Impacts on Animal Operations of Restricting Manure Applications

Large livestock operations produce very large quantities of manure nutrients, often well in excess of nutrient requirements for the crops grown on the farm (Gollehon et al., 2001). Excess nutrients can create environmental risks, and manure management practices are coming under increased scrutiny in the regulatory and legal arenas.

Certain large "concentrated animal feeding operations" (CAFOs) are required to have a pollution discharge permit under the Clean Water Act, and those operations must implement a nutrient management plan (NMP) as part of their National Pollution Discharge System (NPDES) permit. CAFOs not required to obtain a discharge permit must implement a NMP if they wish to claim the stormwater exemption contained in the Clean Water Act. By 2004-2006, 62 percent of U.S. hogs, 60 percent of broilers, and 49 percent of dairy cows were on operations that had NMPs.[18]

[18]In 2004 (hogs), 2005 (dairy), and 2006 (broilers). Correspondingly, 30 percent of hog farms, 32 percent of dairy farms, and 60 percent of broiler farms had an NMP. Plans cover more animals than farms because larger farms are more likely to be required to have one.

An NMP requires that manure nutrients be applied at agronomic rates. If operations had been overapplying manure, then they have several options for complying with NMP requirements. They may adjust feeding regimens to reduce the amount of nutrients in a given amount of manure, thereby reducing manure and nutrient production per finished animal. They may acquire more land for spreading manure, either by expanding their own crop production or by persuading neighboring farmers to take their manure. Manure can also be dried and used as feedstock for energy production or separated into dry and liquid components. Dried manure that retains nutrients can be bagged and sold as garden fertilizer, or it can be shipped greater distances for field crop application.

How individual farms adjust to application restrictions depends on several factors, including the number of animals on the farm, amount of land available on the farm for spreading manure, availability of land off the farm, willingness of neighboring cropland operators to accept manure, type of crops grown, and the type of nutrient standard the farm must meet (nitrogen or phosphorus).

ERS evaluated the costs of such requirements to the hog and dairy sectors in 2003 (Ribaudo et al., 2003). The study combined census of agriculture data on livestock inventories for each U.S. county with ASAE estimates of manure production by species to generate estimates of aggregate farm and county-level manure production.[19] The findings of this analysis can be used to draw inferences for how the rules embodied in NMPs would affect all animal feeding operations, not just those regulated by EPA. The results of this analysis are summarized here.

[19]The Ribaudo et al. estimates are based on older 1988 ASAE standards, and have not been updated to reflect the 2005 revision of the standards.

Hogs

Ribaudo et al. (2003) used the 1998 hog ARMS to estimate the amount of additional land each farm would need to meet nitrogen (N) and phosphorus (P) based standards, and the cost of meeting a nutrient management plan. They accounted for the different manure storage technologies used by hog operations, which affect both the nutrient content and the weight of the material that must be moved and applied. For example, operations in the Southeast tend to use lagoons, which greatly dilute manure, and apply waste to fields with irrigation sprinklers. Operations in the Midwest tend to use slurry tanks or pits and to apply manure with mobile equipment. The cost of implementing a nutrient management plan has three components: recordkeeping and testing, application, and transportation. All three were accounted for in the analysis.

In 1998, the hog sector was dominated by four types of operations—farrow-to-finish (50 percent), feeder pig-to-finish (31 percent), farrow-to-feeder pig, and weanling-to-feeder pig operations. Most hog farms (85 percent) contained less than 300 animal units (defined as 1,000 lbs of live weight). Twelve percent contained between 300 and 1,000 animal units, and only 3 percent were large, with at least 1,000 animal units. When looking at production, however, large operations produced 34 percent of all hogs (Table 5). It is these operations that were the focus of EPA's 2003 regulations.

Farm size plays a major role in whether an animal feeding operation is defined as a CAFO and regulated by EPA. EPA defines size for the purpose of Clean Water Act implementation on the basis of Animal Units (AU) different from USDA's definition of animal units (live weight). EPA defined an animal unit as 2.5 swine weighing more than 25 kg. Those operations with more than 1,000 AU were classified as large and generally made up the bulk of operations that needed a discharge permit from EPA.

In the Ribaudo et al. analysis, operations were classified into three size classes: large (>1,000 AU), medium (between 300 and 1,000 AU), and small (less than 300 AU). Operations with less than 27 animals were dropped from the analysis, on the assumption that these are not confined animal feeding operations. Also, the EPA size definitions did not account for hogs weighing less than 25 kg, so those operations containing only pigs smaller than 25 kg (wean to feeder) were dropped from the analysis.

