MITIGATION OF GREENHOUSE GAS EMISSIONS IN ANIMAL AGRICULTURE

Animal Agriculture in a Changing Climate

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Introduction

Animal agriculture contributes about three percent of all anthropogenic (human-caused) greenhouse gas emissions in the U.S. (EPA, 2011). Although this is small relative to other economic sectors such as transportation and energy, animal agriculture is also being called upon to defend its environmental impact and continually demonstrate its commitment to stewardship. One way to do that is by implementing management practices that mitigate (or reduce) greenhouse gas emissions while at the same time increasing production efficiency.

The purpose of this publication is to 1) define the term mitigation in the context of greenhouse gas emissions, 2) discuss several species-specific mitigation strategies available to farmers and ranchers, and 3) consider how these mitigation practices can have other environmental and financial benefits beyond just reducing greenhouse gas emissions.

What Is Mitigation?

In the context of climate change, mitigation refers to any practice that reduces the net amount of heat-trapping gases (referred to as greenhouse gases) from being released into the atmosphere. Greenhouse gases most often associated with animal production are methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). Mitigation strategies in animal agriculture can be separated into four main categories: production efficiency, manure management, energy efficiency, and carbon capture and storage. By improving production efficiency, farmers and ranchers increase the output of meat, milk, and eggs per unit of input, thus reducing greenhouse gas emissions per unit of product produced. Proper manure management not only reduces greenhouse gas emissions, but helps protect air and water quality. As we continue the trend toward more controlled environments within animal production, installing energy efficient lighting, heating and cooling systems can reduce energy-related greenhouse gas emissions and lower energy bills. Carbon capture and storage (also called carbon sequestration) is accomplished by increasing organic

Continued on page 2

Table of Contents

This project was supported by Agricultural and Food Research Initiative Competitive Grant No. 2011-67003-30206 from the USDA National Institute of Food and Agriculture.

Livestock and Poultry Environmental Learning Center matter in soils and maintaining cover crops and trees on crop, pasture, and range lands. Carbon sequestration is considered a win-win option for farmers and ranchers.

Identifying effective mitigation practices for livestock and poultry operations is challenging due to the wide diversity in livestock and poultry production systems. For example, in beef cattle production, there are confined feeder operations, cow-calf operations, and stocker operations, as well as seed stock and niche markets. Greenhouse gas mitigation options are also somewhat dependent upon location and climate. Dairy operations in the American southwest, for example, may have access to a greater amount of cropland and pastures and long growing season which provides more flexibility and increased opportunity for land application of manure and soil carbon sequestration. In the Northeast, where cropland and growing season is limited, mitigation on dairies may focus more on manure storage and utilization for energy production. Where greenhouse gas emissions occur and which mitigation options are most appropriate must be evaluated on a farm by farm basis.

Species-Specific Mitigation Strategies

Beef Cattle Operations

In beef cattle production, one of the most effective mitigation strategies is to increase cattle production efficiency. In a cow-calf operation, this is accomplished by improving fertility, pregnancy rate, and successful deliveries through good breeding practices. Maintaining herd health results in fewer culled cattle and lower mortality rates. This minimizes feed and pasture resources spent on unhealthy cattle and replacements, as well as reducing overall greenhouse gas emissions. Improving weight gain through improved pastures and supplements is something many ranchers already do to increase profitability, but this also reduces greenhouse gas emission per unit of beef produced.

