

WATER ISSUES AND SUSTAINABILITY

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There is a common misconception that water quality problems due to nutrient loss from agriculture are simply due to poor management on farms. From this conclusion, it is often assumed that all that needs to be done to solve these problems is get farmers to manage better, which will clean up the water, and they will make more money. While improving management on our farms is always important, the real underlying issue is the structure of modern animal agriculture which has evolved through economic competitiveness to be very specialized and regionalized with greater proportions of the feed for animals produced somewhere other than where the animals are located. An unintended consequence of this is that nutrients are transferred from areas where crops are produced to areas where animals are produced and resulting in imbalances of nutrients that can result in pollution. Therefore, solutions to problem must not only include better nutrient management on individual farms, but also must include sustainable strategies to address the regional nutrient imbalance. Otherwise farmers could be forced to make noneconomic and unsustainable management changes on their farms that might only have a very marginal benefit in reducing pollution if the excess is not also addressed.

Effective nutrient management on farms must be site specific and comprehensive. A nutrient management system should start with an assessment of the unique nutrient issues on the farm. A simple assessment is to look at the animal density on the farm. A farm with less than 1250 lb of liveweight animals per acre will usually be nutrient deficient. However, farms with more than 2250 lb of liveweight of animals per acre will very likely have an excess of nutrients above what is needed for the crops. This type of assessment should lead to the selection of appropriate management options. For example, on the low density farms traditional manure best management practices will be effective and will likely be economically beneficial. On the other hand, high density farms will have to focus management on finding ways to sustainably deal with the excess nutrients in an economic way. These management strategies then must be developed into a practical tactical plan to address the economic, agronomic, animal, and environmental management goals of the operator. Prioritization of these goals and targeting of management practices to get the greatest return for the management effort will be challenging but critical. Finally, the plan must be implemented. To be effective this must become an ongoing dynamic process on the farm. Implementation will never completely match the plan. Short term operational adjustments will be necessary as the plan is implemented and longer term adjustments in the plan will be necessary and should be based on records of implementation and what those records show about what worked and what did not work.

The real challenge facing farmers and society in general is the current conflict between food production and the environment. Everyone must understand that there is an additional cost to producing food in a way that has less impact on the environment. This cost must somehow be internalized into the food production system so that managers have the resources to develop and implement sustainable, economically and environmentally sound management systems that adequately address the concerns of society.

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ANIMAL WELFARE, ETHICS & THE U.S. DAIRY INDUSTRY: SOCIETAL & POLITICAL CONTEXTS

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Compared to other animal industries, the welfare of dairy cattle may appear to be unproblematic. However, there is heightened public scrutiny and criticism of many standard dairy industry practices stemming in part from the fact that most people have little knowledge about or connection to farming, and are continuously exposed to anthropomorphic depictions of animals, along with popular press suggestions that large scale, intensive farming is unsafe, unhealthy, and totally disregards the experiences of animals. Concerns are often exacerbated given that the industry has significant welfare issues to address, and because increasingly, consumers use animal welfare to indicate other important product attributes, e.g., safety and healthfulness. It is therefore important for the US dairy industry to address both the scientific and socio-ethical issues that underlie concerns about animal welfare. Failure to do so places the industry at risk of increased regulation, as has begun to occur via legislation of farm animal welfare. For instance, voters passed Proposition 2 in California in 2008, which regulated the housing of gestating sows, egg laying hens and veal calves. Since then, California has also banned the docking of cows' tails. Such activities indicate growing public demand for animal welfare assurance, and the need for all of the animal industries to better regulate their own practices.

Clearly, the dairy industry must move beyond the comfort zone of scientific and economic discussions about production and clearly state how cows *should* be treated. In other words, the industry must make the ethical case for contemporary dairy production and define the ethical parameters for its operations. Unfortunately for those used to dealing purely with science, this is challenging. However, as dairy production practices continue to be challenged on ethical grounds, it becomes increasingly important to understand the constraints of science in addressing these sorts of concerns. Science, for instance, can answer the question of what risks are associated with certain practices, or what the effects may be of feeding or housing dairy cows in certain ways.

However, science cannot tell us whether it is right or even socially acceptable to adopt certain practices or assume the risks that may be associated with them. Thus, the challenge for the dairy industry is to clearly articulate what constitutes acceptable quality of life for a dairy cow, while keeping in mind the perspectives of concerned citizens and consumers.

