Effects of Structural Change: Manure and Excess Nutrients

The shift of production to much larger dairy farms, driven by significant cost advantages, is likely to continue. The shift also concentrates production in fewer locations and on confined feeding operations with smaller land bases. This spatial consolidation concentrates animal wastes as well as cows, and heightens the potential environmental risks associated with milk production. Here, we describe the pace of geographic consolidation in dairy production and evaluate the potential impact on excess nutrients applied to the land. We then review the environmental regulations developed to deal with dairy farms and other confined animal feeding operations, and summarize ARMS-based data on how dairy farms are managing their manure.

Geographic Consolidation of U.S. Dairy Production

What do we mean when we say that dairy production is spatially concentrating? First, although more milk is being produced then ever before, the industry is consolidating into fewer dairy counties. We sorted all U.S. counties according to the number of dairy cows in each, using census of agriculture data. We then determined the number of counties necessary to account for one-quarter of all dairy cows, and the number necessary for half.

The changes over time are striking. In 1969, 71 counties accounted for one-quarter of all dairy cows, but that count fell to 34 counties in 1992 and just 20 by 2002. Correspondingly, 247 counties accounted for half of all dairy cows in 1969, versus 130 in 1992 and 95 in 2002.

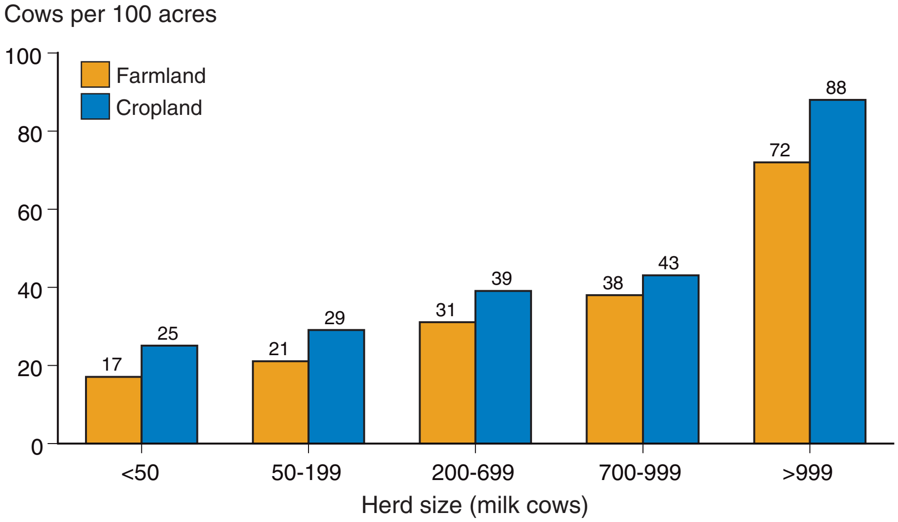
Larger dairy farms concentrate their herds on a more limited land base. Figure 6 shows how cow density varies with herd size for farms in traditional dairy States, where crop production and pasture have historically been combined with milk production. The figure shows two measures of density: cows per 100 acres of farmland and cows per 100 acres of cropland. For each measure, density rises as herd size increases, and densities in the largest class are twice those in the next largest.[18]

As dairy production consolidates geographically, the associated consolidation of manure may lead to the production of manure-based nutrients, primarily nitrogen (N) and phosphorus (P), in excess of what can be taken up by crop production on the dairy farm's land. If improperly managed, excess N and P applications can pose environmental and human health risks. That's not a necessary outcome of geographic consolidation: the farm might be able to remove manure for spreading on other operations or treat the manure to limit environmental harm. Before we consider manure management practices, we will next evaluate the potential changes in excess manure-based nutrients associated with dairy farm consolidation.

[18]Data are drawn from the 2005 ARMS dairy version, and show the ratio of milk cows to farmland operated and cropland across farms in each size class. For this figure, we chose size classes in accordance with regulatory standards.