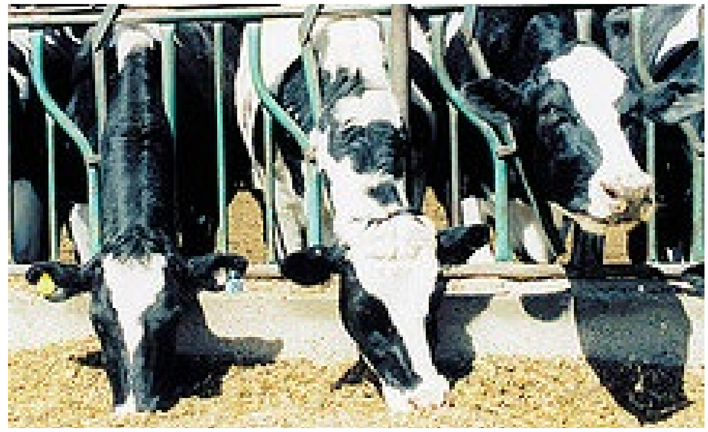
For feeder cattle operations, ongoing research is exploring the potential of dietary additives such as ionophores, oils, and vaccines in reducing enteric methane formation in the rumen. Results thus far show various levels of effectiveness, particularly when examining long-term impacts. A recent FAO report reviewed several hundred published research studies and found significant inconsistency among feed supplements in reducing rumen methane (Hristov et al., 2013). The report considered potential methane mitigating effect and whether the mitigating impact was effective over the long-term. It also considered animal and environmental safety and regional applicability. For many feed additives the mitigation effect was short-lived, dependent upon diet composition, and affected by other factors such as feed intake and daily weight gain. The report found that ionophores such as monensin do not appear to have a consistent direct effect on reducing enteric methane production in beef cattle and in cases where a reduction did occur, the effect was short-lived.

Other diet-related mitigation strategies being studied include inclusion of concentrate feeds, increasing the digestibility of forage, and precision feeding. In general, methane emissions from grain-fed cattle are typically lower than for cattle on pasture. However, concentrate supplementation is not a very practical substitute for high-quality forage, and in many areas of the world is not an economically feasible or socially acceptable option. Improving forage digestibility by feeding legumes or preserved silage also appears to reduce enteric methane and may also reduce urinary nitrogen losses and, consequently, nitrous oxide emissions from manure deposited on soil. Through feed analysis and precision feeding ranchers more closely match animal requirements and dietary nutrient needs. This is important for maximizing feed utilization, stabilizing rumen fermentation, improving rumen health, and minimizing nitrogen excretion in manure and urine.

Another approach growing in popularity among cow/calf and stocker operators in the United States is rotational grazing (sometimes called controlled or mob grazing). In this system, forage supply and growth is controlled by strategically moving herds of cattle through partitioned paddocks within the ranch. Using rotational grazing, along with genetic selection of cattle that conform to local climate conditions, many ranchers are moving from high input operations to low- or no-input systems. These producers are substantially reducing or totally eliminating supplemental feeding and seeing their profit margins increase by using proper stocking rates and adjusting breeding and calving seasons to coincide with forage production cycles. When properly managed, these methods contribute to reduced GHG emissions by providing higher quality forages, greater forage utilization, improved productivity, and eliminating inputs such as supplemental hay, further reducing the use of fuel and fertilizer-related products needed to apply, grow, harvest, and transport grain and forage.

Dairy Operations

The dairy industry has been very successful at increasing milk productivity. While the U.S. dairy herd has declined about two million head since 1985, milk production per cow continues to rise. The dairy industry has also made public their goal to reduce greenhouse gas emissions. In January 2009, the Innovation Center for U.S. Dairy announced a voluntary goal to reduce the greenhouse gas emission of a gallon of milk, from farm to retail, by 25 percent by 2020.



For dairy operations, the key approach to greenhouse gas mitigation is increasing the lifetime production efficiency of the cow through genetic selection, earlier weaning, dietary changes, improving herd health, and reducing cattle stress. On an individual cow basis, methane emission per unit of milk can be reduced using two different approaches. The first approach is to increase milk yield per cow with correspondingly smaller increases in dry matter intake. This "dilutes" the cow's maintenance energy requirement and increases its energy efficiency resulting in less methane produced. The second approach is to reduce body size without reducing milk yield and milk components. This lowers the maintenance energy requirement of the cow and methane produced per cow. Both approaches are based on the fact that maintenance energy requirement is largely a function of body size. Because methane production is proportional to the energy intake of the cow, reducing maintenance energy needs while maintaining milk yield decreases enteric methane both on a per head per day basis and a per pound of milk basis.

Improved genetics and artificial insemination of dairy cattle has enabled farmers to identify and select for breeds genetically superior for milk production. However, breeding for increased milk production alone does have tradeoffs. Genetics selected primarily for milk productivity have shown to increase the incidences of common diseases in dairy cattle (such as ketosis and mastitis) and have low to moderate heritability (Uribe et al., 1995; Zwald et al., 2004).