For each farm in the sample, the acreage needed to apply manure at agronomic rates was compared with the acreage reported as receiving manure and with the total acreage operated by the farm deemed suitable for receiving manure. Farms not meeting the standard were assumed to spread on a larger area, which may have necessitated moving manure off the farm to cropland and pasture operated by other farmers. Ribaudo et al. examined the impact of the standard for all three size classes across five regions.

Table 5

Characteristics of hog producers, by size class, 1998

Item	<300 units	300-1,000 units	>1,000 units
Number of hog farms	52,718	7,153	2,100
Percent of farms	85	12	3
Percent of sales	30	33	37
Percent of production	33	33	34

A unit represents 1,000 lbs of live weight.

Source: 1998 hog ARMS

On average, small farms were spreading on enough land to meet a nitrogen standard and would not be much affected by a requirement to meet an agronomic rate, although this varied by region (Table 6). Medium farms would need, on average, to increase the amount of land receiving manure by 33 percent. Large farms had the greatest need to spread on more land. On average, the amount of land needed for spreading would have had to increase by 114 percent. In addition, a phosphorus-based standard would greatly increase the amount of land required for spreading manure. Large farms would need, on average, about 1,000 acres of additional land for spreading.

The cost of meeting the application limit depends heavily on whether a farm has enough of its own land, or whether it must transport manure off the farm. If moved off the farm, the willingness of nearby crop producers to use manure is a major factor in how far manure must be hauled. Data on willingness-to-accept manure (WTAM) was lacking when the study was conducted, so the authors looked at a range, from 20 to 80 percent. As seen from Figure 11, per-AU costs are negative for medium and large farms and in most regions when willingness to accept manure exceeds 20 percent (because manure then has value, and producers obtain revenue for it). The

Table 6
Percentage of hog farms meeting N-based and P-based standards, by region and EPA size class, 1998

Region	Farms with confined hogs	Farms meeting N-based standard	Farms meeting P-based standard	Farms with adequate land for N-based standard	Farms with adequate land for P-based standard
	Number			*Percent*	
Eastern Corn Belt					
<300 AU	5,891	44.5	16.4	85.1	66.7
300 – 1,000 AU	2,658	34.8	7.3	84.4	59.0
>1,000 AU	1,110	20.1	0	56.1	25.1
Western Corn Belt					
<300 AU	10,903	50.1	11.8	92.1	72.1
300 – 1,000 AU	7,744	37.9	9.9	82.0	48.9
>1,000 AU	2,025	26.9	8.8	66.5	31.0
Mid-Atlantic					
<300 AU	423	15.4	1.1	54.9	46.9
300 – 1,000 AU	582	14.1	0	23.0	10.8
>1,000 AU	1,214	4.5	0	17.3	2.4
South					
<300 AU	1,236	32.5	11.2	81.7	68.6
300 – 1,000 AU	488	21.7	0.6	67.3	43.8
>1,000 AU	177	13.3	7.9	32.0	16.6
West					
<300 AU	393	19.2	7.6	28.2	25.4
300 – 1,000 AU	108	0	0	0	0
>1,000 AU	174	0	0	29.4	0
Nation					
<300 AU	18,846	45.8	12.8	87.1	68.7
300 – 1,000 AU	11,580	35.0	8.3	78.2	48.7
>1,000 AU	4,700	18.0	4.1	48.8	20.6

