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U.S. Dairy Manure Management Literature Review

The Foundation for Food & Agriculture Research (FFAR) seeks a researcher to conduct a scientific literature review focused on manure management in U.S. dairy. The review will synthesize 1) the systems-level manure management research in the U.S., 2) the implications of innovations by manure management system on soil health and fertility, animal and human health, emissions, water quality, economic viability and socio-political factors and 3) a synthesis of identified research needs in sustainable manure management. The researcher will synthesize and build upon the rapidly developing manure management literature, the output of which FFAR and partners will use to help guide additional conversations and agenda setting in manure management in U.S. dairy.

FFAR Background

FFAR is a non-profit organization that builds public-private partnerships to fund audacious research addressing the biggest challenges in food and agriculture. FFAR is committed to providing every person access to affordable, nutritious food grown on thriving farms. The Foundation pioneers scientific and technological innovation by funding research that fills critical research gaps. Ultimately, FFAR's partnership and results benefit farmers, consumers and the environment. FFAR's scientific research programs are developed in partnership with industry, government, academia and non-profit institutions. FFAR is focused on catalyzing innovation to solve pressing food and agriculture challenges that affect the lives of all Americans. Leveraging public and private resources, FFAR increases the scientific and technological research, innovation and partnerships critical to enhancing sustainable production of nutritious food for a growing global population.

Science for Manure Management

Dairy products are rich in essential nutrients, and global demand continues to increase, due in part to population growth and changing dietary preferences. Dairy production necessarily involves the management of manure. In the U.S., manure management accounts for nearly

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10% of all anthropogenic methane emissions, with dairy manure management emissions accounting for nearly half of the total. Field measurements indicate that anaerobic lagoons are the largest source of manure methane, and corrals, solid manure piles and manure land application are significant sources of nitrous oxide. Moreover, land applied manure can contain pathogens, heavy metals and antibiotic-resistant bacteria, and emissions from manure applications have been linked to decreased human health in nearby communities.

FFAR, in consultation with partners, has identified a need and opportunity to advance pre-competitive research in manure management to support the U.S. dairy sector. As such, the planned research scoping effort aligns with the interest of several FFAR stakeholders and aims to inform the dairy sector's needs. This literature review will build from previous FFAR and stakeholder exploration of manure management in the U.S. dairy sector, and the final product may inform the design of a research program in manure management.

The objective of this short-term research agreement is to conduct a review of literature relevant to manure management, under the supervision of the Manure Management Advisory Council ("Advisory Council") and develop a white paper on the state of academic research relevant to this topic. The Advisory Council is a group of specialized experts formed to inform the design and implementation of the literature review and any associated outputs. For example, this work may be used to inform a future research program. We seek a scientist with expertise in manure management in the U.S. dairy sector and experience conducting research within U.S. farming communities, conducting literature reviews and familiarity with agricultural supply chains and stakeholder organizations.

Scope of Work and Deliverables

The primary task will involve evaluation of recent peer-reviewed literature and relevant reports and drafting of a white paper on critical research needs related to manure management in the U.S. dairy sector. The selected candidate will present and receive feedback on a mid-term deliverable of the literature review methods and preliminary findings to the Manure Management Advisory Council. The Advisory Council will review the final product and utilize the output to design an in-person research workshop to outline a new research agenda to advance manure management in U.S. dairy.

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I. Overview of Manure Management Systems

U.S. agriculture has become highly specialized, often with crops and animals grown on separate farms, with specialized crop and animal farms consolidating in certain areas of the country (MacDonald and McBride 2009). In this context, animal feeds can be imported from a great distance with few logistical or financial mechanisms to ensure the return of manure nutrients back to grow more feed. At the same time, some land-extensive dairy systems operate as integrated, circular systems in which manure nutrients from dairy cows are land-applied to grow forage and crops for the cows producing the manure (Dell et al. 2022).

The literature review will first synthesize research on prominent manure management systems in each region, including work on "manuresheds" (the lands geographically and economically connected to animal feeding operations where manure from the operations can be recycled to meet environmental, economic, and social goals) and recent Life Cycle Assessment (LCA) inventories. The white paper will address the scope of literature across geographic regions and production systems in the U.S. The systems-level research will include the following:

- Synthesis of how manure management regions are defined, including regional manuresheds,
- Outline the prevalence of given farm sizes (less than 1,000 milking, 1,000 – 3,000 milking, and 3,000+ milking) by region, and
- Outline of the prevalence of manure collection methods in each region by farm size (solid, semi-solid, liquid) along with common storage practices, treatment methods, and land application practices associated with each collection system.

