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Critical Issue Report: A Deeper Shade of Green

A Deeper Shade of Green:
Lessons from Grass-based Organic Dairy Farms

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Preface

All published life-cycle assessments of dairy farms conclude that methane accounts for the largest share of total greenhouse gas (GHG) emissions associated with milk production. This is particularly true on large-scale dairy operations using freestall barns in combination with a liquid-based manure management system. Across the dairy industry, the search is on for options to reduce methane emissions via changes in a variety of on-farm management practices.

The conventional dairy industry is focusing on changes in diets and animal nutrition, rumen function, genetics, and herd structure through, among other things, the "Cow of the Future" project, with the goal of reducing methane emissions by 25% by 2020 (Knapp et al., 2011).

Three factors most reliably distinguish organic from conventional dairy farms – degree of reliance on pasture, cow longevity, and average daily milk production levels. The first two are generally greater on organic farms, and the third is greater on most conventional farms. Enhancing cow health and longevity and expanding reliance on pasture are not among the priority options under review by scientists working to reduce methane emissions on conventional dairy farms.

In this report, we quantify the degree to which milk production and cow longevity, reliance on pasture, and manure management systems influence the methane emissions associated with a gallon of conventional versus organic milk.

In November 2010, we released our first report on the environmental footprint of dairy farm management systems, based on results from the "Shades of Green" (SOG) calculator. *A Dairy Farm's Footprint: Evaluating the Impacts of Conventional and Organic Farming Systems* compared and contrasted the performance of four hypothetical farms – two conventional and two organic. The 2010 report, the SOG calculator, and a 92-page *Shades of Green Users Manual: Guide and Documentation for a Dairy Farm Management System Calculator* are accessible on the Center's website at www.organic-center.org/SOG, as is this report and application of SOG.

In 2011 we completed several refinements in the SOG calculator and used it to evaluate the performance of two well-managed grass-based organic dairy farms compared to a typical, high-production conventional farm and a dairy farm set up and managed to minimize methane emissions per unit of milk produced. Our goal was to explore how organic dairy farms that place heavy emphasis on grazing and cow health might contribute in the quest to reduce net dairy industry GHG emissions. The results are compelling and will hopefully broaden the list of management options considered in the ongoing effort to lighten the environmental footprint of milk production.

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1. Summary

Tremendous progress has been made in our understanding of the physiological processes, management practices, and biological interactions that determine the nutritional quality and safety of milk and dairy products. Incrementally more sophisticated life-cycle assessments are being conducted, helping to sharpen understanding of those aspects of dairy farm management that contribute most significantly, or only marginally, to farm production, animal well being, and greenhouse gas emissions.

Organic and conventional dairy farms differ in many ways, from detailed aspects of animal care and input use, to the preferred breed of cow and how animals are fed. But at 40,000 feet, three factors most reliably distinguish an organic dairy operation from a conventionally managed one – the degree of reliance on pasture, cow health and longevity, and average daily milk production levels.

Organic farms rely heavily on pasture for several months every year, while most conventional dairies do so hardly at all. Cows tend to live longer and milk through more lactations on organic farms. But cows on conventional farms produce much more milk per day, albeit milk of lower quality in terms of protein and fat content.

Whether organic or conventional, all dairy farmers face common challenges and threats, like keeping feed costs down, improving cow reproductive performance, promoting udder health and keeping somatic cell counts down, while minimizing waste generation, the risk of water pollution, and greenhouse gas emissions. Across the industry, the search is on for dairy farm management system changes that can improve the triple bottom line – increasing or sustaining production, assuring adequate profits, and protecting the environment.

One way to gauge what might be possible in the future is to compare the performance of contemporary, well-managed farms utilizing different systems and strategies. Herein lays the idea behind this report. The two grazing-based organic farms included in this study are not intended to represent all organic farms, or even the average west-coast grass-based organic dairy. They simply are two long-established, well-managed farms whose performance helps quantify what is possible on such farms in terms of production, cow health, inputs, wastes, and environmental impacts.

Likewise, the conventional farm included in the study is not intended to represent any specific farm, but instead is included in this study to establish a baseline for key performance parameters. The characteristics of the farm modeled in Scenario 4 are, in fact, in close alignment to those typically found on today's well-managed, large-scale dairies with freestall barns.

A Dairy Cow's Unique Ability

Dairy cows have a special talent – the ability to convert grasses, legumes and other plant-based feeds into milk, one of our most satisfying, nutritious foods. Millions of microorganisms do the heavy lifting in the rumen of cattle as feedstuffs like pasture grasses, alfalfa hay, grains, and silage are broken down and converted into forms that cows can utilize to drive their metabolism, grow a calf while pregnant, and make milk.

Microorganisms in a cow's four stomach compartments both live off the feed passing through the animal's digestive system and help break it down so that the nutrients and energy contained in the plant matter become available to support the cow's own functions.

Methane gas is an unavoidable byproduct of the microbe-driven mayhem underway in a cow's digestive system. To prevent bloating, the cow must rid herself of GI tract gases via belching and, to a much lesser extent, farting. These natural processes lead to what scientists call "enteric methane emissions."

Additional methane can be emitted to the atmosphere from cow manure, when it is managed in anaerobic (without oxygen) conditions. This so-called "manure methane" is not emitted by the cow, but can be produced by a little-known life form, archaea microorganisms. These microbes produce methane when and as they break down carbon in cow manure, but they thrive only in the absence of oxygen. For example, archaea do well in the lagoons on dairy farms containing the wash water used to flush animal wastes from freestall barns and milking parlors. Stagnant conditions in dairy farm lagoons are, in fact, ideal for methane production. This is why manure methane emissions on dairy farms are driven largely by the portion of manure managed in anaerobic lagoon systems. Manure deposited by cows, or spread by farmers, on fields and pastures, or manure that is stockpiled and composted, does not contribute significantly to manure methane emissions, especially compared to anaerobic lagoons.

Lagoons that are circulated can reduce manure methane losses. Some circulation and aeration systems keep lagoons essentially free of archaea, thereby preventing manure methane formation and release. The key is to expose water in lagoons to oxygen, creating an environment that favors phototrophic bacteria over microbes that produce methane, ammonia and hydrogen sulfide.

Once enteric methane is emitted, it becomes a part of the dairy farm's contribution to greenhouse gases, and there is relatively little farmers can do to alter enteric methane emissions per unit of milk produced. But farmers do exercise considerable control over the production and loss of manure methane. Hence, grazing and manure management practices are one of the major factors driving net GHG emissions from dairy farms.

Competing Paths to Reduce Methane Emissions

The dairy industry is focused on reducing methane emissions for good reason -- methane is 25-times more potent than CO_2 in terms of global warming potential (GWP). This is why the dairy industry has adopted the goal of reducing enteric and total methane emissions 25% by 2020 (Knapp et al., 2011). Most life cycle assessments of dairy farms conclude that methane emissions account for the single largest portion of GWP, with nitrous oxide emissions associated with corn production being the next largest contributor to GWP on most dairy farms feeding a corn-based ration (i.e., most dairy farms).

There is a diversity of views regarding the best way to reduce dairy-farm methane emissions. One set of changes under study strives to fine-tune current, conventional management systems, without making significant changes in animal genetics, feed rations, or barn and manure management systems. Another set of options entail capturing and recycling methane and other GHGs in manure and urine via digesters that convert the carbon and nutrients in animal wastes into electricity or liquid fuels.