In order to retain its autonomy, the dairy industry must develop a coherent plan to address both the scientific and ethical issues that are fundamental to all animal welfare concerns. A clearly articulated ethic of care and compassion for animals is needed along with meaningful efforts to improve animal welfare. Doing so will afford the industry the chance to align better with changing societal expectations and values relating to animal quality of life, and thus give it a better chance of maintaining its social license to operate. As society continues to demand food that is produced affordably and in a manner that offers a "fair deal" for farm animals, understanding and demonstrating a genuine commitment to farm animal welfare will be a key component of long-term viability and profitability.

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ECONOMIC SUSTAINABILITY: IN CONFLICT WITH OR SYNERGISTIC TO ENVIRONMENTAL SUSTAINABILITY?

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The recent focus on climate change and global warming has placed an emphasis on minimizing the carbon footprint associated with the production of commodities. Milk production is not immune to this scrutiny, resulting in questions as to which dairy production systems are most appropriate from an environmental standpoint. A perception that seems to be common in the media and within the general public is that large-scale confinement dairies are worse environmentally than smaller scale dairies and those relying more on pasture grazing and less upon concentrated feeds. If this is true, shifting milk production to more pasture-based dairies (often organic) would reduce environmental risks and burdens associated with dairies. However, if pasture-based dairies have higher costs of production per unit of milk produced, then it may be that lessening the impact on the environment might come at a higher cost to society in the form of higher priced milk. This talk examines past research on alternative dairy production systems, specifically grazing and organic dairies versus confinement dairies, general industry trends, and environmental studies that have been conducted, in an attempt to determine whether economic and environmental sustainability are conflicting or synergistic.

Numerous studies have been conducted comparing pasture-based dairies with conventional confinement dairies. These studies relied upon a number of different data sources (e.g., simulated data, farmer surveys, research trials) and analysis methods. Most studies reported that confinement dairies are more productive (lbs/cow/year), but pasture-based and organic dairies generally were more profitable than confinement dairies due to lower costs per cow. Most studies were in traditional dairy states and considered relatively small dairies (less than 100 cows). Also, a number of the studies placed very low values on owner-provided resources (e.g., family labor, homegrown feeds). Trends in the industry indicate that milk production is increasingly moving to western states and to much larger dairies. An analysis of the dairy industry by the Economic Research Service (ERS) concludes that this trend has been due primarily to economies of size associated with larger dairies. ERS also reported that organic dairies had much higher costs than conventional dairies. Much of the benefits of larger dairies had to do with opportunity costs (e.g., unpaid labor) and costs that are fixed in the short run as well as lower productivity of the smaller dairies.

Studies that have conducted a life cycle assessment of alternative dairy production systems have generally concluded that environmental burdens are lower for more productive dairies because of the much smaller herd required to produce a given amount of milk. Thus, those dairies that are most productive in terms of milk produced per cow will generally be better environmentally than less productive dairies. Based on national data in the US, in addition to large confinement dairies having lower costs of production per unit of milk, they also are considerably more productive than smaller dairies. Thus, the trends observed in the industry (i.e., increasing consolidation) appear to be economically advantageous in terms of minimizing the cost of producing milk and environmentally advantageous in terms of reducing the global warming potential per unit of milk produced.

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LIVESTOCK'S LONG SHADOW (FAO REPORT) – THE WHOLE STORY

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The United Nations, Food and Agricultural Organization (FAO, 2006) report titled 'Livestock's Long Shadow' (LLS) stated that 18% (approximately 7100 Tg CO₂- eq yr⁻¹) of anthropogenic greenhouse gases (GHGs) are directly and indirectly related to the world's livestock. The report's statement that livestock production is responsible for a greater proportion of anthropogenic emissions than the entire global transportation sector (which emits 4000–5200 Tg CO₂-eq yr⁻¹) is frequently quoted in the public press. Recent estimates by the United States Environmental Protection Agency (EPA, 2009) on the impacts of livestock on climate change in the United States and California have arrived at much different GHG estimates associated with direct livestock emissions (enteric fermentation and manure), totaling at less than 3% of total anthropogenic GHG and much smaller indirect emissions compared to the global assessment. Part of the difference of the global versus national predictions is due to the significant weight that has been assigned to the category of "land-use change" patterns related to livestock production (mainly deforestation). Furthermore, LLS attempts a life cycle assessment for global livestock production but does not use an equally holistic approach for its transportation prediction numbers. Our work has examined the relative contributions of livestock to climate change at different geographical and production scales and has recently been published ("Clearing the air: livestock's contributions to climate change"). In April of 2010, the UN FAO released the first of a series of follow-up reports to LLS, namely the contributions of dairy to climate change. In this latest FAO assessment piece, general conclusions concur with our assessment, namely that efficiencies are one of the main driving forces in the impact an industry has on release of greenhouse gases. Therefore, intensive dairy systems, as found in developed countries, will serve as a model for the developing world to both protect the environment while satisfying nutritional demand of a growing world population.