Figure 6

Cow density increases with herd size



Source: 2005 ARMS dairy version.

Farm Size and the Potential for Excess Nutrients

The N and P available for crop production on a farm consists of the quantities of those nutrients found in the manure generated on the farm, along with the level of commercial fertilizers placed in the ground. Only certain levels of these nutrients are required to grow crops. Excess nutrients, if not properly managed, can build up in the soil and contribute to groundwater contamination, excess runoff to streams and rivers, and air pollution. We estimate the nutrients present in livestock manure on dairy farms, and compare them to the nutrients required by the farms' mix of crops, to show that large dairy farms can produce substantial excess nutrients from manure alone.

The analysis is limited to farms in traditional dairy production regions—the Northeast (New York, Pennsylvania, and Vermont) and the Midwest (Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Dairy farms in these regions typically raise crops and spread manure on farmland. With the region's production moving toward large industrialized operations, there may be increased stress on limited land bases.[19]

In developing measures of excess manure-based N and P, we follow the conceptual approach used in earlier ERS research (Gollehon et al., 2001; Ribaudo et al., 2003). We began with year-end livestock inventories for each of the four major species in the States we examine—beef cattle, dairy cattle, hogs, and poultry. To convert onfarm livestock inventories to estimates of manure production, we then applied the Kellogg et al. (2000) estimates of annual manure production, in tons, for animals of each species.[20] The nutrient composition of manure varies across species, and the same source provides species-specific conversion factors to construct estimates of N and P from each ton of manure for each species.

Next, the ARMS database describes each sample farm's crop mix—the acreage devoted to each crop that the farm produced and production, in bushels, from that acreage. We used that data to develop farm-level measures

[19]This analysis relies on data drawn from seven annual ARMS surveys conducted during 1996–2002. The version underlying these surveys carries less dairy farm detail than the dairy version, but nevertheless sufficient detail for these purposes, and a large sample size.

[20]Kellogg et al. report their estimates for animal units (AU), defined as 1,000 pounds of livestock (a mature dairy cow would be about 1.35 animal units, while a 250-pound hog would be 0.25 animal units). We converted their AU estimates to per-animal estimates.

of total N and P use by crops, relying on the estimates of assimilative capacity, in pounds of N and P per bushel, for each crop provided in Kellogg et al. (2000).[21] Finally, we subtracted onfarm nutrient use from manure-based nutrient production to generate estimates of potential manure-based excess nutrients on each farm.

We present mean values of those estimates, sorted by farm size class, in table 9. Superscripts refer to statistical tests of difference in excess pounds across herd sizes; each letter denotes that the entry is statistically different from the estimate reported in the cited column, at a 90-percent level of confidence.

On average, manure production generates nutrients that exceed the amounts required by the crops grown on dairy farms in all size classes. Moreover, consolidation into larger farms exacerbates the potential for excess nutrients. Estimates of excess N and P, based on manure production alone, are positive for all size classes, and rise sharply between the smallest and largest size classes. A great deal of variation in excess nitrogen production occurs within each size class, so that most across-class differences are not statistically significant. However, the phosphorus estimates rise sharply with herd size, and the differences across classes are statistically significant.

These findings are consistent with those reported in another ERS report, which used the 2000 ARMS dairy version to develop measures of potential excess nutrient production from manure (Ribaudo et al., 2003). That study took a different approach to measurement, estimating the amount of land needed for manure spreading in order to meet a goal of zero excess P (and alternatively, zero excess N). It then compared the needed acreage to the acreage over which the farm was actually spreading manure, and to the total acreage on the farm (since farms don't always spread manure on all their land). Most small dairy farms in traditional States had land available to meet nutrient standards, but few farms in the largest size class did.