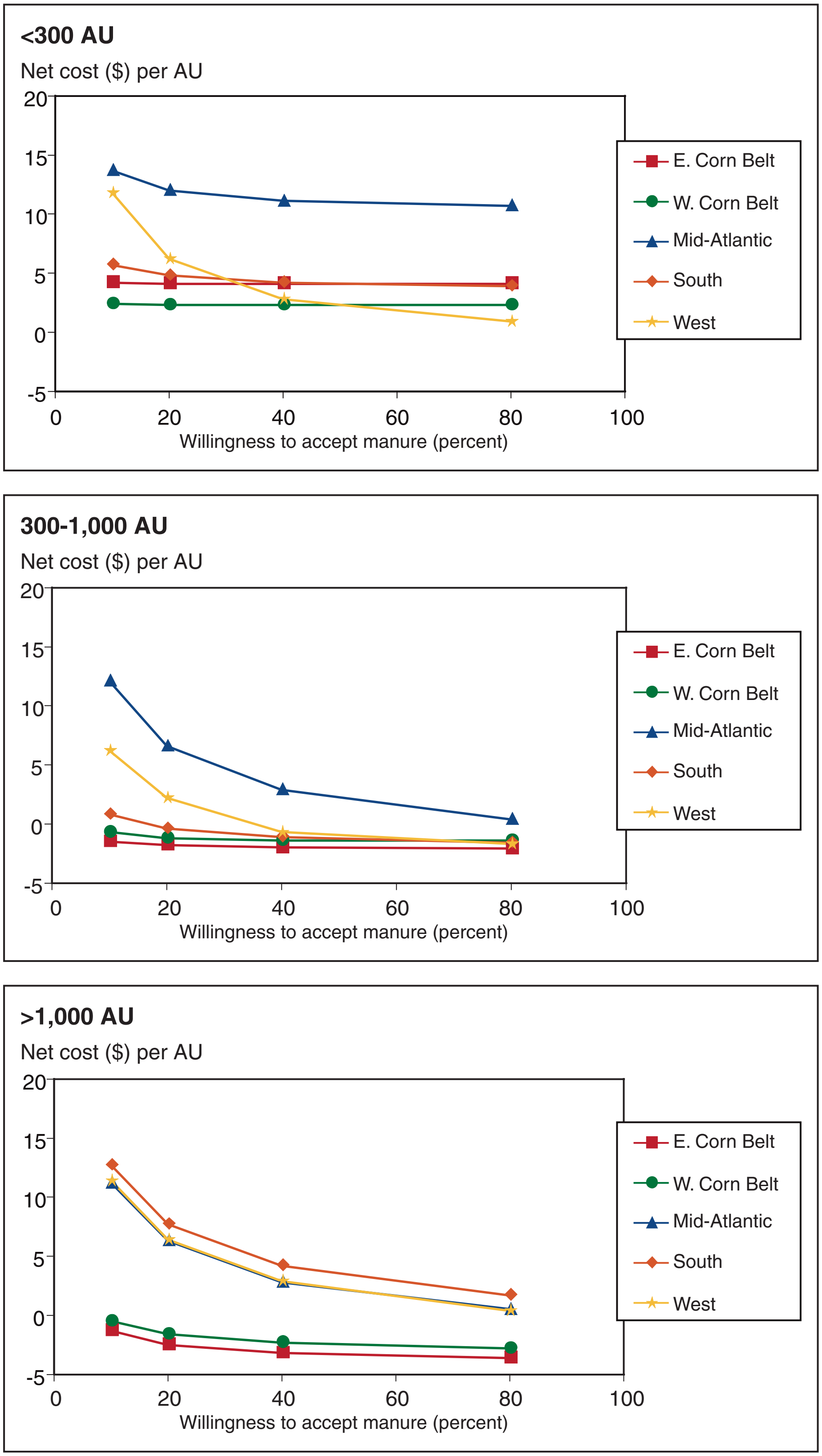
AU = 2.5 hogs of more than 25 kg.

Operations with fewer than 27 hogs, or containing only hogs weighing less than 25 kg, were dropped from the analysis.

Source: Ribaudo et al. (2003)

Figure 11

Average net cost of applying manure from hog farms following a nitrogen standard, by region



Source: Ribaudo et al., 2003.

Table 7
Average acreage being used for spreading and average acreage needed to meet nutrient standard on hog farms, by region and EPA size, 1998

Region	Manure volume	Acres being used	Acres on the farm[1]	Acres needed		
				N-based standard	P-based standard, baseline phytase	P-based standard, all phytase
Eastern Corn Belt	1,000 gal			*Acres*		
<300 AU	382	66.6	365.2	53.8	193.9	140.1
300 – 1,000 AU	1,027	110.7	705.2	145.0	466.6	352.4
>1,000 AU	4,081	179.6	756.7	349.0	1,143.5	863.7
Western Corn Belt						
<300 AU	514	75.9	451.4	61.6	229.2	161.9
300 – 1,000 AU	1,492	119.4	535.5	147.4	493.2	355.2
>1,000 AU	5,204	262.8	789.5	368.7	1,206.8	882.0
Mid-Atlantic						
<300 AU	1,053	16.1	144.0	57.6	172.3	135.5
300 – 1,000 AU	3,800	39.2	134.5	151.7	331.1	242.7
>1,000 AU	12,141	68.7	247.3	397.9	1,166.0	851.5
South						
<300 AU	998	39.5	342.3	49.8	115.3	82.2
300 – 1,000 AU	2,591	57.6	688.2	127.7	366.4	266.0
>1,000 AU	8,067	139.7	276.7	578.8	833.1	693.3
West						
<300 AU	1,646	40.7	163.0	127.5	170.7	120.2
300 – 1,000 AU	3,558	59.2	5.7	138.6	272.3	218.9
>1,000 AU	17,946	139.4	258.6	736.6	1,992.6	1395.2
Nation						
<300 AU	539	68.5	404.5	59.6	208.2	148.4
300 – 1,000 AU	1,562	110.2	556.9	146.2	471.5	344.0
>1,000 AU	7,302	184.2	603.5	393.6	1,196.9	882.1

[1]Acres owned or leased suitable for receiving manure.
Source: Ribaudo et al. (2003)