II. Innovation Implications by Manure Management System

Next, for each of the manure management systems outlined above, the review will map manure management interventions (inclusive of technologies and management practices, such as application method) relative to their respective performances across the following parameters of soil health and fertility, animal and human health, emissions, water quality, economic viability and socio-political factors. Please note that we anticipate insufficient literature for some of the following parameters, resulting in the identification of a research gap.

- **Soil Health and Fertility** - Does a given intervention have a positive or negative impact on the soil by region (e.g., arid, semi-arid, humid and irrigated vs. dryland/rainfed systems)? Specifically:
    - *Suitability of NPK ratio* – To what degree is the NPK ratio of the manure product (e.g., raw manure, compost, biochar, anaerobic digestate, etc.)

suitable for growing crops (e.g., corn silage, alfalfa, wheat, etc.) that are relevant to the region? What additional practices would need to be done to meet the desired NPK ratios? What are the costs of these?
    - *Soil water holding capacity* – Does adding a given manure product increase water soil holding capacity in the soils within a region, given parameters such as soil type, average rain fall, timing of rain fall, and irrigation? In what way should this manure product be applied for best results?
    - *Soil carbon* – How does applying a given manure product to the soil affect carbon cycling and sequestration?
    - *Nutrient holding capacity* – Does a given manure product support the soil in keeping these nutrients available for plant uptake, or does it contribute to undesirable nutrient runoff events? In what way should this manure product be applied for best results?
    - *Microbial biodiversity* – Does a given manure product support microbial diversity that leads to crop health and climate resilience? In what way should this manure product be applied for best results?
- **Animal and Human Health** – Does a given intervention have a positive or negative impact on the animal and human health of the region in which the intervention is deployed? Specifically:
    - *Risks to animal health* – How does a given manure product affect animal health when used appropriately, and what management practices must be changed to achieve the best results? (For example, bedding with anaerobic digestate changes mastitis risk and risk of slips and falls. To bed with digestate, the farm manager must change mastitis prevention practices and make investments like re-grooving concrete, etc.).
    - *Risks to human health* – How does a given manure product affect human health when used appropriately as a fertilizer on certain food crops? What precautions must workers take to manage the creation and application of this product (e.g., polymer safety, enclosed spaces with little oxygen, risk of flammability or combustion)?
    - *Antibiotic resistance* – How does a given intervention affect the transmission of antibiotic resistance genes (e.g., do certain practices kill pathogenic bacteria that may carry antibiotic resistance?)? In what way should this intervention be performed for best results?
    - *Air quality and water quality* – How does a given intervention affect air and water quality for animals and humans? In what way should this intervention be performed for best results?

- **Emissions** – Is there respected literature that establishes the magnitude of the CO_2, CH_4, VOC, N_2O, and NH_3 emissions of a given manure management intervention, given geophysical characteristics of a region and advances in animal management (e.g., many manure emissions factors were established decades ago and only represent non-arid regions)? Specifically:
    - *In storage* – How much does a given manure management intervention emit while the raw materials and post-processed material are in storage? What best practices are required to achieve the best results in a given region? What are the tradeoffs among methane, ammonia and nitrous oxide?
    - *In-field* – How much does a given manure management intervention emit after the manure product is applied in the field? What best practices are required to achieve the best results? What are the tradeoffs among methane, ammonia and nitrous oxide?
- **Water Quality** – Does a given manure product support improved water quality? Specifically:
    - *Water impacts* – In what way should this manure product be applied for best results? How does a given manure product affect water quality in terms of excess nutrients, salts, antibiotics, and pathogens?
    - *Water and air quality tradeoffs* – What are the tradeoffs between air and water quality of given manure management intervention? What are the tradeoffs among methane, ammonia, and nitrous oxide?
- **Economic Viability** – Is there a business case for incorporating a given manure management intervention on a farm? Specifically:
    - *Capital and maintenance expenses* – What labor and materials are required on an ongoing basis to perform the manure management intervention? What equipment is required to process, store, transport and apply the product? What are these approximate costs in 2024 dollars?
    - *Profit Model* – How likely is it that a given manure product can be monetized? (For example, raw manure is difficult to monetize because its quality is unpredictable, it may contain weed seeds and pathogens, and the producer has limited storage capacity.) What prices can a producer expect to achieve for their manure product in 2024 dollars in their region? What activities must the producer engage in to realize this revenue (e.g., sell to coop, build a brand, carbon credits)? How does this compare to operating and capital expenses?
    - *Commercial readiness* – How established is the business and production model of this intervention? Is there a mobilized technical support for farmers

in choosing this intervention in their region? Is there a trained labor force to support its deployment on farm? Are consumables readily available (e.g., polymer shortages). Is there an end-of-life pathway for the equipment used?
    - *Market readiness* – To what degree is a market for a given manure product established? What is the range of willingness to pay for a given product in each region? Is a policy in place to enable this market? What is the commercial potential that is aggregated in the final product (e.g., willingness to pay more for a product produced with climate-smart practices)?
- **Socio-political Factors** – What are the social factors that influence manure management systems? Specifically:
    - *Adoption level* – In a given region, approximately how many farms use this intervention? What are the barriers to adoption? What factors are associated with the adoption of certain manure practices (e.g., the types of farms and farmers)?
    - *Policy* – How does the regulatory landscape across regions (e.g., state or federal laws impacting manure management) enable or hinder sustainable manure management?