A third set of strategies are being pursued by organic dairy farmers and milk processing companies:

- Improving a cow's ability to efficiently utilize forage-based feeds,
- Promoting cow health and longevity and enhancing the nutritional quality of milk, and
- Capturing and sequestering more methane and CO_2 in the soil through advances in manure, pasture, crop, and range management.

In this report, we use the "Shades of Green" (SOG) dairy farm calculator to quantify total methane emissions per unit of milk production on four well-managed, but very different dairy farms. Each farm is modeled as one of four scenarios within the SOG calculator. The first scenario reflects the 2010 production year on the Double J Jerseys Farm in Monmouth, Oregon managed by the Bansen family. The herd is composed of Jersey cows producing, on average, 40.5 pounds of unadjusted milk per day. This organic farm makes heavy use of high-quality, home-grown pasture and forages year round, and cows are managed to minimize stress and disease and maximize health and longevity.

In the race of the tortoise and hare, the animals on the Double J Jerseys Farm are akin to the tortoise, whereas high-production Holstein cows (Scenario 4) are more like hares.

Scenario 2 covers cows on the California Cloverleaf Farm (CCF), another organic, grazing-based operation that milks crossbred and Jersey cattle. Unadjusted milk production is 41.5 pounds per day, and the animals are milked seasonally (i.e., all cows are dried up in early winter, so no milk is produced in the middle of winter). A premium is placed on cow hardiness and health through heavy reliance on pasture and high-quality forage-based feeds.

Scenario 3 represents a hypothetical organic farm designed and managed to minimize methane emissions per unit of milk production. Crossbred cattle are moderately reliant on high-quality forages, grain, and protein supplements, such that milk production levels are about 50% higher than on the two, grass-based organic farms. Manure is managed to minimize manure-methane emissions.

Scenario 4 reflects the average performance of a large, conventional dairy farm with Holstein cows administered rbST (bovine growth hormone) to boost milk production, a freestall barn, and a nutrition program based year-round on a "Total Mixed Ration" (TMR). The paramters in this scenario are taken, to the full extent possible, from the results of a national survey of the dairy industry carried out by the USDA's National Animal Health Monitoring Service (NAHMS, 2007). Unadjusted average daily milk production is 73.4 pounds per cow. Cows spend their time mostly on concrete or on bedding packs in freestall barns, with little or no access to pasture. Manure and urine are flushed out of the barn daily with water, which is collected and stored in an anaerobic lagoon system.

ABOUT SHADES OF GREEN (SOG)

The SOG calculator projects the impacts of dairy farm management practices on several indicators of dairy farm performance: milk and meat production, feedstuffs required, crop production inputs, cow health and longevity, several measures of milk production, environmental performance, and gross revenues. It is designed to compare the environmental footprint of dairy operations under four scenarios that can differ in one, a few, or many parameters.

Unlike other models and studies, SOG takes into account the many impacts of dairy farm management on animal health, reproductive performance, and cow longevity, as well as financial performance.

The structure and equations in the SOG calculator are fully explained and referenced in a user-manual document (Benbrook et al., 2010; accessible free at www.organic-center.org/SOG). Results are reported in several different ways to facilitate comparisons with other models and studies.

KEY FINDINGS

The "Cow of the Future" project strives to reduce enteric methane emissions by 25% by 2020, while other projects are focused on achieving comparable reductions in manure methane emissions. The dairy scientists carrying out the "Cow of the Future" project anticipate that existing, proven technologies, coupled with genetic improvement, will reduce emissions by 10% to 12%. Hence, new technology will be needed to reduce emissions the additional 13% to 15% in order to reach the 25% goal.

Using standard organic dairy farm management practices, the grass-based farms in Scenarios 1 and 2 cut methane emissions per unit milk by 20% and 40% compared to the level of emissions on a conventional dairy farm like the one modeled in Scenario 4. Hence, grass-based organic dairy farms clearly have something to offer the whole dairy industry as it strives to reduce GHG emissions per unit of milk produced.

Virtually all studies comparing dairy farm performance across cattle breeds and farm types focus on differences in "Energy Corrected Milk" (ECM), a measure of production that takes into account differences in milk nutritional quality (and specifically, differences in fat and protein content). Significant bias in results can arise from failure to take milk nutritional differences into account when comparing farms that are milking Jerseys or crossbreed cattle, versus Holsteins.

The SOG model reports production both on the basis of unadjusted and energy corrected milk. While the Jersey cows on the Double J Jerseys Farm produce about one-half the volume of unadjusted milk compared to the Holsteins in Scenario 4, the Jersey milk is much richer. The higher fat and protein content results in ECM production of 49.8 pounds per day (22.6 kg/day), compared to unadjusted milk production of 40.2 pounds/day (18.4 kg/day).

This milk-quality-driven 23% increase in milk production reduces total methane emissions per pound or kilogram of milk by 23%.

In addition, the seasonal grass-based California Clover Leaf Farm (CCLF) performs very well compared to the hypothetical, methane-reducing farm in Scenario 3. The hypothetical farm in Scenario 3 reduces total methane per unit of ECM milk by 49% compared to the Scenario 4 farm, while the CCLF achieves a 40% reduction.

Cow longevity is the other factor that improves the performance of the grass-based organic dairies compared to the conventionally managed cows in Scenario 4. In general, as cows are pushed to produce more milk per day, they are placed under incrementally more stress, even on well-managed farms. Reproductive performance and the number of breeding attempts needed for a cow to give birth to a calf can suffer, especially when climatic or other factors add to stress levels. This is why the lactating cows in Scenario 4 require, on average, 2.5 breeding attempts per calf carried to term, compared to 1.5 to 1.8 attempts on the two grass-based organic dairies.

Problems getting cows to rebreed on high-production farms lead to longer lactations, extended calving intervals (the time period between the end of one lactation and the beginning of the next), fewer lactations in a productive life, and shorter lifespans. Cows milk through 6.3 lactations on average on the Bansen farm modeled in Scenario 1 and live to be 8.5 years old. In Scenario 4, cows milk through just 2.3 lactations on average and live to be just 4.3 years old.

This significant difference in longevity has a big impact on methane and GHG emissions per unit of milk produced over an animal's life because of the significant feed inputs, wastes generated, and GHG emissions generated in the first two years of a cow's life, prior to the birth of her first calf. On Scenario 4 farms, this upfront, two-year investment in feed and the wastes generated are, in effect, amortized over just 2.3 lactations, while on a grass-based organic dairy like the one in Scenario 1, the feed and wastes generated are amortized over 6.3 lactations.

If unadjusted milk production per day, or total methane per unit of milk produced in a single year determined the winner in the race between the tortoise and the hare, the large-bodied, productive Holsteins modeled in Scenario 4 would win most of the time by a comfortable, 10% to 20% margin. But if minimizing methane emissions and GHG emissions per unit of energy corrected milk produced over a cow's lifetime determined the winner, the tortoise-like Jersey and crossbred cows on farms like those modeled in Scenarios 1 and 2 would win most of the time, and by an even more comfortable margin.