Most farms do not rely on manure alone for crop nutrients; manure is costly to transport to fields, and often does not contain the appropriate combination of nutrients for specific crops and fields. Since farms also apply commercial fertilizers to crops, our estimates (table 9) understate the potential excess nutrients from manure and commercial fertilizer applications. While dairy farms of all sizes have the potential for substantial excess nutrient production, the potential appears to increase noticeably among larger dairy opera-

[21]In generating these estimates, we assume that soybean and alfalfa plants are net fixers of N, with each crop fixing nitrogen (35 pounds per bushel of soybeans, and 135 pounds for alfalfa hay) into the soil.

Table 9
Herd size and excess manure-based nutrients

Nutrient	Herd size (number of cows)				
	<50 (a)	50-199 (b)	200-699 (c)	700-999 (d)	>999 (e)
	Excess nutrients (pounds per cropland acre)				
Nitrogen	20[bce]	30[a]	24[ae]	39	54[ac]
Phosphorus	2[bcde]	7[acde]	10[abde]	16[abce]	29[abcd]

Notes: The superscripts refer to the results of statistical tests of difference between columns. All tests are expressed at a 90-percent level of confidence. A lettered superscript denotes that the value reported in a column is significantly different from that in the superscript column.

Source: Agricultural Resource Management Survey (ARMS), version 1, 1996-2002, for 5,183 farms with dairy cows in IA, IL, IN, MI, MN, MO, NY, OH, PA, VT, and WI.

tions, particularly for phosphorus and as herd sizes exceed 1,000 cattle of all types. As dairy farming continues to consolidate into larger operations, this problem will likely become more widespread.

Regulations

Dairy farms, as well as other livestock and poultry operations, are subject to regulation of their manure management practices by Federal, State, and local governments. Regulatory efforts often focus on large operations.

Under the Clean Water Act of 1972, the Environmental Protection Agency (EPA) issued regulations in 1974 and 1976 that established effluent limitation guidelines for large feedlots. In 1999, EPA and USDA published a rule proposing a unified national strategy to limit the environmental impacts of animal feeding operations (AFOs). Following widespread discussion, proposals, comments, and analyses, a revised rule was published in February 2003, effective in April 2003, consisting of a set of regulatory requirements aimed at concentrated animal feeding operations (CAFOs). However, following a legal challenge to the 2003 rule, EPA was remanded to revise some portions of the regulations.[22]

[22]The history leading up to the 2003 rule is described in "National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (CAFOs); Final Rule," 40 CFR Parts 9, 122, 123, and 412, at http://www.epa.gov/fedrgstr/EPA-WATER/2003/February/Day-12/w3074.pdf .

An AFO is defined as an operation that confines animals for at least 45 days in a 12-month period with no vegetation in the confinement area. A CAFO is simply a concentrated AFO. The operation's size, location, means of wastewater conveyance, site characteristics, and other risk-related issues all factor into the authority's decision to categorize an operation as an AFO or a CAFO.

There are three main classes of CAFOs—large, medium, and small. All dairy operations with at least 700 cows are considered large CAFOs. A medium dairy CAFO has 200–699 cows and either discharges animal wastes directly, or has some manmade device (e.g., ditch, flushing system, etc.) that allows animal wastes to discharge directly into U.S. waters. A small dairy CAFO has fewer than 200 cows but is found by a local permitting authority to be a significant contributor of pollutants in the area.

The final ruling established guidelines that CAFOs must adhere to. Under the original 2003 regulations, all CAFOs had to apply for National Pollutant Discharge Elimination System (NPDES) permits, in effect recognizing all CAFOs as point sources of pollution.The revised rule requires only some CAFOs to obtain an NPDES permit—those that either discharge or propose to discharge animal wastes into U.S. waters. Unpermitted discharges are not allowed, except for agricultural stormwater. All CAFOs, permit holders as well as those obtaining the stormwater exemption, had to have a nutrient management plan (NMP) in place by July 2007.

To the extent possible, NMPs must meet nine minimum elements.[23] They must document:

[23]Described in the 2003 rule, p. 7226.