Studies also indicate that heat tolerance is a heritable trait (Ravagnolo et al., 2000), and the threshold at which cows begin experiencing heat stress is lower in higher producing dairy cows. Since high-producing cows generally eat more, maintenance energy requirement is also increased. Ideally, the industry would move toward genetic approaches that increase lifetime productivity, including those that promote better health, disease resistance, reproduction, and heat tolerance, and improve individual cow and herd productivity, and indirectly reduce methane emissions per unit of milk.

A growing concern in the dairy industry is declining pregnancy rate over the past 60 years. The decline in fertility, with the advent of artificial insemination and genetic selection, is found in all the major dairy breeds in the U.S., but is most pronounced in Holsteins (Lucy, 2001). This trend has been associated with the selection for increasing milk yield; however, there are many management factors that may be responsible for the decline in reproductive efficiency over this time period. Approximately 19 percent of culling decisions are for reproductive reasons (Hadley et al., 2006). Better estrus detection, estrus synchronization, prevention of early embryonic death, heat stress abatement, and transition cow health improve reproduction rates and reduce the number of cows culled due to poor reproduction. In turn, this reduces the need for replacement animals and lowers whole-herd methane emissions.

Continued on page 4

Swine Operations

In swine operations, mitigating greenhouse gas emissions can be achieved by improving feed efficiency and increasing the number of piglets weaned per sow over her lifetime. Because healthy pigs utilize feed more efficiently, improving overall herd health and reducing animal stress are also essential. Since most swine operations take place in environmentally controlled structures, reducing energy consumption by installing energy efficient cooling, heating, and lighting systems and by performing regular fan maintenance are also considered effective mitigation strategies.

Much of the attention for reducing greenhouse gas production in swine operations is focused on feeding strategies, such as increasing the average daily gain and minimizing feed waste. One strategy is switching from a dry feed to wet/dry feeders. Research trials have evaluated the effects of conventional dry feeders versus wet/dry feeders on the growth performance of finishing pigs. Studies performed by Kansas State University in 2008 found that pigs using the wet-dry feeder had greater average daily gain, higher daily feed intake, and a final weight comparable to pigs using the conventional dry feeder. However, pigs using the wet-dry feeder consumed more feed, had a higher feed-to-gain ratio, and had a higher feed cost per pig than pigs using the conventional feeder (Bergstrom et al., 2008).

Another mitigation option showing potential is reducing the amount of manure nitrogen excreted by reducing crude protein content in feed and supplementing the diet with amino acids.

In one study, researchers reported a reduction of methane emissions by 27 percent and carbon dioxide emissions by nearly 4 percent when pigs were fed 16 percent crude protein diets supplemented with amino acids compared to a diet containing 19 percent crude protein (Atakora et al., 2003). In a separate study, researchers found that by reducing the crude protein diet and supplementing the diet with amino acids greenhouse gas emissions were reduced by 16 percent (Atakora et al., 2004).

Poultry Operations

Compared to beef and dairy cattle and swine, greenhouse gas emissions from poultry operations are relatively small contributors to overall U.S. emissions. Greenhouse gas contribution attributed to poultry operations is mainly carbon dioxide released during the burning fossil fuels used to produce electricity, power combustion units such as furnaces and incinerators, and to power trucks, tractors and generators used on the farm. Methane and nitrous oxide emissions also occur during manure handling and storage and land application of manure.

A recent University of Georgia study found that the greenhouse gas mitigation practices are largely farm dependent, and the relative amounts of greenhouse gas emissions vary considerably with type of poultry operation (Dunkley, 2011). For example, the study found that about 68 percent of emissions from broiler and pullet farms came from propane heating use, while only 3 percent of emissions from breeder farms. Minimizing heat loss in poultry barns is the key to reducing propane use. For houses without walls, insulated curtains help to limit heat loss, while for enclosed houses, walls and ceilings can be insulated. Other energy reduction strategies include installing circulatory fans to prevent temperature stratification inside barns and using radiant instead of propane heaters for brooding operations.