Economic Performance and Land Use

In terms of total milk and meat income per cow per year of life, the two grazing-based organic farms equal or exceed the performance of the Scenario 4 farm. The organic milk price premium is obviously the major factor accounting for this finding.

This version of SOG does not calculate the costs of feed and other management inputs. It is worth noting that organic dairy farms have to pay substantially more for feed, compared to conventional dairy operations. But grazing-based farms minimize the need for either home-grown or purchased grain and protein supplement feeds, and hence are insulated to a large degree from the sometimes dramatic spikes in the price of organic feed.

The smaller, thriftier cattle on the two organic, grazing-based farms require 3.08 and 3.5 acres to produce the feed needed to sustain a milking cow, while on the Scenario 3 and 4 farms, about 1.0 acre more cropland is needed to sustain the larger animals and higher levels of production.

Not only do grazing-based farms require less land to sustain a cow, they also need fewer acres of highly productive, relatively flat prime cropland. SOG projects that 58% of the 3.08 acres needed to sustain a Jersey cow on the Scenario 1 farm would likely be, on average, high-quality prime land, while 42% could be rolling, less productive grazing land most suitable for grass production usually because of the risk of soil erosion.

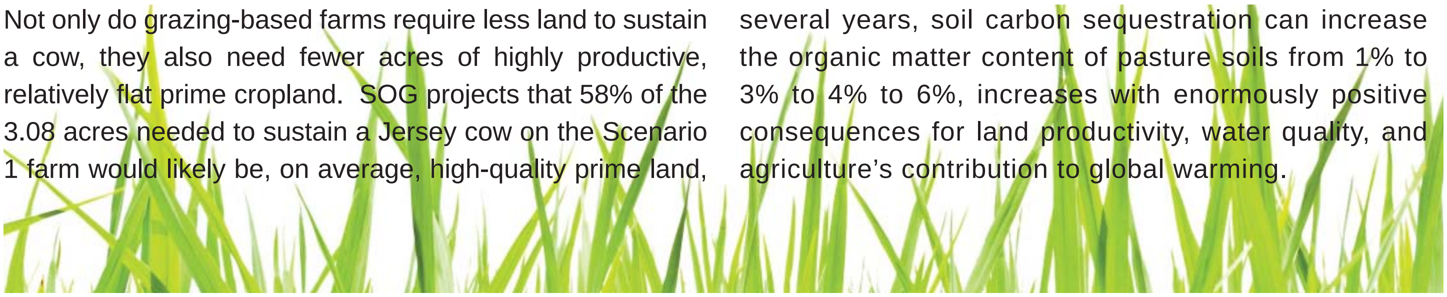
On the Scenario 4 farm however, 77% of the land required to produce the feed for a lactating cow would likely be prime cropland in light of the heavy reliance on corn, soybeans, and alfalfa hay in the overall ration on that farm.

Three key environmental benefits are inherently linked to grazing. The solid mat of grasses and legumes in a pasture protect the land's surface from the erosive potential of rainfall, reducing erosion in most cases to below 1.0 ton per acre from 10-50 tons in the case of cultivated, sloping lands.

Grazing contributes to water quality by reducing the volume of runoff from cropland and pastures used to produce feed for dairy aniimals, as well as the levels of sediment, fertilizers, and agricultural chemicals in runoff. Well-managed pastures on dairy farms essentially eliminate the flow of fertilizers, chemicals, and sediment into nearby water bodies.

Pasture also contributes dramatically to reducing the net greenhouse gas emissions from a dairy farm. It does this directly, by reducing the loss of manure methane, and indirectly by reducing reliance on corn in cow rations. The production of corn is generally regarded as the second most significant source of net GHG emissions associated with milk production, because of the relatively high losses of nitrous oxide from cornfields.

But grazing has an additional, highly significant benefit – it builds soil organic matter levels, thereby sequestering tons of carbon from the atmosphere. A recent study by USDA scientists concluded that well-managed pasture can sequester 3,400 pounds of carbon per acre per year, compared to using the same land for row crop production (Perry, 2011). If sustained over several years, soil carbon sequestration can increase the organic matter content of pasture soils from 1% to 3% to 4% to 6%, increases with enormously positive consequences for land productivity, water quality, and agriculture's contribution to global warming.



2. Introduction and The Four Scenarios

Many studies have either directly measured or projected the environmental footprint of dairy farms. A widely debated 2008 study concluded that high-production, input-intensive dairy farm management systems have a lighter footprint than organic dairy farms (Capper et al., 2008), while other studies have reached the opposite conclusion (Benbrook et al., 2010; Haas et al., 2001; Arsenault et al., 2009).

The different results reached by past efforts to model dairy farm environmental performance result from how researchers draw boundaries around the factors or variables included and excluded in the analysis, how results are measured and reported, the time period studied, and decisions regarding the best equations and input values to use in model simulations. In addition, several core scientific issues are unsettled, like the impact of cow health, grazing and forage quality on methane emissions. A major greenhouse gas study released in 2006 by the Food and Agriculture Organization (FAO) of the U.N. concluded that livestock accounted for as much as 18% of global greenhouse gas emissions (Steinfeld et al., 2006). Recent work argues that the true figure is closer to 3% (Pitesky et al., 2009).

NEED TO FOCUS ON ENERGY CORRECTED MILK

Dairy industry advertising repeatedly asserts that "milk is milk," a claim that is actually not supported by well-known facts. The nutritional quality of milk varies significantly as a result of differences in the levels of fat, protein, antioxidants, and heart-healthy fats including conjugated linoleic acid (CLA) and omega 3 fatty acids (Butler et al., 2008; Ellis et al., 2006; O'Donnell et al., 2010). Many dairy farmers receive premiums for milk that is richer in fat and protein.

Certain breeds of cattle, like Jerseys, produce less milk per day, but richer milk that has much higher levels of fat, protein, CLAs, and omega 3s. Dairy cows on pasture produce more nutrient-dense milk with elevated heart-healthy fats (Butler et al., 2009). Nutrient levels (i.e., concentrations) in milk generally decline as cows are managed intensively to produce at levels near their genetic potential.

To account for fat- and protein-related differences in milk nutritional quality, dairy scientists typically calculate what is known as "Energy Corrected Milk" (ECM). The standard formula for estimating ECM uses three variables: unadjusted milk production per day, fat content, and protein content.

Energy corrected milk is used by dairy scientists as the basic measure of milk production when comparing cow or dairy farm performance. It is also the appropriate and most unbiased metric of production when comparing a cow's or farm's environmental footprint per unit of milk produced. It is especially important to use ECM instead of unadjusted milk when comparing performance on high-production farms milking Holsteins, in contrast to low- or moderate-production farms milking Jerseys or crossbreed cattle.

Table 2.1 drives this point home. Unadjusted milk and ECM production levels across the four scenarios are shown. The Holstein dairy cows on conventional farms like those modeled in Scenario 4 produce 86% more unadjusted milk on a daily basis than the Jerseys in Scenario 1, but only 48% more in terms of Energy Corrected Milk.