1) Adequate onsite waste storage;

2) Proper management of all animal mortalities;

3) Diversion of clean water, as appropriate, from any production areas on the operation;

4) No direct contact between confined animals and any waters of the United States;

5) Proper disposition of all chemicals and other contaminants used onsite;

6) Site-specific conservation practices to be implemented;

7) Protocols for the appropriate testing of the waste generated on the farm;

8) Protocols to land-apply waste in an acceptable fashion; and

9) Proper documentation of implementation and management of all the elements.

While these nine elements comprise the minimum necessary to operate in the new regulatory environment, more detailed requirements exist for CAFOs depending on their size, with larger CAFOs subject to more stringent guidelines than smaller ones.

EPA rules set minimum standards that CAFOs must meet. States implement the EPA regulations and may also set higher standards or pursue additional strategies. States have imposed minimum facility setback requirements to separate facilities from their neighbors and limit their odors. Some have also imposed tighter land application rules for manure that may apply to broader classes of farms.

Manure Management Strategies and Structural Change

Farms that cannot meet nutrient standards with their current land base have several options. They could reduce the size of their dairy operation. If this were the least costly option, it would lead to a change in farm structure away from large dairy farms. However, given the substantial production cost advantages to size, this would be a likely choice only if the alternatives were quite expensive.

Farmers could also expand the land base for spreading manure on crops, either by acquiring more land and expanding the farm's cropping enterprise, or by selling the manure to others, giving it away, or paying to have it removed.

Manure contains a lot of water, making it very costly to transport, but farmers can reduce those costs with treatment strategies that aim to separate manure solids from liquids. Solids can be more easily transported and applied to cropland or converted to garden fertilizers and other processed products, whereas liquids remain to be applied to onsite cropland. Treatment may also separate methane gas, used for power generation, from manure. Farmers can also reduce the amount of nutrients in manure, and the amount of manure produced per cow, by altering the feed provided to cows.

Ribaudo et al. (2003) analyzed the costs of removal, which may be the most likely mitigation strategy. They evaluated the increase in production costs that would arise from meeting different nutrient standards (N-based and P-based) for farms in three broad size classes and two broad production regions, under different assumptions of the willingness of other farms to accept manure. In general, the estimated effects on production costs were small. If 20 percent of nearby crop producers were willing to accept manure, production cost increases would range from 0.5 to 3.5 percent. Furthermore, while larger farms would see greater percentage increases in production costs, the differences were modest. The smallest farms (less than 425 head, in this analysis) in traditional dairy States would see cost increases of around 0.5 percent, while farms in the largest size class (more than 1,425 head) would see increases of 1.5 (N-based standard) to 3.5 (P-based standard) percent.[24] Given the production cost differences among farms in different size classes (table 4), the analysis suggests that the cost impacts of meeting N- or P-based standards are unlikely to alter the path of structural change.

[24]Costs were sensitive to variations in the willingness of nearby crop farmers to accept manure. As willingness increased from 20 percent, costs would fall. If only 10 percent would be willing to accept manure, then estimated costs for large operations could double, still a small impact compared with the production cost advantages of size.

We used data from the 2005 ARMS dairy version to ascertain the manure management strategies that dairies are following, particularly movement offsite (table 10). For ease of presentation and to generate useful sample sizes for some questions, we classified farms broadly by herd size (1–699 cows versus 700 or more, the cutoff used to define large CAFOs) and by region (Western dairy States and traditional dairy States).

Table 10

Manure management practices, by region, 2005

	Western dairy States		Traditional dairy States	
	0-699 cows	700 or more cows	0-699 cows	700 or more cows
	Percent			
Manure removal				
Farms removing manure (%)	22	57	5	27
Of the farms that remove:				
Percent of manure removed	17	47	2	15
Percent removed that is:				
Sold	16	17	42	34
Given away for free	49	48	53	41
Hauled away for a fee	35	35	5	25
	100	100	100	100
	Percent of farms			
Other practices and assets				
Have a CNMP[1]	70	45	26	91
Use a manure separator	6	16	2	12
Use an anaerobic digester	0	1	0	9
Use dewatering technology	9	37	1	15
Control manure dust	7	32	0	8
Manage feed for nutrients	4	9	4	39
Raise heifers offsite	15	16	10	25

[1]A CNMP is a comprehensive nutrient management plan.