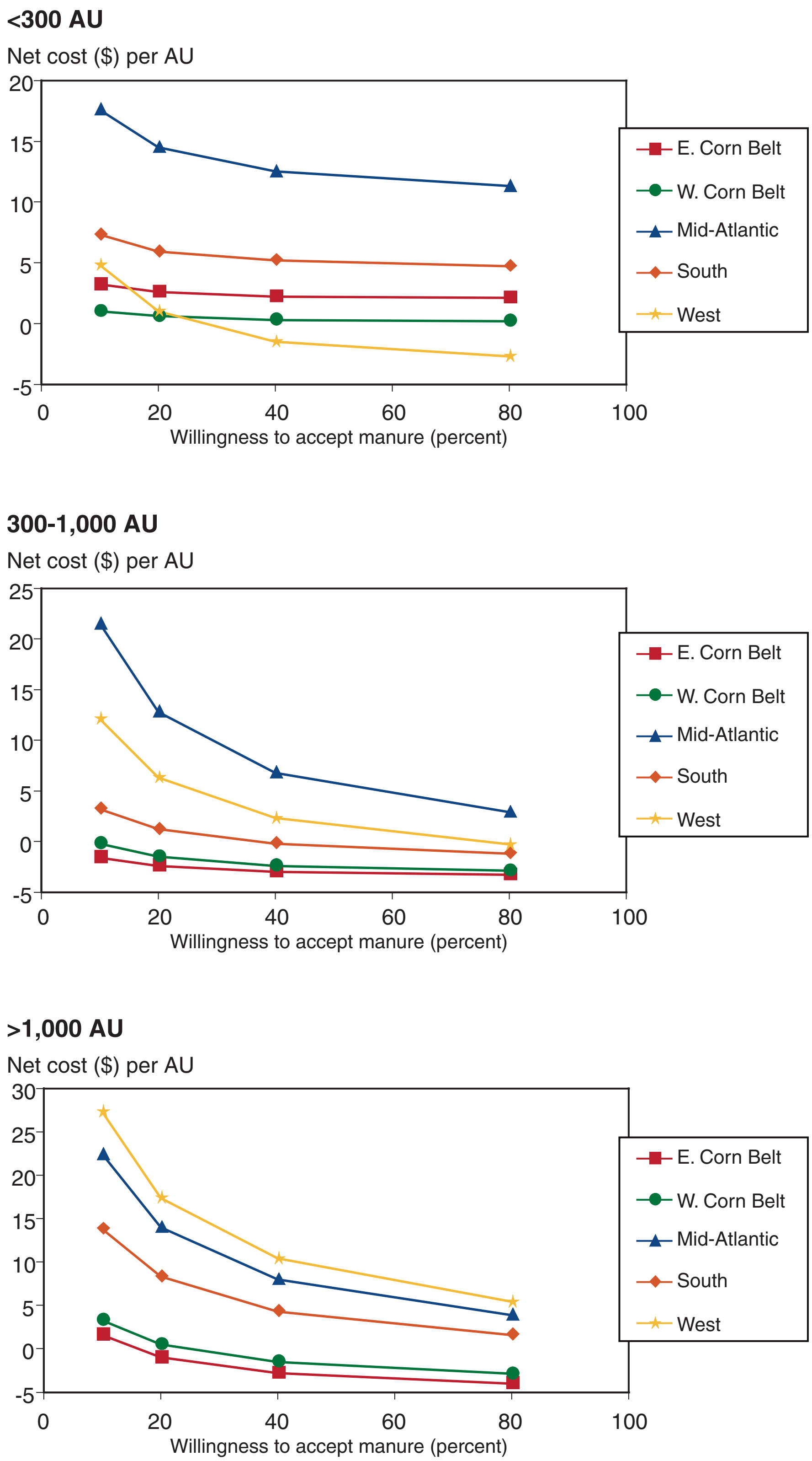
Mid-Atlantic and West regions showed higher costs, primarily because of the relative scarcity of cropland suitable for receiving manure (manure must be transported farther). Among farms affected by a standard, small farms tend to have higher unit costs of meeting a standard. Costs are generally higher for P-based plans, but again, become negative for medium and large operations when willingness to accept exceeds 20 percent, in most regions (Figure 12).

To put these costs in context, they can be compared to production costs (operating costs plus allocated overhead). Data from ARMS indicated that hog production costs ranged from $360 to nearly $1,000 per animal unit for 1998, depending on the region, size of operation, and type of operation. At a high WTAM (80 percent), production costs would increase 1 percent or less across all regions and all size classes, for meeting either an N- or P-based standard.