Table 2.1 Unadjusted and Energy Corrected Milk (ECM) Production per Day and Milk Fat and Protein Levels

	Scenario 1 Double J Jerseys	Scenario 2 CA Cloverleaf Farms	Scenario 3 Reduce Methane Emissions	Scenario 4 Typical High-Production Conventional
Unadjusted Milk Production Pounds per Day	40.5	41.5	65	73.4
Milk Fat	5.02%	4.34%	4.0%	3.6%
Milk Protein	3.7%	3.65%	3.4%	3.1%
ECM Pounds per Day	49.8	47.3	70.1	73.8

THE FOUR SCENARIOS

The current application of the SOG calculator includes two grass-based organic dairy farms, a hypothetical organic dairy farm designed and managed to minimize methane emissions per unit of milk produced, and a typical high-production, large-scale conventional dairy operation. The key characteristics of each farm are described below and captured in Table 2.2. Full details on the four scenarios are accessible in the "Bansen-Burroughs SOG Application" accessible via the Center's website **www.organic-center.org/SOG**.

Scenario 1 reflects the 2010 production year on the Double J Jerseys Farm in Monmouth, Oregon managed by the Bansen family. The herd is composed of Jersey cows producing, on average, 40.5 pounds of unadjusted milk per day over lactations spanning 333 days. The farm makes heavy use of high-quality pasture and forages year round. The cows are fed limited grain in the summer months (6% of "Dry Matter Intake," or DMI), rising to 10% of DMI in the winter. The farm places a premium on cow health and longevity and manages the animals to minimize stress and disease pressure.

Scenario 2 models the 2010 performance of the California Cloverleaf Farm (CCF), another grazing-based operation that milks mostly crossbred and Jersey cattle seasonally. Unadjusted milk production is 41.5 pounds per day over lactations lasting 321.5 days. Grain accounts for 16% to 22% of DMI with forages accounting for most of the rest of the animal's rations.

The seasonal milking schedule has several impacts on the performance of the farm and age structure of the herd, since cows that do not breed in the desired window are often culled. Most of the manure produced annually is deposited on pastures, since over the winter months, the herd is dried up and managed outside on pasture. Much like the Double J Jerseys Farm, CCF places an emphasis on cow hardiness and health through heavy reliance on pasture and high-quality forage-based feeds.

Scenario 3 represents a hypothetical farm designed and managed to minimize methane emissions per unit of milk production. Crossbred cattle are milked year-round and are heavily reliant on high quality forages, but not to the degree present on the Scenario 1 pasture-based farm. Grain accounts for 14% to 19% of DMI, and concentrates add another 3% to 4%. The greater reliance on energy-dense feedstuffs supports a higher level of unadjusted milk production – 65 pounds per day over lactations averaging 340.5 days. Solid manure is collected and composted prior to field application, a management method that minimizes manure-methane emissions.

Scenario 4 captures the performance of a typical, high-production, conventional dairy farm with Holstein cows, a freestall barn, and a nutrition program based on a "Total Mixed Ration" (TMR). To the extent possible, the parameters in Scenario 4 are derived from the latest USDA survey of the dairy industry carried out by the National Animal Health Monitoring Service (NAHMS, 2007), and reflect data reported for large farms with 500 or more cows. Unadjusted average daily milk production is 73.4 pounds per cow over lactations lasting, on average, 345 days. The production-enhancing hormone rbST is administered to sustain the relatively high levels of milk production over extended lactations.

The longer than average lactations are brought about by greater difficulty in rebreeding cows on high production farms, many of which use hormone injections to help synchronize heat cycles and increase the success rate of each breeding attempt. Extended periods of negative energy balance also increases the frequency of embryonic losses and spontaneous abortions, leading to the need to rebreed cows, as well as much higher involuntary cull and death rates than on the lower-production, pasture-based farms.

Table 2.2 Key Parameters in the Reducing Methane and Nitrogen Losses Application of the "Shades of Green" Calculator [see notes]

	Scenario 1 Double J Jerseys	Scenario 2 CA Cloverleaf Farms	Scenario 3 Reduce Methane Emissions	Scenario 4 Typical High-Production Conventional
Herd Profile				
Breed	Jersey	Crossbreed	Crossbreed	Holstein
Longevity				
Involuntary Cull Rate	9%	10%	15.5%	21.2%
Voluntary Cull Rate	17%	15%	14%	11.7%
Death + Downer Rate	2.7%	3%	2.5%	6.1%
Replacement Rate	28.7%	28%	32%	39%
Among Cows Spending Full Productive Life on the Farm --				
Number of Lactations	6.3	3.7	4.8	2.3
Average Lifespan (years)	8.5	5.6	7	4.3
Lactation Profile				
Unadjusted Milk Production	40.5	41.5	65	73.4
Energy Corrected Milk (ECM)*	49.8	47.3	70.1	73.8
Length of Lactation	330	321	340.5	345
Reproductive Performance				
Number of Breedings per Calf	1.8	1.5	2	2.5
Days Between Breeding Attempts	37.5	36.5	37.5	42.3
Calving Interval	383	371	391	403
Lactating Cow Ration				
Percent of Dry Matter Intake from --				
Pasture	65%	66%	37%	1%
All Forages (includes corn silage)	92%	78%	80%	60%
Grain	8%	19%	17%	26%
Protein Supplements	0%	3%	3%	14%

NOTE: * "Energy corrected milk" takes into account differences in milk nutritional quality when comparing levels of production across farms or as a function of farming systems. The standard equation used to calculate ECM is based on unadjusted milk production, and the fat and protein content of the milk.

NEW FEATURES IN THE SOG CALCULATOR VERSION 1.2

SOG Version 1.1 was used in the original application of the calculator to four hypothetical dairy farms. The results are reported in the November 2010 report *A Dairy Farm's Footprint: Evaluating the Impacts of Conventional and Organic Farming Systems* (Benbrook et al., 2010). The current application has been made in SOG Version 1.2.

Several steps in the calculator were either slightly modified or explained more clearly in Version 1.2. The order of several steps and worksheets has been changed. During the course of adding data on the Bansen and Burroughs farms into SOG, it became clear that one aspect of the calculator was producing results that did not accurately reflect cow longevity.

In Version 1.1 there were two options to record the average age of cows at the end of their productive life. The user could report this data, if known from farm records, or SOG would calculate the age based on other parameters already entered in the model including:

- Age of cow at first breeding;
- Breeding success rates and the days between breeding attempts;
- The length of the gestation period;
- Average length of lactations and dry-off periods;
- Calving intervals; and
- Average number of lactations.

From one dairy farm to the next, the key variables driving a cow's age at the end of its life are the calving interval and number of calves born, and hence the number of lactations. The calving interval is simply the average length of lactation plus the dry-off period.

Double J Jerseys Farm records on the lactating cows currently on the farm were used to calculate the herd's average number of lactations. The result was 3.2 lactations. As a measure of cow longevity, this number is biased downward because of the criteria and process used on the farm for voluntarily culling lactating cows.

Each year a significant surplus of heifer calves are born on the Double J Jerseys Farm. Since the farm is at steady state in terms of cow numbers, the surplus of heifer calves must either be sold off the farm or added to the herd of lactating cows. In any given year, the Bansens select the number of high-quality replacement heifers that have been raised to weaning age. They next determine the number of freshening heifers needed to replace cows that died or became downers, or were culled involuntarily because of production or health issues. They subtract the latter number from the former, and this produces an estimate of the number of high-quality, but still surplus heifers in the herd.

