policy brief

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Greenhouse Gas Mitigation Opportunities for Livestock Management in the United States

Based on a report by Shawn Archibeque, Karen Haugen-Kozyra, Kristen Johnson, Ermias Kebreab, Wendy Powers-Schilling, Lydia Olander,[1] and Abigail Van de Bogert

This work synthesizes and communicates foundational information for designing greenhouse gas mitigation and reporting programs for livestock systems in the United States, in particular for reductions in enteric and manure methane emissions.

Key Points

- Livestock contribute significantly to agricultural emissions in the U.S., primarily from associated land management, enteric fermentation (methane from the animal), and manure management.
- Beef, dairy, and swine production systems are by far the largest contributors to U.S. livestock emissions.
- Livestock populations and production have held relatively steady over the last decade, suggesting that changes to the management of existing systems may be more cost-effective than whole-scale shifts in production systems and infrastructure.
- Manure management may yield a greater GHG reduction at source, but enteric emissions reductions, taken across a large segment of the beef and dairy population, can create a larger overall impact on GHG emissions.
- For swine, manure management strategies are most promising. Reducing the amount of time that manure is stored in a pit and using anaerobic digestion are both likely ready for implementation where cost-effective.
- A number of programs are in development to reduce GHG emissions from livestock systems in the U.S.; some are developing offset protocols for projects, while others are focused on production systems and are conducting life-cycle assessments for certification or supply chain initiatives.

Changes in livestock management can benefit air and water quality and help to slow global climate change.[2] Several efforts are under way to create incentives for greenhouse gas (GHG) mitigation from the agricultural sector. For example, the U.S. Department of Agriculture encourages management practices that reduce GHG emissions in several of its incentive and extension programs. The state of California is launching a carbon offsets market under which agriculture may be a significant supplier. And supply chain and certification programs for agricultural products associated with corporate sustainability initiatives are also exploring opportunities for GHG reductions from the agricultural sector.

Although livestock management is a small contributor to overall GHG emissions in the United States, it is a significant contributor to the total emissions from agriculture, making up more than half of such emissions in the United States.[3] Most of livestock's direct impact on global climate comes in the form of methane (CH_4). Because methane is roughly 20 times more potent than carbon dioxide (CO_2), small reductions can have significant effects on overall emissions. Recent analysis suggests that reductions in methane and black carbon together can greatly reduce predicted near-term temperature increases and climate change impacts, potentially keeping global temperatures below the well-known 2°C threshold in the near term.[4]

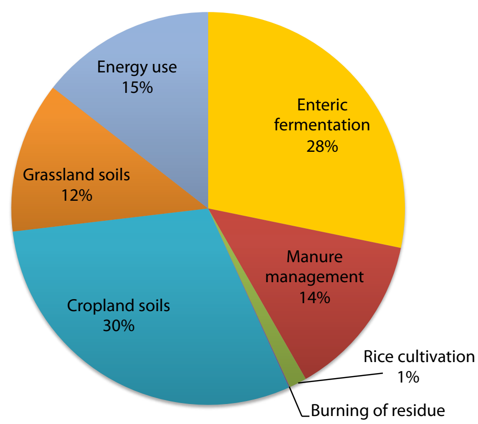

Figure 1. Gross agricultural GHG emissions, 2009. *Note*: Land use change and liming of soils are not included. *Sources*: EPA, 2011 (note 3); USDA, 2011 (note 9).

As shown in figure 1, livestock contributes around half of all agricultural emissions in the United States. Of this, enteric fermentation, which releases methane from animal digestion, is the largest contributor from livestock, followed by emissions from manure and grazing

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2. P. Smith et al., "Agriculture," in *Climate Change 2007: Mitigation; Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. B. Metz et al. (Cambridge: Cambridge University Press, 2007); B.A. McCarl and U.S. Schneider, "Greenhouse Gas Mitigation in U.S. Agriculture and Forestry," *Science* 294, no. 5551 (2001): 2481–2482; D. Shindell et al., "Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security," *Science* 335, no. 6065 (2012): 183–189; C. Hellwinckel and J. Phillips, "Land Use Carbon Implications of a Reduction in Ethanol Production and an Increase in Well-Managed Pastures," *Carbon Management* 3, no. 1 (2012): 27–38.
3. U.S. Environmental Protection Agency (EPA), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2009* (Washington, D.C.: U.S. EPA, 2011).
4. Shindell et al., "Simultaneously Mitigating."

lands.[5] Within the United States in 2010, enteric fermentation from livestock contributed 141.3 teragrams of carbon dioxide equivalent (Tg CO_2e), accounting for 70% of the annual methane emissions associated with agricultural production systems; this is equivalent to 21% of all U.S. anthropogenic methane emissions.[6] Methane emissions from livestock manure management in 2010 contributed 52 Tg CO_2e, or 8% of the total. Emissions from livestock manure in the United States have increased by roughly 56% since 1990 (fig. 2), mainly as a result of the increasing use of liquid manure management systems, which have higher methane emissions than other management methods.[7]

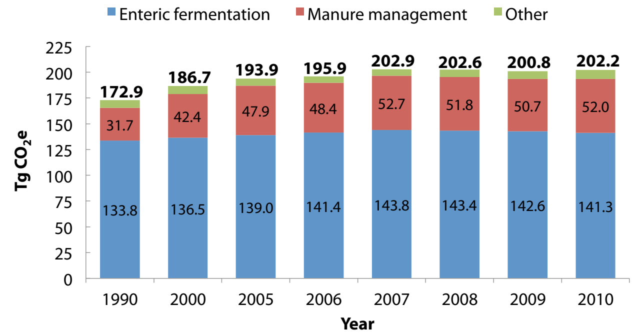

Figure 2. Sources of methane emissions from U.S. agriculture. *Source*: U.S. EPA, 2012 (note 6).