At lower WTAM, impacts on production costs are noticeably higher for large operations than for small and medium operations in some regions. Under an N-based standard with a WTAM of 20 percent, the impact on production costs for large operations in the Corn Belt are negligible and slightly higher

Figure 12

Average net cost of spreading manure from hog farms following a phosphorus standard, baseline phytase use, by region



Source: Ribaudo et al., 2003.

for medium and small operations (Figure 13). In the other regions, production costs increase from 1 to 2 percent for large operations. For a P-based standard, the increases in costs for regions other than the Corn Belt are larger, ranging from 2 to 3.5 percent for large operations.

Animal diet modification is one approach for reducing nitrogen and phosphorus content of excreted manure. The phosphorus content of hog manure can be reduced by using reformulated feed containing the enzyme phytase. Phytase enables hogs to better utilize phosphorus in grain, thus reducing the need to add dicalcium phosphate or other inorganic phosphorus additives common in hog feed mixes. The addition of phytase to feed can reduce the P content of manure by up to 45 percent and, because phytase replaces dicalcium phosphate in hog diets, usage may also reduce feed costs.

This reduction is seen in the study results. The amount of land needed by farms having to spread manure is reduced by about 27 percent for all size classes. Large operations would benefit most if phytase were used in feed, as hauling costs make up a larger share of the costs of meeting a P-based standard (Figure 14).

The hog sector changed measurably in the decade after 1998. We looked at how those changes might alter the Ribaudo et al. findings, by comparing data from 1998 with data from the 2004 ARMS hog version. The number of small farms fell greatly, while the number of medium and large operations increased—large hog operations with at least 1,000 AUs accounted for 46 percent of production in 2004, up from 34 percent in 1998.

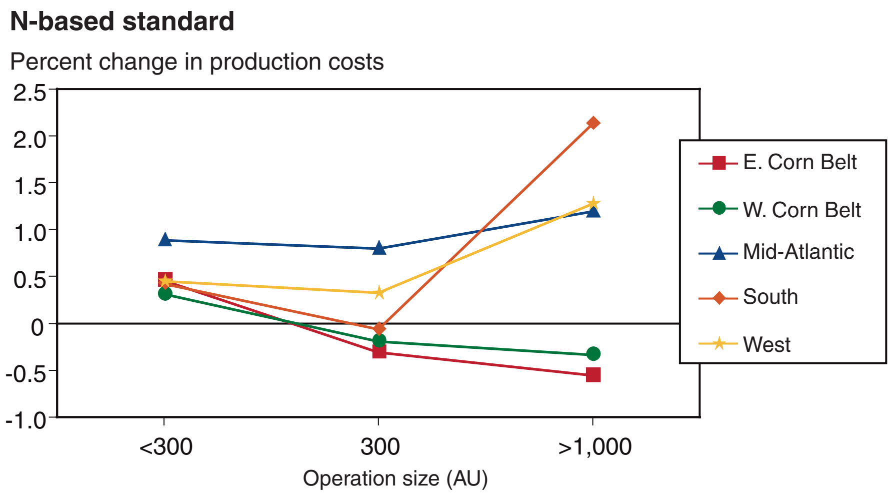
Perhaps in response to public pressure to reduce environmental impacts, larger operations more often removed manure from the farm, added microbial phytase to hog feed, and followed a comprehensive nutrient management plan (Key, McBride, and Ribaudo, 2009). Whereas 23 percent of hog manure was removed from farms in 1998, farms removed 31 percent of all hog manure in 2004. With more manure removed, and with manure application intensities (animal units per acre) on large farms dropping by 15 percent, overall application intensities did not change between 1998 and 2004, even though production shifted to larger farms. Farmers also took steps to alter the nutrients in manure; in 1998, 4 percent of hog producers, accounting for 12 percent of production, added phytase to their feed. By 2004, 13 percent of producers, accounting for 30 percent of production, were doing so. These steps make it easier for large farms to meet a nutrient application standard, thus reducing the added cost of meeting a standard. Similar changes were not observed for small and medium sized operations. Application intensity increased for small and medium sized operations, implying that the costs of meeting a nutrient standard may be higher among smaller operations than in 1998.