These surplus animals can either be sold as calves to other dairy farmers, or moved into the milking herd, resulting in the need to voluntarily cull and sell a healthy milking cow, which are typically purchased by other farmers and kept in production. When faced with the need to sell a mature, lactating cow, the Bansen's maximize the sale value of the animal by picking from those in their third or fourth lactation. And so, in most years a half-dozen to a dozen healthy lactating cows are sold to other dairy farms to make room for genetically promising first-calf heifers. When the average number of lactations per cow on the farm at any given time is calculated, there are several dozen additional younger animals in the milking herd in their first, second, or third lactation than would be the case if the Bansens decided to sell all surplus heifers at weaning.

In order to remove this bias, SOG Version 1.2 includes Worksheet C for Step 4.4.2. It calculates the average age of cows at the end of their productive life among only those cows that spent their entire lives on the farm. These cows include those in two groups for any given year:

- Cows that were involuntarily culled and shipped to slaughter because of declining production or health problems; or
- Cows that died or became downers.

Worksheet C appears on the following page. In each of the four scenarios, the number of cows falling into each of the above two groups is recorded, along with their average age at the time of shipping, or death or becoming a downer. A simple weighted-average formula is then used to calculate the average age of all cows falling in these two groups. This number reflects the average age at the end of their productive life of lactating cows that spent their whole life on the farm.

Worksheet C for Step 4.4.2 Calculating the Average Age of Cows that Spent Their Entire Life on the Farm (i.e., Cows that are Involuntarily Culled or Die on the Farm) (see notes)

	Cows Involuntarily Culled		Cows that Die or are Downers		Weighted Average Age of Cows Sold to Slaughter or that Die/Downer (months)	Calculated Average Age of Cows or Enter User Reported Value Here
	Number of Cows	Average Age of Cows (months)	Number of Cows	Average Age of Cows (months)		
Scenario 1	13	114	41	63	102.00	102.00
Scenario 2	45	67	9	71	67.67	67.67
Scenario 3	10	110	3	90	105.38	105.38
Scenario 4	10	60	6	38	51.75	51.75

Notes:

1) This calculation of the average age of cows that die, become downers, or are involuntarily culled and sent to slaughter should be made using data covering a representative, recent time period. (e.g., the last one to three years). Cows involuntarily culled but likely to remain in milk production shoud be excluded from this calculation. Cows killed or which go down because of an unusual weather or other events (e.g., barn fire, serious flood, herd-scale poisonous event, building collapse) should also be excluded.

2) The values in the "Weighted Average Age of Cows Sold to Slaughter or that Die/Downer" column are calculated based on the previous 4 columns. These values are automatically transferred to the "Calculated Average Age of Cows or Enter User Reported Value" column. The value in this column is automatically inserted in the "User Reported" box in Step 4.4.2 for the variable "Age of Cow at End of Productive Life, for Cow's the spend their entire life on the Farm". If a user does not have the data required to calculate the average age of cows at the end of their lifes using this worksheet, replace this parameter with the best estimate or a default value in the "Calculated Average Age of Cows or Enter User Reported Value" column.

It is typically not possible for a given dairy farm operator to track down information on how long a cow sold off the farm remains in production on another farm. In addition, once sold to another farm, the cow's health and longevity might be altered relative to what it would have been on the farm it was born on. For these reasons, the approach adopted in Worksheet C is the most accurate, data-driven way to calculate the impact of a specific farm or farming system on cow longevity.

The data in the last column of Worksheet C is then used in Step 4.4.2 to calculate the average number of lactations in a cow's full life. This is done by first calculating the duration of the cow's "productive life," which is simply the age at death, less the animal's age upon birth of its first calf (usually around 24 months).

In the case of the Bansen farm among cows spending their whole life on the farm, the average cow's full life spanned 102 months, or 8.5 years, and its productive life covered 6.46 years. This later period of time is then converted to days and divided by the calving interval, to equal the number of lactations.

The average cow on typical, high-production conventional farms represented in Scenario 4 lives for 4.3 years, and there is little difference between the average age of cows on the farm at a given point in time and the age of cows that spend their entire productive life on the farm. This is because barely enough heifer calves are produced on such farms to assure an ample supply of replacements, and hence very little difference between the age of cows on the farm at a given time and the age of cows that spend their whole life on a farm.

The lactating cows on the Bansen farm in 2010 produced through 3.2 lactations, on average, but among the cows that spent their full life on the farm, the number of lactations rises markedly to 6.3, nearly double the former average. This major difference in number of lactations and lifespan highlights the importance of properly measuring cow longevity when assessing the performance of dairy farm management systems.

3. Impacts of Alternative Systems on Waste Generation and Methane Emissions

Liquid manure storage tanks and lagoons are responsible for substantially higher manure methane losses from large-scale conventional farms. Photo courtesy of Gary and Anne Wegner

Dairy cows excrete wastes through urine and manure, and via the release of enteric methane from belching and farting. The method farmers use to manage and field apply manure also contributes to methane emissions, although not to the same extent as enteric emissions. Most studies show that enteric emissions account for between two-thirds and three-quarters of total methane emissions associated with a lactating dairy animal.

The quantities of wastes generated in each scenario within the SOG calculator are a function of:

- Animal breed and size;
- Levels of milk production, and hence overall need for Dry Matter Intake (DMI);
- The mix of feedstuffs in an animal's ration;
- Degree of reliance on pasture;
- Cow longevity and health; and
- How manure is managed and field applied.

In general, the bigger the animal, the more it needs to eat, and hence the greater the volume of wastes generated. Animals pushed to produce at maximum levels require more feed, and hence generate more wastes. Pushed to extremes, animals under physiological stress from high levels of production tend to suffer a range of health problems and have difficulty conceiving and carrying a calf to term. They tend to produce through only one, or at most two, relatively long lactations.

The shorter lifespan of lactating cows means that the two years of feed inputs invested in them prior to the birth of a first calf, and the wastes generated in this time period, are amortized over fewer lactations and less overall milk production than from longer-lived cows.

The mix and quality of feedstuffs can impact methane emissions and production levels in many complex ways and is a focus of intense research. In general, higher quality feed, especially when delivered in a balanced ration, maximizes the efficiency of the cow's digestive system and minimizes waste generation per unit of milk production.

Manure management systems impact what is called the “Methane Conversion Factor” (MCF) – a key variable used to estimate the volume of manure methane emitted per unit of manure managed in different systems. The U.S. Environmental Protection Agency (EPA) has published MCFs for many different manure management systems in different regions. These parameter values are built into SOG for seven manure management options.

WASTE GENERATION ON DAIRY FARMS

The smaller Jersey and crossbreed lactating cows on the Double J Jerseys and California Cover Leaf Farms produce less manure per day than the larger Holsteins modeled in Scenario 4, but more manure per kilogram of energy corrected milk (ECM), as shown in Table 3.1.

Why Focus on Methane?

Methane is 25-times more potent than CO_2 in terms of global warming potential. Enteric methane emissions from dairy cattle can be projected in SOG using four formulas based on milk production, Dry Matter Intake, percent forage in the diet, and measures of energy intake. In the current application, we rely on the energy intake method recommended in the EPA’s most recent national inventory of GHG emissions from agriculture (U.S. EPA, 2007). EPA’s formula is driven by Gross Energy (GE) intake, which is in turn calculated from diet digestibility and total net energy intake (see Appendix A for details). In most applications, the EPA method produces enteric methane emission estimates in between the maximum and minimum levels projected using the other three formulas in SOG.