Beef, dairy, and swine systems are the largest contributors to livestock-related greenhouse gas emissions in the United States (fig. 3).[8] Livestock populations and production have held relatively steady over the last decade;[9] thus, implementing changes to the management of existing systems may be more cost-effective than trying to effect whole-scale shifts in production systems and infrastructure. Opportunities to reduce methane emissions through changes in feed and manure management are significant, as is the potential for smaller reductions in other GHGs, including carbon dioxide (CO_2) and nitrous oxide (N_2O). Each livestock production system is different, and no single management change will work for every operation. However, resources identifying a suite of economically sustainable options and the impact of adoption will allow producers to identify those practices that can fit their system.

For beef and dairy cattle, a number of mitigation strategies can improve productivity by reducing methane emissions per unit of product. Improved diet and genetics can help these animals use feed more efficiently and reach maturity more quickly. Other strategies focus on reducing enteric emissions through feed additives such as ionophores and organic acids. Although limited in scale, improved pasture management holds promise for reducing methane emissions and is well enough understood to be implemented now. Other strategies need additional research; most are expected to have moderate to low mitigation potential.

For beef and dairy cattle, the most promising manure management strategies include aeration, compaction, composting, and the shift from liquid to solid systems. Aeration and shifting from liquid to solid systems are likely to be expensive. The mitigation potential and financial viability of these strategies require further research. The most well-studied high-potential activity is use of a digester for methane capture and flaring or combustion to produce energy. This activity is already incorporated in many carbon offsets programs and renewable energy programs. However, the capital, operation, and maintenance costs of changing manure handling systems can present a significant hurdle. Overcoming it could require external investment and changes in energy sector policy and business models.

Feeding strategies for swine, with the possible exception of reducing dietary protein, do not appear as promising. However, many manure management strategies do. These strategies include increasing manure removal frequency, separating solids and liquids, optimizing bedding materials for dry manure management, covering manure storage, and composting. The mitigation potential and financial viability of these strategies should be further researched.

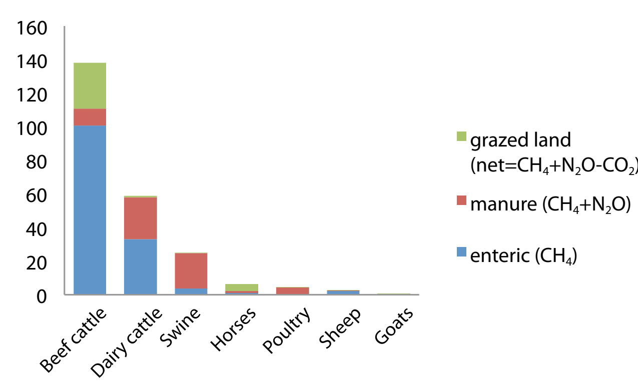

Figure 3. Greenhouse gas emissions by livestock source in 2008. *Source*: USDA, 2011 (note 9).

5. U.S. EPA, 2011.
6. U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010* (Washington, D.C.: U.S. EPA, 2012).
7. U.S. EPA, 2011.
8. Ibid.
9. U.S. EPA, 2011; U.S. Department of Agriculture (USDA): *U.S. Beef and Cattle Industry: Background Statistics and Information* (Washington, D.C.: USDA, 2011).

Covering manure may have only moderate costs, and composting could generate money through production of a value-added fertilizer for off-site marketing. Anaerobic digestion, although costly, also has a high mitigation potential and is ready for use in programs similar to those developed for dairy cattle manure digesters.

Tables 1 and 2 provide a qualitative summary and a comparison of the reviewed mitigation practices. The action category indicates whether the management action

- is *ready* for integration into programs and protocols as a mitigation practice and is of *high* or *moderate priority*, given its potential;
- is likely to have significant mitigation potential but is supported by little research, making it a *research priority*;
- appears to have low mitigation potential or significant implementation barriers and thus is a *low priority* for research or action; or
- is supported by too little research to make a recommendation and is therefore *uncertain*.

Table 1. Summary of beef and dairy mitigation practices, based on the opinions of expert authors.

