Opportunities for reducing greenhouse gas emissions through livestock waste management in Florida

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Management of livestock wastes can affect greenhouse gas emissions through attenuating both methane and nitrous oxide emissions, as well as by displacing carbon dioxide emissions from fossil fuel use that can be avoided through biogas production and use. Methane is naturally produced from the anaerobic decomposition of livestock manure and is a potent greenhouse gas with 21 times the greenhouse warming potential of CO_2, on a mass ratio basis (U.S. EPA 2007). Nitrous oxide is naturally produced as a result of the nitrogen cycle where organic nitrogen in manure and urine undergoes nitrification and denitrification. Nitrous oxide is an even more potent greenhouse gas, with a greenhouse warming potential 310 times that of CO_2 on a mass ratio basis (U.S. EPA 2007). Unfortunately, estimates for N_2O emissions are uncertain and methods to reduce these emissions are not well developed. In contrast, methods for reducing CH_4 emissions have received more attention. Anaerobic digestion in a closed vessel allows microbial degradation of manure to biogas containing CH_4. Biogas can be used as a renewable fuel to displace fossil fuel consumption, which not only lessens CH_4 emissions from manure management but also lowers fossil CO_2 emissions.

Methane emissions from livestock include enteric emissions and manure management emissions (IPCC 1996). Enteric emissions of CH_4 occur principally from the ruminant activity in cows (dairy and beef) and are a function of feed quality and intake. Other than reducing cow numbers, there is little opportunity to reduce enteric CH_4 emissions. In contrast, CH_4 emissions from livestock manure management are impacted by chosen management options. EPA (2007) estimates that manure management contributed 41.3 Tg of CO_2eq from CH_4 emissions and 9.5 Tg of CO_2eq from N_2O emissions to the U.S. greenhouse gas emissions inventory in 2005. Liquid handling of manure and long-term manure storage increase CH_4 emissions. Dry handling systems, dry storage, and short-term storage lower CH_4 emissions. Anaerobic digestion of manure with biogas capture can result in lower CH_4 emissions, yet some leakage of biogas (estimated to average 1%) prevents complete elimination of CH_4 emissions from livestock manure management.

IPCC (1996) has developed methods for estimating greenhouse gas emissions from livestock manure management that account for climate, animal type, regional development, and management practices. Generally, the number of animals, the average manure volatile solids (VS) production, and the maximum methane yield (Bo) of the VS are combined with an emission factor to estimate methane emissions. Emission factors have been developed based on both scientific studies and measurements, as well as through model development and calculations. The emission factors vary with region, climate, animal type, and manure handling, thus adding a level of uncertainty to greenhouse gas emissions estimates. For cattle, IPCC (1996) has developed both Tier 1 methods (simple) and Tier 2 methods (more complicated) for estimating emissions.

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Emissions from Florida manure management

Livestock production in Florida includes both confined animal operations and pastured animals. The increase in production and concentration of intensive livestock operations along with increased urbanization of rural regions has resulted in greater awareness and concern for the proper storage, treatment, and utilization of livestock manure. Pastured animals offer limited opportunity for managing livestock manure to lessen greenhouse gas emissions. The principal opportunities for altering manure management, therefore, occur in dairy and poultry operations with confined livestock.

Most dairies in Florida use hydraulic flushing for manure collection and short-term storage in manure pits, followed by frequent land-application of liquids onto croplands. The temperate weather conditions and long growing season eliminate the need for long-term manure storage caused by frozen ground or lack of a standing crop. For temperate regions with liquid manure handling and short-term storage, IPCC (1996) suggests a CH_4 emission factor (Tier 1) for dairy cows of 54 kg head^{-1} yr^{-1}.

For poultry in Florida, manure is handled using dry manure management methods. In the broiler industry, sawdust bedding is usually added to the barns and several flocks of broilers may be raised before the manure is removed and stockpiled, at least annually. In poultry layer production, manure is collected under cages in deep pits with annual removal, collected on bedding or scraped from the barn daily. The amount of time that poultry manure is stockpiled prior to application onto croplands is variable. The University of Florida Institute of Food and Agricultural Sciences (Jacob and Mather 2004) estimates that annual litter production from producing 140 million broilers amounts to 1 million tons of used litter (manure and bedding). For temperate regions with dry manure handling and stockpiling, IPCC (1996) suggests a CH_4 emission factor for poultry of 0.117 kg bird^{-1} yr^{-1}.