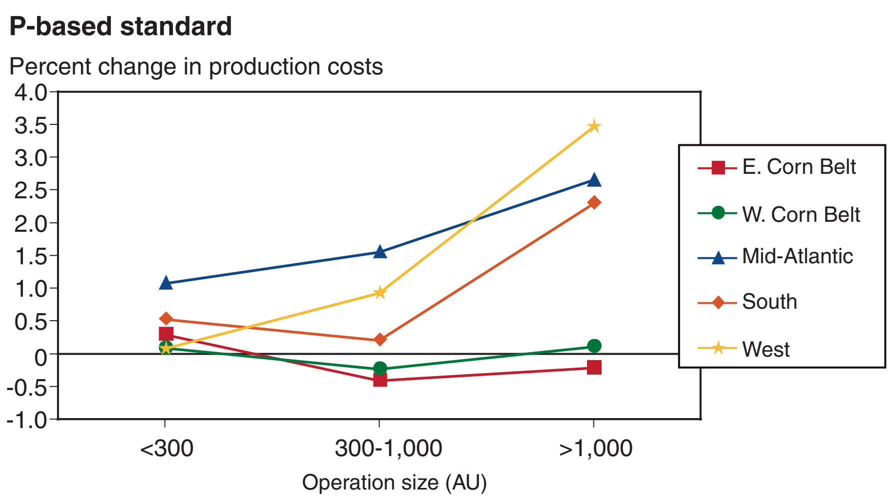
Dairy

Ribaudo et al. (2003) also analyzed the impacts a nutrient application standard would have on dairies, using data from the 2000 dairy ARMS survey. As with hogs, the dairy sector has many small operations. In 2000, 92 percent of all dairies had fewer than 200 head. Less than 1 percent of operations had 1,000 or more cows, but they contained over 19 percent of the sector's cow inventory and accounted for 23 percent of production.

Figure 13

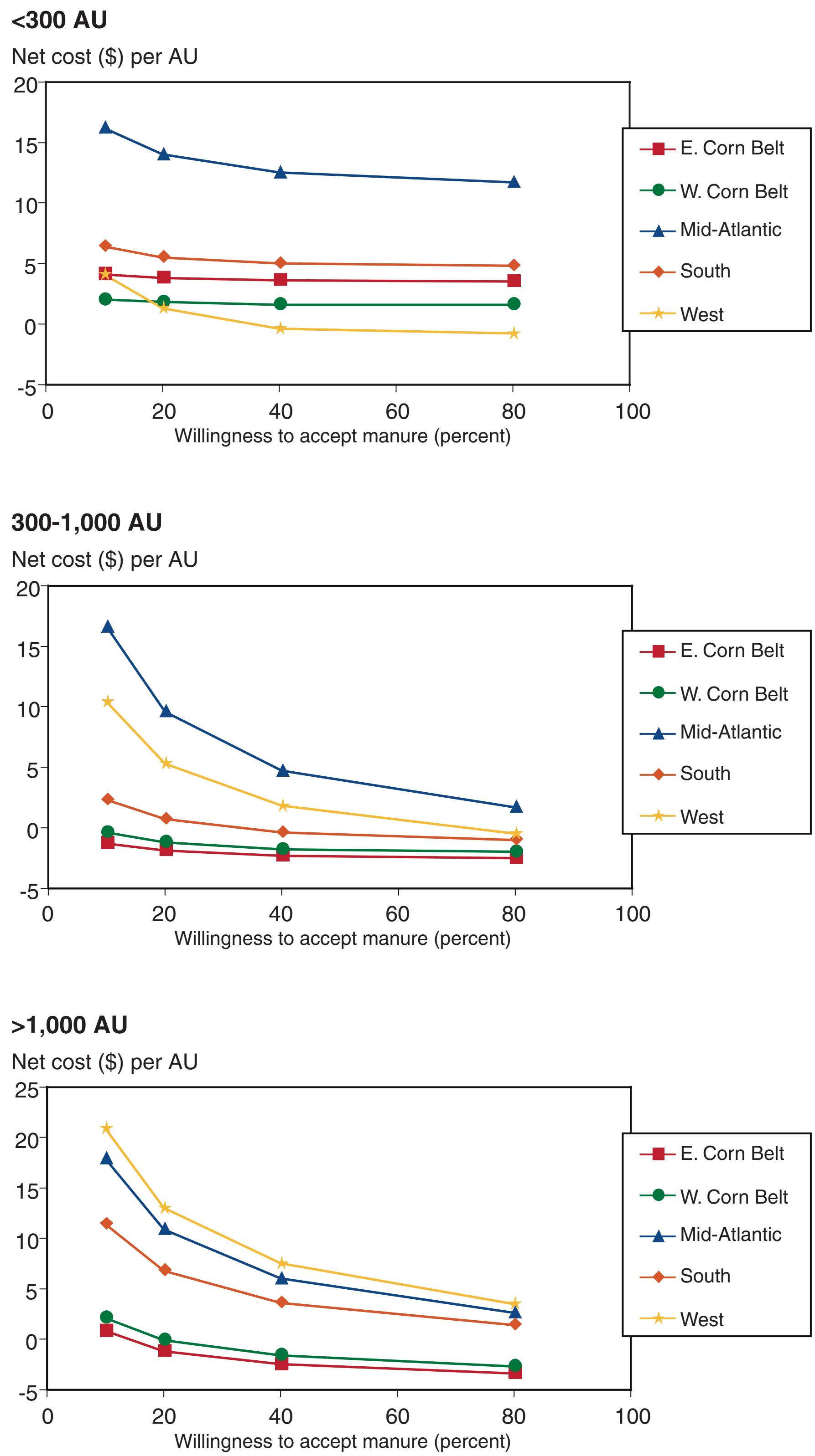
Increase in production costs for hog farms under a nutrient standard with a willingness-to-accept-manure of 20 percent, by size





Source: Ribaudo et al., 2003.