The literature review output will be organized by manure management system (i.e., collection system by region and farm size) and outline the literature on prevalence, soil health and fertility, animal and human health, emissions, water quality, economic viability and socio-political factors.

III. Research Needs

Once the above literature is reviewed, the output should conclude with recommendations for sustainable manure management. These recommendations will consider the following:

- Identify knowledge gaps, unknowns, future research priorities to enhance soil health and fertility, animal and human health, emissions, water quality, economic viability and socio-political factors through sustainable manure management,
- Outline manure management specific findings and critical gaps and tradeoffs (e.g., water quality versus air quality), especially noting convergent and divergent findings across the literature,
- Synthesis of how manure management systems are telecoupled via dairy supply chains (e.g., Spiegal, Williamson, et al., 2022), and
- Outline enabling factors or barriers to adoption of high potential innovations.

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The literature review should assess published literature and literature syntheses about the topics listed above and identify areas of research community consensus (or lack thereof) on key conclusions and future research needs. We are seeking a clear framing of recent research that will help guide future conversations and agenda setting in sustainable manure management in U.S. dairy.

Project Timeline

This is anticipated to be a 6-month part-time contract, with a mid-term deliverable due for review by the Advisory Council by the end of February 2025 and the main deliverable due May 2025. The work will be conducted remotely and include regular video calls with the Manure Management Advisory Council. The work will include travel to a manure management research convening in June 2025.

Proposals

Applicants should submit a written proposal to develop the literature review. Proposals should contain:

- Applicant profile, including qualifications and experience with similar efforts,
- Approach description, including intended methodology for the literature review,
- Anticipated outputs and approximate timeline for producing documents, including high level outline of the final output, and
- Other items or information that may assist us in evaluating the proposal (e.g., letters of recommendation or sample reports).

Proposals will be evaluated by the Manure Management Advisory Council and will be ranked in accordance with the following criteria:

- Completeness and quality of response,
- Ability to meet requested service needs,
- Experience with literature reviews and scientific writing, and
- Hourly cost and proposed level of effort.

The final award will be based on the best overall value when taking into consideration the competence in scientific writing.

Proposals will be accepted and reviewed on a rolling basis. The position is open until filled. Proposals should be developed in Microsoft Word or PowerPoint and should be submitted in PDF form. Direct proposals and inquiries to Jasmine Bruno at jbruno@foundationfar.org.

FFAR will negotiate contract terms upon selection. All contracts are subject to internal FFAR review. An individual or university/institution will be awarded the work upon signing of a contract, which will outline the terms, scope, budget and other necessary items.

References

Dell, C.J., Baker, J.M., Spiegal, S., Porter, S.A., Leytem, A.B., Flynn, K.C., Rotz, C.A., Bjorneberg, D.L., Bryant, R.B., Hagevoort, G.R., 2022. Challenges and opportunities for manureshed management across US dairy systems: Case studies from four regions. Journal of Environmental Quality 51, 521–539.

Saha, G.K., Cibin, R., Elliott, H., Gall, H., Shortle, J., Alber, D., 2018. Geospatial Landscape Analysis for Livestock Manure Management in Western Pennsylvania. ASAABE Paper No. 1801218. Presented at the 2018 ASABE Annual International Meeting, American Society of Agricultural and Biological Engineers, St. Joseph, Michigan.

Spiegal, S., Kleinman, P.J., Endale, D.M., Bryant, R.B., Dell, C., Goslee, S., Meinen, R.J., Flynn, C., Baker, J., Browning, D., McCarty, G., Bittman, S., Carter, J., Cavigelli, M., Duncan, E., Gowda, P., Li, X., Ponce-Campos, G.E., Raj, C., Silveira, M., Smith, D.R., Arthur, D.K., Yang, Q., 2020. Manuresheds: Advancing nutrient recycling in US agriculture. Agricultural Systems 182, 102813.

Spiegal, S., Vendramini, J.M.B., Bittman, S., Silveira, M.L., Gifford, C., Rotz, C.A., Ragosta, J.P., Kleinman, P.J.A., 2022. Recycling nutrients in the beef supply chain through circular manuresheds: Data to assess tradeoffs. Journal of Environmental Quality 51, 494–509.