders*. Retrieved from https://www.vcm-mestverwerking.be/en/manureprocessing/10302/state-of-affairs
6. Scarlat, N., Fahl, F., Dallemand, J., Monforti, F., & Motola, V. (2018). A spatial analysis of biogas potential from manure in Europe. *Renewable and Sustainable Energy Reviews* **94**, 915-930. https://doi.org/10.1016/j.rser.2018.06.035.
7. Li, J., Akdeniz, N., Kim, H., Gates, R., Wang, X., & Wang, K. (2021). Optimal manure utilization chain for distributed animal farms: Model development and a case study from Hangzhou, China. *Agricultural Systems*,**187**,102996. https://doi.org/10.1016/j.agsy.2020.102996.

Competing Interests

The authors declare no competing interests.

Figure 1. Credit: brytta / Getty Images Stock Photo