Figure 14
Net cost of spreading manure from hog farms following a phosphorus standard with all farms using phytase, by region



Source: Ribaudo et al., 2003.

Operations with fewer than 25 animals were eliminated from the analysis on the grounds that they were not confinement operations. Dairy farms were grouped into three size classes based on the EPA definition of animal unit, 0.7 mature dairy cows (Table 8). Two regions were considered, North and South.

Most small dairies would not have been affected by a nitrogen-based standard, as they were not overapplying manure N, although there are regional differences (Table 8). Most medium and large dairies generally do not own enough land for applying all their manure under an N-based standard, and must move some off the farm. As with hog farms, large operations would have to increase the amount of land receiving manure the most (Ribaudo et al., 2003) (Table 9). If farms were required to meet a phosphorus-based standard, the amount of land needed off the farm would increase substantially, as well as the number of farms needing to move manure off the farm.

The net costs of meeting a nitrogen based applications standard would be highest for medium-sized dairies (Figure 15). Even with a high willingness to accept manure, manure application costs are about $10 per AU for medium-sized dairies. For large operations, costs approach 0 as WTAM approaches 80 percent. Small operations also see costs that are higher than large operations. Meeting a P-based standard would increase the net costs of spreading manure for all size classes because of the larger amount of land needed for spreading (Figure 16). Costs approach $20 per AU for medium operations, even at high WTAM. Costs are much higher at lower WTAM.

Table 8

Percentage of dairy farms meeting N-based and P-based standards, by region and EPA size class, 2000

Region	Farms with confined dairy cows	Farms meeting N-based standard	Farms meeting P-based standard	Farms with adequate land for N-based standard	Farms with adequate land for P-based standard
	Number			*Percent*	
South					
<300 AU	1,998	19.5	4.8	33.2	18.4
300 – 1,000 AU	1,921	5.7	0	8.5	1.1
>1,000 AU	1,268	21.3	1.0	26.6	2.6
North					
<300 AU	55,622	72.1	27.3	91.2	66.4
300 – 1,000 AU	1,893	46.4	10.9	66.2	31.6
>1,000 AU	603	26.5	0	26.5	0
Nation					
<300 AU	57,620	70.8	26.7	89.8	65.3
300 – 1,000 AU	3,814	27.5	5.8	39.4	17.5
>1,000 AU	1,871	23.0	0.7	26.6	1.8

AU = 0.7 mature dairy cow.

Operations with fewer than 25 cows were dropped from the analysis

Source: Ribaudo et al. (2003)

Table 9

Estimated acreage being used for spreading and acreage needed to meet nutrient standard on dairy farms, by region and size, 2000

Region	Acres being used	Own available acres[1]	Acres needed	
			N-based standard	P-based standard
			Acres	
South				
<300 AU	52.6	76.5	143.4	262.0
300 – 1,000 AU	129.4	114.8	343.8	795.3
>1,000 AU	310.4	319.6	661.3	2001.0
North				
<300 AU	100.7	207.0	63.6	147.2
300 – 1,000 AU	328.3	584.0	338.8	756.8
>1,000 AU	330.9	391.4	564.2	1,979.0
Nation				
<300 AU	99.5	203.8	65.6	150.1
300 – 1,000 AU	235.9	366.0	341.1	774.6
>1,000 AU	316.9	342.4	630.5	1,994.0

[1]Acres owned or leased suitable for receiving manure.

Source: Ribaudo et al. (2003)