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AIR ISSUES AND SUSTAINABILITY

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Environmental concerns involving the dairy industry are shifting from an exclusive focus on water quality to encompass climate change and air quality issues. The dairy industry's climate change air emissions of concern are the greenhouse gases methane and nitrous oxide. With regard to air quality, the dairy industry's major emissions are particulate matter, volatile organic compounds, and ammonia. The emissions of these compounds can be variable because of a number of factors including weather conditions, animal type, management, and nutrition. To evaluate and compare emissions across the diverse operations that comprise the US dairy industry, emissions should be reported per unit of output (e.g., per kg of 3.5% fat-corrected milk). Accurately modeling emissions can predict the complex bio-geochemical processes responsible for dairies' emissions, which helps in the development of mitigation strategies. Improving the dairy industry's production efficiency (e.g., improvements in management, nutrition, reproduction, and cow comfort) is a critical and effective way to reduce emissions per unit of milk. As historical observations have shown, improving production efficiency is an important method to reduce emissions per unit of milk while concurrently improving dairy farm profitability. Through use of process-based models and life cycle assessments, a holistic analysis of the dairy food production system is possible, and mitigation strategies can be developed to reduce air emissions per unit of output. A thorough scientific understanding of climate change and air quality impacts of the dairy industry, taking into account its historical progress for context, would best serve the world's simultaneous needs for safe, high-quality dairy products and environmental stewardship.

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Sustainability in the Dairy Industry: A Wicked Problem for New Knowledge and Engaged Action

SUSTAINABILITY is not a four letter word, is not a code word for environmental concerns being trump in decision making, is not assured by being small, any more than it is assured not to be so by being big. It is about achieving better outcomes across 3 fundamental dimensions: *economic, environmental and social*. *Sustainability* is a **WICKED PROBLEM!**

Wicked problems are messy, complex, indefinable problems that are not solved, but managed. In dairy, they include animal welfare and CAFOs.

Takeaway Concepts:

- Wicked problems will be more relevant to what knowledge institutions, governments, businesses, and societal organizations must manage.
- New knowledge is critical to managing wicked problems by overcoming the twin barriers of stakeholder legitimacy and “frozen” tradeoffs.
- New knowledge creation requires multiple stakeholders democratically co-creating system innovation through aligned incentives and active experimentation in practice and in scholarship.
- To play a role, knowledge institutions must practice *transdisciplinary scholarship* combining:
 - Transdisciplinary research
 - Transdisciplinary outreach and education
 - Engagement of stakeholders as peers

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INTEGRATION OF AIR AND WATER QUALITY ISSUES

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The environmental sustainability of dairy farms is dependent upon a number of air and water quality issues. Atmospheric emissions include hazardous compounds such as ammonia and hydrogen sulfide along with greenhouse gases and their implications with global climate. Runoff of sediment, phosphorus, and nitrogen affect surface water, and the leaching of nutrients can pollute groundwater. Comprehensive, whole-farm evaluations are needed to determine and compare the environmental impacts of dairy production systems, and this must be done along with an assessment of farm economics. This type of evaluation is essentially impossible through experimental methods. Process-level farm simulation provides a more practical approach, particularly when supported by limited measured data.

The Integrated Farm System Model (IFSM) has been used to evaluate the performance, economics, and environmental impacts of a wide range of dairy production systems. The model simulates crop growth, harvest, feed storage, feeding, animal performance, manure production and handling, and crop establishment for many years of weather. Predicted environmental impacts include ammonia emission, nitrate leaching, denitrification losses, greenhouse gas emissions, carbon footprint, sediment erosion, sediment-bound and dissolved phosphorus runoff, and whole-farm balances of each of the major nutrients.