Table 9 gives the CH_4 emission estimates for confined dairy and poultry production with their CO_2 equivalent global warming potential. It appears that greenhouse emissions from broilers are more than twice that of dairy cows, while the layer population produces about one-sixth of the emissions of dairy operations.

Table 9. Estimated methane emissions from manure management of confined animal populations in Florida

Animal Type	Number of Animals[1]	CH_4 Emission Factors[2] kg animal^{-1} yr^{-1}	CH_4 Emissions Gg yr^{-1}	CO_2 Equivalent Tg CO_2 yr^{-1}
Dairy cows	135,000	54	7.29	0.153
Poultry layers	10,700,000	0.117	1.25	0.026
Poultry broilers	139,800,000	0.117	16.36	0.343
Total			**24.90**	**0.523**

[1] NASS (2005), [2] IPCC (1996).

Biogas potential from confined livestock manure in Florida

The production and use of biogas from livestock manure offers an opportunity for reducing CH_4 emissions from manure management as well as avoiding greenhouse gas emissions from fossil fuels that are displaced through biogas use. When biogas is combusted, like fossil fuels, it produces CO_2. However, the carbon in this CO_2 originated from atmospheric CO_2 that was recently fixed into plant matter. Biogas production and use, therefore, repre-

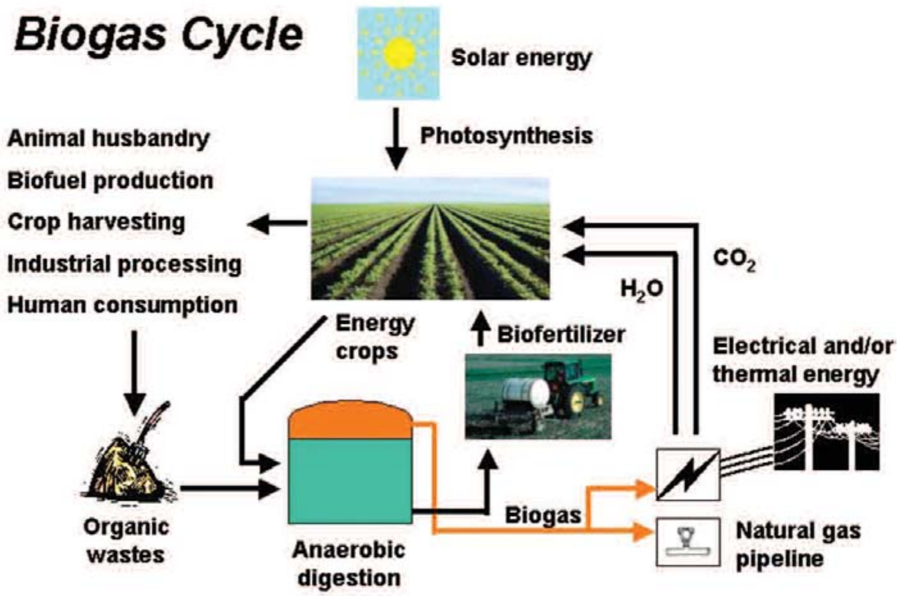

Figure 12. The biogas cycle.

sents a closed renewable carbon cycle that does not contribute to increased greenhouse gas emissions (Figure 12). In effect, anaerobic digestion is a carbon dioxide neutral process. Local biogas production and use also reduces emissions associated with transporting fossil fuels from distant sources.

The production of biogas from animal manure is not a novel application of anaerobic digestion and many successful biogas facilities are in place at swine and dairy operations throughout the U.S. (AgSTAR 2007). Generally, manure collected from animal housing is diluted to a slurry and pumped into an enclosed heated vessel where a mixed culture of anaerobic microorganisms consume the degradable fraction of the manure and convert it to biogas, a mixture consisting principally of CH_4 and CO_2. On average, the manure is retained in the vessel for 15 to 30 days. The biogas is conveyed from the vessel and can be used in place of natural gas. Often, the biogas is used to provide hot water for on-site use and generate electricity for sale, though the methane in biogas can be used for any natural gas application. In addition, the process is effective for conserving plant nutrients, reducing manure odor, and lowering pathogen levels (Wilkie 2005). The effluent from the digester retains soluble plant nutrients and an inert fiber residue, both of which have positive agronomic properties. Digester effluent can be recycled to cropland as nutrient-rich biofertilizer, reducing the demand for synthetic fertilizers that are produced using less sustainable methods with significant CO_2 emissions. Also, digester effluent could be used to grow algae for biodiesel production, providing another renewable fuel for on-farm use to displace fossil fuels and further reduce greenhouse emissions from livestock operations.