Source: 2005 Agricultural Resource Management Survey, version 4 (Dairy). Western dairy States in ARMS 2005 include AZ, CA, ID, NM, OR, TX, and WA. Traditional States are IA, IL, IN, ME, MI, MN, MO, NY, OH, PA, VT, and WI.

In traditional dairy States, only about 5 percent of dairy farms with fewer than 700 cows, and less than 30 percent of those with 700 or more cows, removed manure from the farm to other sites. Of those that removed manure, smaller farms removed 2 percent of the manure generated on the farm while large farms (700 or more cows) removed about 15 percent, on average. So as of 2005, manure removal was not widely used in traditional production regions.

Removal is far more important in the Western dairy States. Twenty-two percent of farms with fewer than 700 cows, and 57 percent of those with 700 or more, removed manure from the farm. Farms that remove manure also remove a lot more of it: the smaller farms removed 17 percent while the larger farms removed nearly half, on average, of the manure generated onfarm. Large Western dairy farms often raise no crops, whereas dairy farms in traditional dairy States usually grow crops for feed and retain substantial acreage for spreading manure.

About half of the manure removed from dairy farms was given away for free in each region, but Western dairies (large and small) paid fees to have over a third removed. Eastern dairies were able to sell over a third of the manure removed from those operations. Because Western dairies remove far more manure, the increased quantities likely depress manure values, such that fees for removal must be paid more often.

There were enough observations of manure removal on Western dairy farms to allow for estimates of the effect of manure sales or removal fees on farm revenues and costs, expressed in terms of dollars per cwt of milk produced for easier comparison. Among farms that sold manure, the median fee received was 6 cents per cwt. Reported payments for manure ranged from 5 cents at the 25^{th} percentile to 6 cents at the 75^{th}—a narrow range, and a very small contribution to revenues for those farms. For those who paid to remove manure, the median expense was 15 cents per cwt, and reported fees ranged from 7 cents at the 25^{th} percentile to 30 cents at the 75^{th}.

Reported removal expenses ranged more widely than revenues, but even at the high end the removal fees were modest compared with the production cost advantages reported for large operations. At the high end of 2005 manure removal fees (30 cents per cwt of milk at the 75th percentile, or 2.2 percent of production costs at a large farm), the expense is still a fraction of the production cost advantage of large operations.

Another manure management strategy is technology that allows for less costly, and therefore more distant, manure transport, and that can produce other benefits from manure. Large dairy farms were much more likely, in each region, to use technologies that ease the transport and promote the further processing of manure. Nevertheless, none of the technologies—manure separators, dewatering, or anaerobic digesters—is widely used (table 10). The anaerobic digester, which produces electricity from the methane in manure and leaves a dry, nutrient-intensive product that can be transported easily, appears on less than 9 percent of large farms in traditional dairy States, and is virtually absent elsewhere.

Farms can also reduce manure and nutrient production from a given herd by raising replacement heifers offsite, or by altering feed mixes to reduce manure or its nutrient content. Each of those strategies is common, although not widespread, on large dairy farms in traditional dairy States (table 10).

Little manure is currently removed in traditional dairy States. However, pressure is growing for a substantial expansion of manure removal because of the expansion of large dairy farms, the links between herd size and excess nutrient production, and the requirements in nutrient management plans. In turn, if the costs of manure removal were high, then regulations could, in principle, slow or reverse the expansion of large dairy farms. However, current evidence indicates that manure removal expenses add only modestly to milk production costs. Furthermore, given the abundant cropland in traditional dairy States, along with deep markets for gardening fertilizers, short hauling distances, and the opportunities for easier removal offered by available processing technologies, it seems likely that markets could well develop for manure removal as more large farms appear in traditional dairy States.