	Mitigation potential	Amount of research	Expert confidence	Potential expense	Action category
Grazing systems changes					
Change from traditional pasture grazing to managed pasture	Some soil C benefits and efficiency of animal production	Low	Moderate	Moderate	Ready; high priority
Change from traditional pasture grazing to intensive feedlot system	Will likely produce ~50% reduction in enteric CH_4, but more research needed on leakage issues	Significant	Significant	Significant	Research priority
Feeding strategies					
Lipid supplements	Unclear	Moderate	Significant	Low	Research priority
Intake modification/measurement in association with reduced CH_4 production	Unclear	Low	Low	Unknown	Research priority
Ionophores	10% to 25% reduction in CH_4, but duration may be limited*	Significant	Significant	Low	Research priority
Halogenated compounds	Low	Low	Moderate	Very high	Low priority
Plant compounds	Unclear	Low	Low	High at effective doses	Research priority
Probiotics and organic acids	Unclear	Low	Low	High at effective doses	Research priority
Vaccination	Unclear	Low	Low	High	Low priority
Improved genetics	Unclear	Moderate	Low	High (long term investment 10–20 years)	Research priority
Manure management					
Manure cooling of 10°C	Unknown	Low	Low	High	Low priority
Altering manure pH	Unknown	Low	Low	High	Low priority
Compaction	Theoretically high, but little data	Low	Moderate	Low	Research priority
Frequent spreading	Unknown	Low	Low	Low	Research priority
Methane use for energy – methane digesters	High	Moderate	High	Very high	Ready; high priority and research priority
Manure aeration	High	Moderate	Moderate	High	Research priority

* Less is known about the potential to "cycle" the ionophore (e.g., 6 weeks on, 6 weeks off).

Table 2. Summary of swine mitigation practices, based on the opinions of expert authors.

	Mitigation potential	Amount of research	Expert confidence	Potential expense	Action category
Feeding strategies					
Lower protein diet	10% reduction in protein ~ 10% reduction in CH_4; and potential to lower N_2O not studied	Little	Low	Low	Research priority
Feed ingredients	Unclear	Little	Low	Low	Uncertain
Oil additives	Unclear	Little	Low	Low	Uncertain
Manure management					
Reduced time in pit	30% reduction in CH_4; but often limited by when can move manure	Moderate		Uncertain	Ready; moderate priority
Floor openness	Unclear	Little	Low	High	Low priority
Solid-liquid separation	Unclear	Little	Low	High	Research priority
Solid manure storage	Unclear	Little	Low	Significant	Uncertain
Bedding materials	N_2O uncertain; CH_4 30%	Little	Low	Uncertain	Research priority
Lower temperature and better ventilation	10–20°C drop ~ 20%–60% for CH_4; unclear for N_2O; increase CO_2 from energy need	Moderate	Moderate	High	Uncertain
Covering manure storage	Can be significant depending on cover type, ranges from 88% reduction to an increase	Moderate but all with different cover types	Moderate	Moderate	Research priority
Composting	Significant but variable	Moderate	Moderate	Potential profit	Research priority
Anaerobic digestion	Significant	High	High	High	Ready; high priority

All of these management practices need further study and a comparison of costs. Emissions reductions from manure methane capture systems can be measured directly, but quantifying emissions reductions from other livestock systems will likely require the use of various modeling approaches. A wide range of models are being tested and used for national inventory quantification concurrently with the development of a number of farm-scale accounting tools for carbon offsets programs and corporate supply chain life-cycle assessment (LCA) tools. These models and system-level tools can be helpful in ensuring that management changes do not inadvertently increase one greenhouse while reducing another.

Accounting approaches for tracking GHG emissions from livestock are also in development. Carbon offset protocols are designed to track changes in emissions resulting from a specific project (or management change). Many livestock-related offset protocols have been approved or are in development (table 3). LCAs, on the other hand, are used to assess changes in a production system or supply chain for a product; they indicate emissions hot spots and facilitate emissions comparisons across supply chains, products, and time. As yet, LCA methods have little consistency across applications.

Table 3. Livestock protocols developed by program and registries.

Protocol/initiative	Emissions scope	Status
Alberta Offset System* Dairy Cattle Emissions Reduction	Enteric CH_4, manure CH_4, N_2O	Approved
Innovative Feeding of Swine and Storing and Spreading of Swine Manure	Manure CH_4 and soils N_2O	Approved
Beef Feeding – Edible Oils	Enteric CH_4	Approved
Beef Reduced Days on Feed Beef Reducing Age to Harvest Selecting for Low Residual Feed Intake in Beef	All 3 protocols: enteric CH_4, manure CH_4, N_2O	Approved Approved Pending
Modification of Alberta Offset System Livestock GHG protocols for U.S.	Enteric CH_4, manure CH_4, N_2O	In development (ACR)
Development of a Modular Methodology for Quantification and Measurement of GHG Emission Reductions from Ruminant Livestock Production	Enteric CH_4, manure CH_4, N_2O	In development (ACR)
Soil Carbon Sequestration through Rangeland Management	CO_2, CH_4, N_2O	In development by Environmental Defense Fund, UC Berkeley, and other organizations

* See www.carbonoffsetsolutions.ca.

In summary, livestock management has a few well-researched and ready-for-action opportunities for making measurable and substantial methane reductions. These more established opportunities, such as anaerobic digesters, tend to be costly. The mitigation potential and financial viability of many other potentially significant management opportunities require further research and pilots before widespread implementation.

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