The production of biogas from confined animal operations in Florida provides opportunities as well as challenges. First, the use of flush water at Florida dairies greatly exceeds water use in less temperate climates and results in large volumes of dilute wastewater. Most of the applications of anaerobic digestion have been at dairies with dry scraped manure handling where there is controlled addition of dilution water. Conventional digesters are not suitable for very dilute manure wastewaters and the cost of heating the wastewater can exceed the biogas potential in the waste. Fortunately, recent developments in digester technology have extended the application of anaerobic digestion to such dilute wastewaters. An ambient temperature fixed-film digester (Figure 13), designed specifically for Florida conditions, has been demonstrated for treatment of the liquid fraction of flushed dairy manure (Wilkie 2003).

In contrast to dairy manure, manure from confined poultry operations is quite dry and cannot be pumped without significant water addition. Broiler manure contains significant quantities of bedding and application of biogas production using broiler litter has not

Figure 13. Fixed-film anaerobic digester.

been demonstrated at commercial scale. Layer manure conversion to biogas has been demonstrated commercially on a limited basis. The high level of ammonia and the requirements for dilution water offer challenges to poultry manure digestion. In spite of limited full-scale demonstrations, poultry manure has a high biogas potential and merits consideration as a renewable resource for biogas production.

Table 10 gives the estimated methane production potential from anaerobic digestion of dairy and poultry manure in Florida. Table 10 also gives an estimate for the amount of fossil CO_2 that could be avoided if the methane was used to replace natural gas consumption. It is apparent that the amount of fossil CO_2 emissions avoided by production and use of biogas is comparable to the manure management CH_4 emissions (on a CO_2eq basis) and in the case of layers it is actually greater. The conversion of manure to biogas mitigates GHGs by reducing fugitive methane emissions and fossil CO_2 emissions.

Table 10. Estimated methane production potential from biogasification of manure from confined animal populations in Florida and the resulting reduction in fossil CO_2 emissions

Animal Type	Number of Animals[1]	CH_4 Production Factors[2] m^3 $animal^{-1}$ yr^{-1}	CH_4 Production million m^3 yr^{-1}	CO_2 Displaced[3] Tg CO_2 yr^{-1}
Dairy cows	135,000	440	59.40	0.117
Poultry layers	10,700,000	1.48	15.84	0.031
Poultry broilers	139,800,000	1.05	146.79	0.288
Total			**222.03**	**0.436**

[1] NASS (2005). [2] Estimated from ASAE (2005). [3] Assumes biogas displaces natural gas.

Revenue from biogas and carbon credits

On-farm biogas production in Florida has been limited by low energy costs, the cost of capital, the uncertainty of animal production, and lack of public awareness. These factors are rapidly changing and opportunities exist to implement biogas production from manure. Still, the value of fertilizer and soil-amendment by-products are low and cash flow to cover investments must come principally from the sale (or savings) of energy. A further opportunity for income occurs in the sale of carbon credits (AgCert 2007; ECC 2007), where companies purchase greenhouse gas reductions to compensate for their own emissions. The trading of carbon credits is an emerging global market and provides an opportunity to improve the economics of biogas projects. Economies of scale could also be realized with centralized digesters in areas with a large concentration of livestock operations.