Manure methane is also calculated using the method adopted by EPA in its 2007 GHG inventory. “Volatile Solids Produced” (VSP) is multiplied by a “Methane Conversion Factor” (MCF) that is determined by manure management system, and then by two constants that do not vary across the scenarios (see Appendix A for details). The EPA reported methane conversion factors used in SOG vary by region, climate, and manure management system. In general, the hotter and drier the region, the higher the MCF will be.

Step 14 in SOG includes two wet manure management systems and five dry manure systems. Each is assigned a unique region and climate-specific MCF by the EPA. For each of the four scenarios, the annual manure excreted by a lactating cow is apportioned across the seven manure management systems. The percentages managed under each of the seven methods is multiplied by the method’s

Table 3.1 Average Annual Manure, Nitrogen, and Methane Excretions from One Lactating Cow

	Scenario 1 Double J Jerseys	Scenario 2 CA Cloverleaf Farms	Scenario 3 Reduce Methane Emissions	Scenario 4 Typical High-Production Conventional
Manure (kg)				
Kg per Day	59.5	59.5	61.9	63.1
Per kg Energy Corrected Milk	2.63	2.77	1.95	1.88
Per Year of Productive Life	25,945	26,107	27,295	33,467
Nitrogen (kg)				
Kg per Day	0.33	0.34	0.37	0.4
Per kg Energy Corrected Milk	0.015	0.016	0.012	0.012
Per Year of Productive Life	154	161	172	239
Enteric Methane				
Kg per Day	0.34	0.27	0.44	0.46
Manure Methane				
Kg per Day	0.21	0.13	0.05	0.57
Total Methane				
Kg per Day	0.55	0.39	0.50	1.03

applicable EPA MCF, and then added together to produce a weighted average MCF reflecting management of the manure generated by a cow over a year. These values are then used in Step 15 to calculate enteric, manure, and total methane emissions associated with one lactating cow, measured in pounds and kilograms per day.

The heavier reliance on grain and protein supplements on California Clover Leaf Farms, compared to the Double J Jerseys Farm, accounts for most of the difference in enteric methane emissions per day (see Table 3.1). Relatively higher emission rates in the two higher-production scenarios reflect the sizable increase in daily DMI needed to support the much higher levels of daily milk production. In general, the more feed going through a lactating cow's rumen in a given day, the more enteric methane emitted.

Manure methane, on the other hand, is driven both by levels of production, feed intake, and manure management systems. The lowest MCFs apply to manure deposited in the field on growing grass by grazing cows or via the daily spread of manure or compost; the highest MCF applies to that portion of annual manure production that is managed in a liquid, anaerobic lagoon-based system.

As evident in Table 3.1, methane from manure is lower per day on the California Clover Leaf Farm compared to Double J Jerseys Farm. This is because in Step 14, an estimated 33% of annual manure on the Scenario 1 farm is deposited in the loafing shed and milking parlor areas and alleyways leading to these facilities. This manure winds up in a liquid-based lagoon system with a MCF of 0.74. Only 20% of the manure generated in a year on the CCLF is managed in a lagoon-based system, most of it from cleaning the milking parlor and the alleyways.

On the Double J Jerseys Farm, the manure management system weighted average MCF is 0.217, or about 30% higher than the level on the CCLF. In Scenario 4, where cows are kept in a freestall barn 24/7 and 69% of manure is managed via an anaerobic lagoon system, the weighted average methane conversion factor is 0.44, 2.75-times higher than on the California Clover Leaf Farm.

The methane-reducing farm modeled in Scenario 3 utilizes a liquid/slurry system to manage the 10% of manure that is deposited in and around the milking parlor and loafing sheds. This design feature, coupled with heavy reliance on pasture, minimizes the share of manure managed using a wet system, while also utilizing a wet system with a much lower MCF (0.21 instead of 0.63 for an anaerobic lagoon system). Nearly all other manure is deposited directly on pasture (50%) or composted (35%), manure management options with MCFs at or below 0.015. The weighted average methane conversion factor for the farm in Scenario 3 is 0.041, about 11-times lower than the case in Scenario 4.

The last rows of data in Table 3.1 report total methane generated by a lactating dairy cow in an average day and is simply the sum of enteric and manure methane. The seasonal grazing system on the California Clover Leaf Farm, coupled with mostly dry manure management, results in the lowest daily emissions of total methane, 0.39 kg, about 38% of the level on the high-production farm in Scenario 4.

Nitrogen Excretions and Emissions

Nitrogen is essential to dairy farm operations in fueling crop growth and supporting animal growth, metabolism, and productivity. Nitrogen in animal feed is the building block for the protein in cow's milk, as well as the protein in meat from mature cows and calves. Cattle breed, milk production levels, feed rations, feed quality, manure management, and crop production systems impact the efficiency of nitrogen use and uptake as this essential nutrient passes through a dairy farm operation, including on the farms growing the feed supporting dairy animals.

Most life-cycle analyses of dairy farm operations highlight nitrous oxide emissions from conventional corn fertilizers as a significant source of the greenhouse gas emissions associated with milk production, second only to total methane emissions. Together, nitrous oxide plus methane emissions account for three-quarters or more of total global warming gas emissions emanating from dairy farm operations.

As shown in Table 3.1, the smaller Jersey cattle on the Scenario 1 farm excrete 0.3 kilograms of nitrogen per day, while the high-production Holsteins excrete 0.4 kilograms–21% more than on the Scenario 1 farm. But per unit of energy corrected milk produced in a day, nitrogen excretions are just marginally lower on the Scenario 4 Holstein farm (0.015 versus 0.012). However, nitrogen excretions for lactating cows per year of productive life are 36% lower on the Double J Jerseys Farm compared to the high-production Holstein farm. This difference takes into account the impact of cow health and longevity on the number of replacement animals needed.

The shorter lifespan of the Holstein cows in Scenario 4 require about twice the number of replacement cattle to be raised in any given year. The nitrogen wastes generated by these added replacement cattle increases the total nitrogen excretions for a single Holstein cow and her supporting population on Scenario 4 farms to 0.72 kilograms per day (1.58 pounds/day), compared to 0.5 kilograms per day on the Scenario 1 farm (1.1 pound/day).

This 36% increase in nitrogen excretions per lactating cow and her supporting population on Scenario 4 farms compared to Scenario 1 reflects one of the important tradeoffs between grass-based organic systems that emphasis cow health and longevity, compared to farms that intensively manage cows for maximum unadjusted daily milk production.

4. Key Findings and Conclusions

Virtually all studies comparing dairy farm performance across breeds and farms focus on differences in "Energy Corrected Milk" (ECM), a measure of milk production that takes into account differences in milk nutritional quality (and specifically, differences in fat and protein content). Failure to take milk nutritional differences into account when comparing farms milking Jerseys or crossbreed cattle versus Holsteins introduces serious bias into results.

The SOG model reports performance both on the basis of unadjusted and energy corrected milk. While the Jersey cows on the Double J Jerseys Farm produce just over one-half the volume of unadjusted milk per day compared to the Holsteins in Scenario 4, the milk from Jersey and crossbreed cows is much richer. In the all-Jersey herd in Scenario 1, the higher fat and protein content results in ECM of 49.8 pounds per day (22.6 kg/day), compared to unadjusted milk production of 40.5 pounds/day (18.4 kg/day).