As an example application, organic and conventional dairy production systems were compared. For organic systems that relied heavily upon tillage for weed control, sediment and phosphorus losses were substantially greater than that of conventional systems using minimum or no tillage practices. When an organic fertilizer such as poultry manure was used, greenhouse gas emissions and the carbon footprint were increased and the long term accumulation of soil phosphorus and other nutrients was high relative to more precise use of inorganic fertilizers. During a 20 to 30 year transition from rotated crops to perennial grassland though, carbon sequestration may greatly reduce the carbon footprint of pasture-based organic systems.

A comparison of manure handling systems provides another example. Compared to surface application of manure with no-till crop establishment, rapid incorporation reduced ammonia emissions but increased sediment and phosphorus runoff losses. Separation of manure solids for use in bedding and export from the farm reduced soil phosphorus accumulation and reduced greenhouse gas emissions. An enclosed manure storage with a flare to burn any biogas produced reduced the carbon footprint by 35%. Use of an anaerobic digester for biogas production and electric generation reduced the carbon footprint by 20% with a slight increase in ammonia emission.

Process-level farm simulation provides an effective tool for integrating environmental and economic issues. Because of the difficulty in quantifying societal concerns and the major differences in environmental concerns that occur among geographic regions, it does not appear feasible to obtain an integrated sustainability index for comparing production systems.

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PRODUCTION EFFICIENCY AND THE USE OF NITROGEN AND PHOSPHORUS IN LACTATING DAIRY CATTLE

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The dairy industry is under increasing public scrutiny and regulation concerning the environmental impact of these businesses. Enhancements in productive efficiency have been made over the last 60 years and these increases in efficiency have been profound, but often misinterpreted by the consumer and in some cases groups of scientists not familiar with modern concepts of physiology, husbandry and whole animal metabolism. The first part of this talk will deal with the changes in milk production, nutrient utilization and the evidence that highly productive animals are under less stressful conditions and that high production is actually an indicator of the absence of stress. To further this concept, most dairy farms are continuing to improve their use of nutrients and resources to enhance efficiency and increase income over feed costs. Improving the efficiency of use of feed nitrogen has become a central component of the ration formulation process for two reasons: the desire to be more environmentally friendly and in some cases the ability to reduce feed costs or make best use of the farm-specific feeds. Strategies are available that allow the industry to reduce the amount of protein fed while maintaining milk production. Overall nitrogen efficiency is driven by energy supply to the cow but relationships with waste nitrogen, like urinary nitrogen is a function of over-feeding feed protein relative to either ruminal or post-ruminal requirements. On farm efficiencies for nitrogen use range from 20% to 30% and the most efficient farms groups are in the range of 35% to 42%. The relationship between milk nitrogen excretion and urinary nitrogen excretion provides an opportunity to evaluate waste nitrogen and reduce protein intake. Most cows range from 0.6 to 0.7:1 for milk N:urinary excretion however with improved feeding, this relationship should range from 1.0 to 1.4:1. This approach can reduce whole farm nitrogen excretion by 35% and improve income over feed costs by over 5%. Similar improvements have been made in phosphorus feeding and the outcome of that management strategy has implications for manure and fertilizer applications for optimum forage yields and groundwater regulations. Overall, improved nutrition and management of the dairy cow has the potential to reduce the environmental impact of the industry by a significant amount. This will require further enhancements of our understanding of nutrient utilization, but also the willingness of the industry to improve feed and feeding management to reduce variation. Similarly, the consumer will need to be better informed about the value of technology and the science behind animal management that improves the efficiency of use of resources and reduces the environmental impact, while producing cost effective food.

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Improving the Welfare of Dairy Cattle: Key Concepts in Animal Welfare and the Role of Science

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Concern about the welfare of dairy cattle is nothing new; producers and veterinarians have always been concerned about the condition of animals in their care and have tried to ensure that they are healthy and well nourished. In the tradition of good animal husbandry, good welfare can be seen largely as maintaining production and the absence illness or injury. However, more recent interest in farm animal welfare stems more from concerns about pain or distress that the animals might experience, and concerns that animals are kept under “unnatural” conditions, with limited space and often a limited ability to engage in social interactions and other natural behaviors. Our first objective is to describe a conceptual framework for these different types of animal welfare concern, using examples from dairy production systems. Over the past decade we have seen a tremendous increase in scientific research on the welfare of cattle. Although research alone cannot tell us which types of concerns are most important, it can and has provided solutions to a number of issues. Our second objective is to provide examples of how science can help provide solutions to identified welfare concerns in the dairy industry (e.g. lameness, disease, access to pasture).

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