On breeder farms, the same study found that electricity used for lighting and ventilation was responsible for about 85 percent of greenhouse gas emissions. Improving energy efficiency of exhaust fans, lighting, generators and incinerators can reduce the total amount of electricity used, thus resulting in fewer emissions.

Animal Manure Management

www.ny.nrcs.usda.gov/news/images/eqip_anaerobic_digester_lg_nrcsny.jpg

Animal production systems typically generate large quantities of manure. This presents both a significant challenge and potential opportunity for mitigating greenhouse gas emissions. Manure management is critical to maintain healthy animals, reducing nuisance odors, and controlling emission of greenhouse gases. Proper storage, treatment, and application of manure can help prevent excessive ammonia, hydrogen sulfide, methane and nitrous oxide emissions. Separating manure into liquid and solids and anaerobically composting the solids has been shown to reduce methane, however, the effect on nitrous oxide emissions and total manure nitrogen loss is variable.

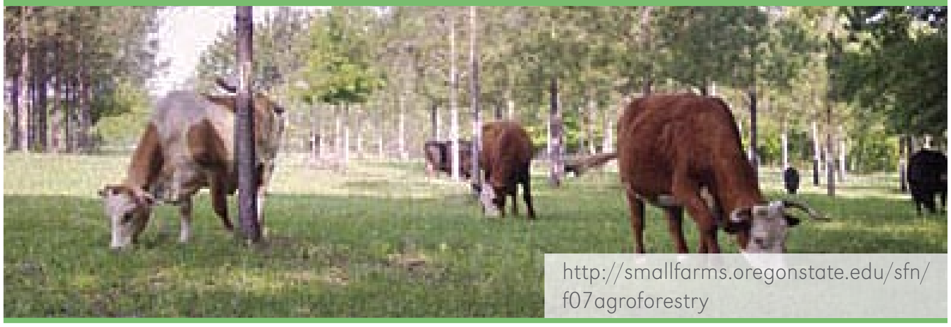
Semi-permeable and impermeable manure storage covers offer many benefits, including odor control and reduction of greenhouse gas emissions for liquid manure storages. Covers trap manure gases such as methane, hydrogen sulfide, and ammonia within the manure liquid that would otherwise escape into the atmosphere. Captured methane can be flared off or combusted to generate on-farm power.

Like covered manure storage systems, anaerobic digesters provide a way to reduce methane emissions from animal manure that would have been emitted into the atmosphere, and use it to generate power for on-farm and off-farm uses. There are several different types and designs of aerobic digesters that can be customized for different livestock and poultry operations and site-specific conditions. These include plug flow, covered lagoons, and complete mix digesters. Anaerobic digesters separate the biogas (mainly methane) from the solids and liquids portion of the manure. The biogas is conditioned to remove moisture and hydrogen sulfide, and the methane combusted to power electric generators, boilers, heaters, or chillers. Heat and electricity generated can be used for farm or home use, and in some cases sold to energy companies. The solids and liquids portion of the manure can then be separated. Liquids can be stored in lagoons and used with irrigation as a fertilizer. Solids can be used or sold as organic fertilizer, compost, or bedding material.

While anaerobic digestion technology is still cost prohibitive to many farmers and ranchers, the benefits of aerobic digesters should be weighed against the initial capital costs. These benefits include better control of manure odors, renewable energy generation, and potential revenue sources such as a reduction in energy purchased, sale of excess electricity or biogas, value-added products such as fertilizers and compost, and the potential value of carbon credits. Other benefits of anaerobic digestion include removal of manure pathogens and improvement in water quality.

Land application of manure solids, slurry, and liquids offers many management and agronomic benefits such as reducing manure storage time and providing advanced biological treatment by soil organisms. Land application enables beneficial utilization of manure nutrients such as nitrogen and phosphorus, and helps build soil organic matter. Surface application techniques are relatively fast and inexpensive compared to other application methods, however, subsurface application of manure can reduce nitrogen and phosphorus loss and minimize ammonia volatilization. Tilling, knifing in, or injecting manure into the soil places nutrients under the soil surface where they are less vulnerable to those losses. There are several strategies to minimize emission of greenhouse gas subsequent to land application such as lowering the overall concentration of nitrogen in manure being applied (applying composted manure for example). It is also important to avoid applying manure to saturated soils since this encourages anaerobic conditions conducive to formation of nitrous oxide. Other recommendations include restricting application to land during the growing season and balancing the quantity of manure with the nutrient requirements of the crop.