This 23% increase in milk production, corrected for nutritional quality, reduces all waste emissions per pound or kilogram of milk produced by 23%. This is why it is so important to assure that studies quantifying environmental performance across dairy farms, breeds of cattle, or management systems are based on energy corrected milk production levels.

METHANE EMISSIONS PER UNIT OF MILK PRODUCTION

The most objective way to compare methane emissions across dairy farm management systems is per unit of energy corrected milk (ECM) over a cow's lifetime. Studies that focus on unadjusted milk in a given lactation or year ignore both milk quality differences and the impact of cow longevity on key, lifetime performance parameters. In general, the longer a cow remains productive, the lower the impact of the enteric and manure methane generated in her first two years of life, prior to the birth of her first calf. Plus, replacement rates are lower on farms with long-lived cows, and hence less methane is generated in the course of sustaining herd numbers.

Table 4.1 reports methane per kilogram of unadjusted milk, as well as per kilogram of ECM. Enteric methane per unit of energy corrected milk varies by ~20% across the four scenarios, and is nearly identical in Scenarios 3 and 4.

Differences are greater in the case of manure methane and reflect, in large part, the big differences in reliance on grazing and manure management systems and associated methane conversion factors. Cows on the California Clover Leaf Farm emit 0.006 kilograms of manure methane per kilogram on energy corrected milk, compared to 0.017 from cows in Scenario 4, or 2.8-fold more.

The farm designed and managed to reduce methane emissions performs even better as a result of its very low average manure system methane conversion factor, coupled with its relatively high level of production. Compared to cows in Scenario 3, the average animal in Scenario 4 emits almost 11-times more manure methane per kg of ECM.

Differences are not as dramatic in the case of total methane emissions. The two pasture-based organic farms in Scenarios 1 and 2 emit about one-third less total methane per kilogram of ECM, compared to Scenario 4 cows. The 26% increase in total methane per kg of ECM between the Jerseys in Scenario 1 and the Holsteins in Scenario 4 nearly disappears when the comparison is made based on unadjusted milk production.

Table 4.1 Methane Emissions from One Lactating Cow per Unit of Milk and Year of Productive Life

	Scenario 1 Double J Jerseys	Scenario 2 CA Cloverleaf Farms	Scenario 3 Reduce Methane Emissions	Scenario 4 Typical High-Production Conventional
Enteric Methane				
Kg per kg of Unadjusted Milk	0.0187	0.0141	0.0151	0.0139
Kg per kg Energy Corrected Milk	0.0152	0.0124	0.0140	0.0138
Kg per Year of Productive Life	172	129	214	266
Manure Methane				
Kg per kg of Unadjusted Milk	0.0114	0.0068	0.0017	0.0171
Kg per kg Energy Corrected Milk	0.0093	0.006	0.0016	0.0170
Kg per Year of Productive Life	105	61	25	327
Total Methane				
Kg per kg of Unadjusted Milk	0.0301	0.021	0.0168	0.031
Kg per kg Energy Corrected Milk	0.0245	0.0184	0.0156	0.0308
Kg per Year of Productive Life	277	189	239	593

There are also large differences in Table 4.1 in methane emissions per year of productive life. These differences reflect the much greater amounts of feed required to sustain the relatively high milk production levels in Scenarios 3 and 4, as well as differences in manure management systems across the scenarios.

Cow Health Benefits

Differences in methane emissions per unit of milk production across the four scenarios in this analysis understate one other advantage of grass-based organic dairies. The physical exercise associated with walking to and from pastures, and grazing for several hours per day, promote animal health. The much lower level of daily milk production reduces physiological stress on the animals. As a result, lactating cows on well-run, grass-based dairy farms live three to four years longer on average than cows on high-production conventional farms. They produce through three or four more lactations, and hence produce more calves. Lifelong milk and meat earnings are also much higher as a result of their longer lives, coupled with the higher prices received for organic milk and meat.

Longevity on organic farms reduces the annual need for replacement cattle. It is common for conventional dairies like those modeled in Scenario 4 to require 40% to 60% replacements annually, compared to about 20% to 30% on farms with long-lived cows. Accordingly, there is a substantial quantity of feed, nutrient excretions, and methane emissions tied up in raising the additional replacement cows needed to sustain herd size on Scenario 4.

Economic Performance

The SOG calculator models the gross income from milk and meat sales. Users can enter the actual prices received for milk, calves, and meat sold, or rely on default values. In the current application, the average milk price per hundredweight was set at $30.00 for Scenarios 1-3, and $20.00 in Scenario 4. Price differentials of this magnitude have been common over the last decade. Calf and meat price differentials were also set to reflect typical market conditions.

Despite producing 33 pounds more milk per day, the Scenario 4 farm's annual milk income per cow is less than the Scenario 1 farm by a wide margin -- $2,575 in Scenario 4 versus $2,931 in Scenario 1. The higher producing farm in Scenario 3 earns by far the most from milk sales per cow per year -- $4,411.

In terms of total milk and meat income per cow per year of life, the two grazing-based organic farms equal or exceed the performance of the Scenario 4 farm. The organic milk price premium is obviously the major factor accounting for this finding.

This version of SOG does not calculate the costs of feed and other management inputs, although hopefully it will in the future. It is worth noting that organic dairy farms have to pay substantially more for feed, compared to conventional dairy operations. The differential in the cost of purchased organic versus conventional feed typically is much greater than the differences in on-farm costs of production between nearby conventional and organic dairies that grow their own feed. Moreover, grazing-based farms minimize the need for either home-grown or purchased grain and protein supplement feeds, and hence are insulated to a large degree from the differences in the costs of organic versus conventional feed, or the sometimes dramatic spikes in the price of organic feed.

Land Use

The smaller, thriftier cattle on the two organic, grazing-based farms require 3.08 and 3.5 acres to produce the feed needed to sustain a milking cow, while on the Scenario 3 and 4 farms, more land is needed to sustain the larger animals and higher levels of production – 4.5 acres in Scenario 3 and 4.1 acres in Scenario 4. The ration feed to milking cows in Scenario 4 includes heavy reliance on two high-yield crops -- alfalfa hay and corn silage, whereas cows on the Scenario 3 farm utilize much more pasture, hay silage/baleage, and much less corn silage.

Not only do grazing-based farms require less land to sustain a cow, they also need fewer acres of highly productive, relatively flat prime cropland that could be used to grow small grain, row crops, or even vegetable crops like potatoes and sugar beets. SOG projects that 58% of the 3.08 acres needed to sustain a Jersey cow on a farm like the one modeled in Scenario 1 would likely be, on average, high-quality prime land, while 42% could be rolling, less productive grazing land suitable mostly for grass production and only accessional crop production because of the risk of soil erosion.On the Scenario 4 farm, however, 77% of the land required to produce the feed for a lactating cow would likely be prime cropland in light of the heavy reliance on corn, soybeans, and alfalfa hay in the overall ration.