Table 11 . Estimated value of carbon credits and methane production from biogasification of confined livestock manure in Florida

Animal Type	Sum of GHG reductions Tg CO2 yr-1	CH_4 Production million m^3 yr^{-1}	Value of Carbon Credits[1] \$ yr^{-1}	Value of CH_4 [2] \$ yr^{-1}
Dairy cows	0.270	59.40	$1,079,074	$16,779,312
Poultry layers	0.057	15.84	$229,585	$4,473,353
Poultry broilers	0.632	146.79	$2,527,304	$41,465,239
Total	0.959	222.03	$3,835,964	$62,717,904

[1] *Based on a value of \$4 Mg^{-1} CO_2eq.* [2] *Based on \$8 per 1000 cft of natural gas (EIA, 2007).*

Table 11 shows the estimated value of carbon credits and methane produced from biogasification of confined livestock manure. The sum of greenhouse gas (GHG) reductions is the sum of the CH_4 emissions from manure management avoided (on a CO_2eq basis) from Table 9 and the displaced CO_2 emissions from biogas use in Table 10. The carbon credit, at a value of \$4 Mg^{-1} CO_2, adds about 5% to the revenue projection of biogas sales (as natural gas). The value of carbon credits is expected to rise and the cost of energy is expected to increase, improving the potential revenue stream for biogas production.

Co-digestion and integrated biorefineries

Combining wastes from animal manure with other regionally available wastes and feedstocks is called co-digestion. Co-digestion offers opportunities for on-farm biogas facilities to increase revenues from tipping fees (fees charged for accepting waste products) as well as from the enhanced production of biogas. Food and yard wastes from surrounding communities and commercial establishments are suitable for co-digestion. Co-digestion can also help improve the waste characteristics by changing the moisture or nutrient content of the waste to beneficial levels.

By-products from ethanol and biodiesel production can also be used in co-digestion (Wilkie 2006). Florida is unlikely to have significant ethanol production from corn, while cellulosic ethanol production will not be able to capitalize on a feed market from non-grain by-products. Condensed solubles from stillage evaporation and spent yeast at cellulosic ethanol plants could be transported to biogas plants for co-digestion. Biodiesel production results in crude glycerol and spent washwater by-products that have high biogas yields and are suitable for co-digestion.

Another opportunity for biogas production from confined animal manure occurs in the context of integrated biorefineries where animal production is located close to ethanol or bio-diesel production facilities. Feed from ethanol byproducts can be used in animal production with minimal drying and storage, while biogas from manure and spent yeast can power the ethanol plant. Spent oilseed cake from biodiesel production can be used in animal feed rations, with manure, crude glycerol, and spent washwater used for biogas production. Excess biogas can be sold as fuel or electricity. The synergies from integrating animal production with biorefineries can offer savings in energy conservation and improved efficiencies to lower feed and energy costs.

Biogas from other wastes and biomass

Manure is by no means the only suitable feedstock for biogas production. Wastes from food processing can also be used as a renewable feedstock. Waste from meat production, dairy processing, breweries, canneries, seafood processing, aquaculture production, juice processing, beverage production and sugar production can all be converted to biogas. There are also many biomass crops that could be used as feedstocks for biogas production. Nutrients from crop conversion can be returned to the cropping system for a truly sustainable renewable energy production system, which can displace greenhouse emissions from fossil energy consumption. Finally, high rates of algae and aquatic weed production in Florida offer additional feedstocks for biogas production, with the additional benefit of removing nutrients from surface waters.

Conclusions

Management of livestock manure can result in substantial emissions of greenhouse gases, especially methane. The principal opportunities for reducing GHG emissions occur in concentrated dairy and poultry operations. The estimated methane emissions from manure management of confined animal populations in Florida total 24.9 Gg CH_4 yr^{-1}, which is equivalent to a global warming potential of 0.523 Tg CO_2 yr^{-1}. The conversion of manure to biogas reduces these CH_4 emissions and avoids CO_2 emissions from fossil fuel use that is displaced by biogas use. The estimated methane production potential from anaerobic digestion of dairy and poultry manure in Florida is 222 million m3 CH_4 yr^{-1}. If this methane were used to replace natural gas, approximately 0.436 Tg CO_2 yr^{-1} of fossil CO_2 emissions would be avoided. In addition to the energy value (or savings), this two-pronged attack on GHG emissions offers a potential for additional revenue from the sale of carbon credits to help finance biogas installations. Higher energy costs and greater recognition of the value of environmental benefits are improving opportunities for renewable biogas production. Tipping fees from taking local organic waste into on-farm biogas plants can improve revenue prospects and increase biogas production through co-digestion. Wastes from ethanol and biodiesel production can also be used in co-digestion. Animal production can be integrated with biorefineries to improve by-product utilization and energy use efficiencies.

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