Carbon Sequestration



http://smallfarms.oregonstate.edu/sfn/f07agroforestry

For pasture and rangeland livestock systems, there are several options that can reduce greenhouse gas emissions as well as sequester carbon in soils. Grassland systems are one of the most productive systems for sequestering carbon into the soil. One of the most important things ranchers can do, particularly with beef cattle, is to utilize appropriate stocking rates to maintain vegetation that can sequester and utilize carbon. Rotational grazing as part of intensive pasture management is also effective in maintaining healthy pastures.

In some parts of the country, silvopasture is considered a mitigation option—this is where trees are strategically planted within a pasture system and cattle are allowed to graze among the trees. This gives the benefit of shade to the cattle which tend to increase productivity as well as having a double cropping system on that acreage.

For crop and forage based systems, advanced manure application strategies and fertilizer methods can limit nitrogen loss and encourage carbon storage in soils.

Whether applying organic or synthetic fertilizer, a soil test will determine baseline levels and nutrient deficiency in the soil, and enable farmers to balance fertilizer application with the appropriate needs of the forage. Other practices include using slow-release forms of fertilizer to slow microbial processes which cause nitrous oxide formation, scheduling fertilization to coincide with plant uptake, and placing the fertilizer more precisely into the soil so that it is more accessible to plant roots.

Summary

Mitigation is any practice that reduces the net amount of greenhouse gases released into the atmosphere. The four main categories of mitigation mentioned include improved production efficiency, manure management, energy efficiency, and carbon sequestration. One should recognize that each farm and ranch is different, and that mitigation practices should be tailored to the specific species, type of operation and the local environment. Finally, while some mitigation practices are currently cost prohibitive, many have additional environmental benefits that should be weighed. Benefits include odor reduction, improved air and water quality, and reduced pathogens, as well as the potential to produce alternative revenue sources from the sale of biogas or electricity to off-farm users and manure bi-products such as compost and organic fertilizers.

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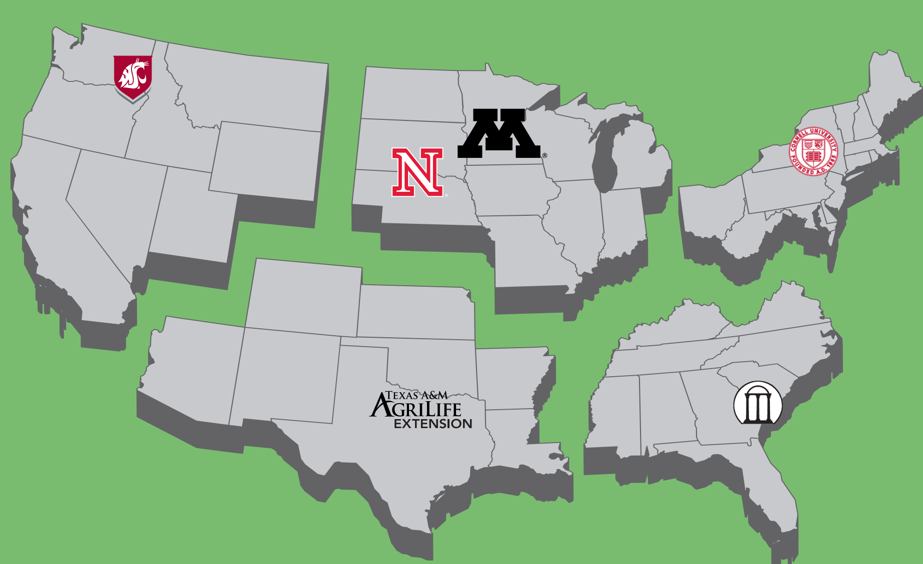

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