Grazing also is associated with three key environmental benefits. The solid mat of grasses and legumes in a pasture protect the surface of the soil from the erosive potential of rainfall. The standard equation used by the USDA to predict annual soil erosion losses projects losses of less than 1.0 ton per acre in the case of most well managed pastures, even on slopping ground. If the same land were used for crop farming, erosion losses would likely exceed 10 tons per acre annually, and if the land were heavily tilled, losses could exceed 50 tons per acre.

Grazing contributes to water quality by reducing the volume of runoff from pastures, as well as the levels of sediment, fertilizers, and agricultural chemicals in runoff. Numerous USDA-sponsored research projects have shown that grass buffer strips along creeks, streams, and rivers that are at least 30 feet wide can filter out 80% or more of the sediment and chemicals in runoff from cultivated cropland. A pasture on a dairy farm performs the same valuable function, but even more effectively because most pastures are so much wider than a typical buffer strip.

Grazing also contributes dramatically to reducing the net greenhouse gas emissions from a dairy farm. It does this directly, by reducing the loss of manure methane, as discussed previously. It does so indirectly by reducing reliance on corn in cow rations. The production of corn is generally regarded as the second most significant source of net GHG emissions associated with milk production,

because of the relatively high losses of nitrous oxide from cornfields.

But grazing has an additional, significant beneficial impact – by enhancing soil organic matter levels, it helps sequester carbon from the atmosphere and holds it in the soil, where it enhances future agricultural productivity at no risk or harm to the atmosphere. A recent study by USDA scientists concluded that well-managed pasture can sequester as much as 3,400 pounds of carbon per acre per year, compared to using the same land for row crop production (Perry, 2011). If sustained over several years, soil carbon sequestration can increase the organic matter content of pasture soils from 1% to 3% to 4% to 6%, increases with enormous consequences for land productivity, water quality, and agriculture's contribution to global warming.

OPTIONS TO REDUCE METHANE EMISSIONS

The "Cow of the Future" project strives to reduce methane emissions by 25% by 2020. The team of dairy scientists carrying out the project anticipates that adoption of existing, proven technologies and practices, coupled with genetic improvement, will reduce emissions by 10% to 12%. New technology and systems will be needed to reduce emissions the additional 13% to 15% needed to reach the 25% goal.

Using standard, widely accepted organic dairy farm management practices, the grass-based farms in Scenarios 1 and 2 cut methane emissions by 20% and 32% below the level typical on today's conventional, high-production dairy farms, as modeled in Scenario 4. These reductions are two- to three-fold greater than those considered feasible on conventional dairy farms based on existing technology and systems, according to the "Cow of the Future" project. This finding suggests that the conventional dairy industry could benefit from taking a closer look at how grass-based organic dairy farms are already reducing methane emissions.

In addition, the performance of the California Clover Leaf Farm relative to the hypothetical farm in Scenario 3 is remarkable and encouraging in terms of the farm's ability to reduce methane emissions per unit of milk produced. The methane-reducing farm in Scenario 3 produces 0.0156 kg of methane per kg of energy corrected milk, compared to 0.0184 on the California Clover Leaf Farm.

Our findings point to several options to reduce methane emissions per unit of milk production, in addition to those pursued by the "Cow of the Future" team. Increased reliance on pasture and grazing will help promote cow health and longevity, and will reduce the portion of manure that winds up in anaerobic lagoons notorious for their ability to emit methane. It will also increase the quantity of carbon sequestered in the soil, enhance soil organic matter levels, and reduce the risk of soil erosion compared to growing crops.

Switching from Holstein cattle to crossbreeds or Jerseys will dramatically improve milk nutritional quality, and hence increase energy corrected milk, compared to farms milking Holsteins. While average per cow production will be lower, so too will feed inputs and the wastes generated per cow. It is widely recognized that Jersey and crossbreed cattle are more efficient than Holsteins in utilizing pastures and forage-based feeds for milk and meat production.

Getting cows out of freestall barns and off of concrete, where liquid manure systems are common, offers great potential to reduce manure-methane and total methane production. While manure methane accounts for one-third to one-half of total methane on most farms, practical options exist to dramatically reduce losses through grazing and the composting of dry manure. Manure methane can be cut as much as 10-fold, reducing its share of total methane emissions from over 50% (Scenario 4) to about 10% (Scenario 3).

Accordingly, farms that rely heavily on grazing and utilize dry manure management systems for most of the rest of a year's manure can cut total methane per unit of milk production by one-half or more. Currently, the National Organic Program rule requires dairy cattle to consume at least 30% of daily Dry Matter Intake from pasture during the typical grazing season, and in no event for fewer than 120 days.

Most organic dairy farms in regions with relatively mild winters meet this 30% of DMI requirement for 200 or more days. As a result, cows spend substantial time on pasture and walking to and from pastures, time during which manure is deposited in or near fields, leading to very low manure-methane losses. While some pasture-based organic dairies cut manure methane emissions by 90% compared to emissions with an anaerobic lagoon system, the average organic dairy likely reduces manure-methane emissions by around 50%.

Promoting animal health and longevity has the potential to cut the number of replacement cows needed by about one-half, from 40% to 60% to 20% to 30%. In a milking herd of 100 cows, this means that around 25 fewer animals would be needed as replacements annually, each of which must be fed and will emit methane for two years prior to the birth of a first calf. The methane generated by these 25 extra animals must be added to the total methane produced by lactating cows, thereby driving upward total methane emissions per unit of milk produced.

Recent research highlights options to reduce enteric methane emissions through changes in the diet of lactating cows. In particular, forage quality, the balance of nutrients and fiber, and the addition of omega 3 fatty acids in rations impact rumen performance and enteric methane emissions.

An Organic Research and Extension Initiative research grant was awarded in 2011 to a team based at the University of New Hampshire to explore forage management and feeding options to improve the nutritional profile of milk. Supplemental feeding with flax will be among the innovations studied. It is likely that progress made in improving the nutritional profile of milk will also reduce enteric methane emissions. Optimizing progress toward both goals is clearly an important and timely focus for organic dairy farms, processors, and the research community.

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Appendix A. Basis for and Sources of Key Variables and Equations

1. Formula for ECM
The equation to calculate “Energy Corrected Milk,” or ECM is –
ECM (kgs or pounds/day) = (UMPD x 0.323) + (7.13 x Protein Content) + (12.82 x Fat Content)
Where:
UMPD is unadjusted milk production per day
Protein content is kgs/pounds of protein
Fat content is total kgs/pounds of fat.

Source: Washington State University Extension, 2008; http://www.extension.org/faq/27579.

2. EPA Method for Calculating Enteric Methane Emissions per Cow
The EPA-recommended formula for estimating enteric methane emissions from a cow is –
Enteric Methane (kg/day) = (GE x Ym)/55.65
Where:
GE is Gross Energy intake,
Ym is a constant, and reflects the portion of GE converted to methane
55.65 converts millijoules to kilograms

3. EPA Method for Manure Methane Emissions
The method used by EPA to project manure methane emissions is –
Manure Methane (kg/day) = VSP x Bo x MCF x 0.662
Where:
VSP is Volatile Solids Produced
Bo is the methane producing potential of waste
MCF is the Waste Management System Methane Conversion Factor (MCF), composed of a weighted average of the MCFs associated with the different methods used on a farm to manage manure.

For full discussion of these and all other equations and data sources used in the SOG Version 1.2, see the *SOG User Manual.* http://www.organic-center.org/SOG/Home