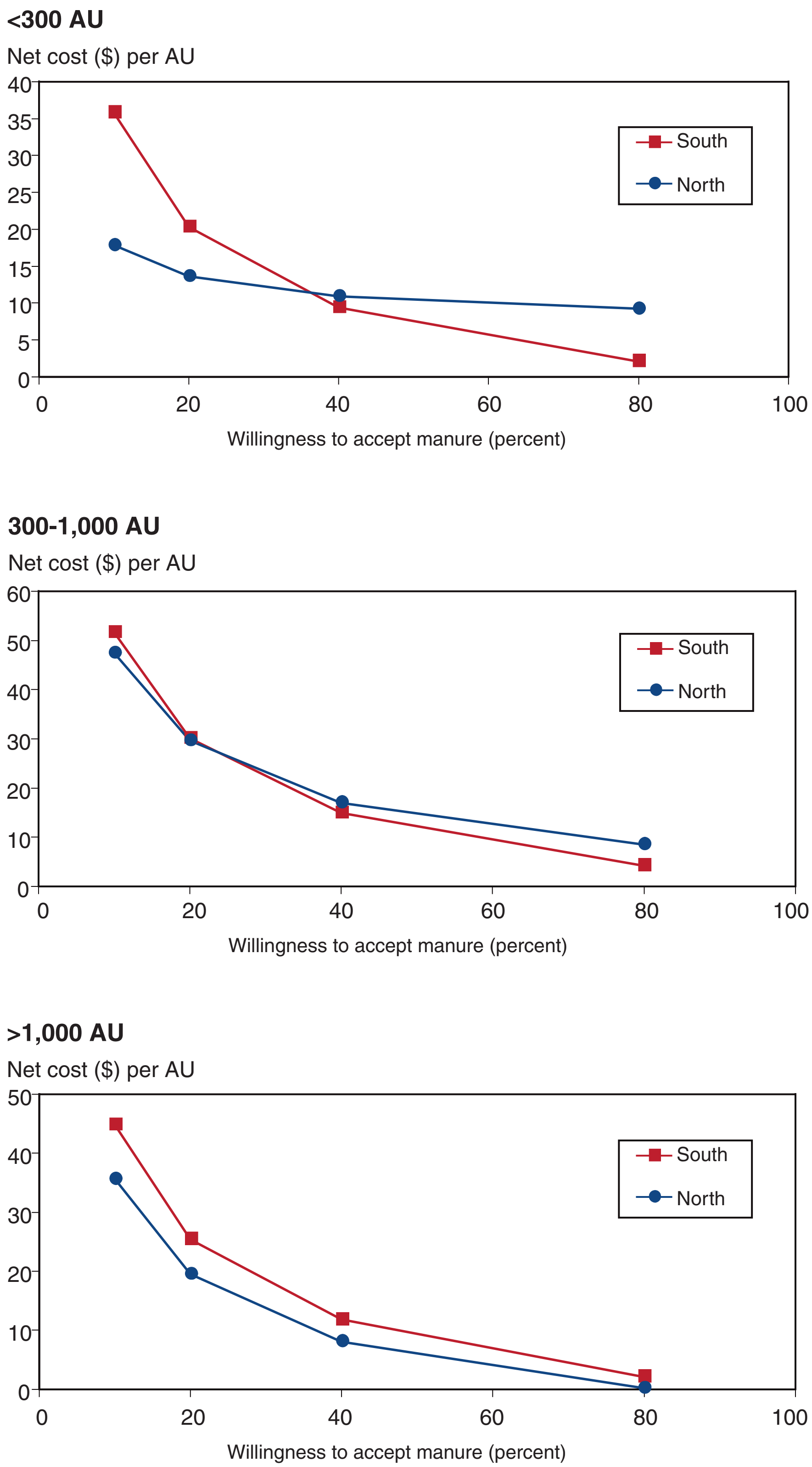
When viewed in relation to production costs (operating costs plus allocated overhead), the increase in costs from meeting a nutrient standard are relatively small, even when willingness to accept manure is low (Figure 17). As a percentage of production costs, impacts of a manure application standard would be about 1 percent or less for all regions and size classes, assuming a high willingness to accept manure (80 percent). Small operations saw the smallest impacts on production costs, primarily because of the adequacy of their land base. Even for a lower willingness to accept (20 percent), productions costs for any size class would increase less than 2 percent for an N-based standard, and less than 3.5 percent for a P-based standard.

Since 2000, dairy industry production has shifted to much larger farms. Farms with fewer than 100 cows accounted for 20 percent of all milk cows in 2008, down from 34 percent in 2000, while farms with at least 1,000 accounted for 42 percent of all cows in 2008, compared to 19 percent in 2000. An ARMS dairy version was again conducted in 2005, allowing for comparisons to the 2000 data used in Ribaudo et al. (2003).

The structural shifts, along with expanding regulation, have placed more production under nutrient management plans (49 percent of cows were covered by NMPs in 2005, compared to 40 percent in 2000). There was some increase in manure removal from farms, from 16 to 19 percent of all manure, between 2000 and 2005. Dairies could also take steps to alter feed formulations so as to reduce manure nutrients—operations covering 11 percent of all cows were adding phytase to diets in 2005.

In general, large hog and dairy operations consolidate substantial amounts of manure, and continued structural change is leading to greater consolidation. Large operations will need to comply with regulations by expanding the amount of cropland that manure is applied to, either by operating more

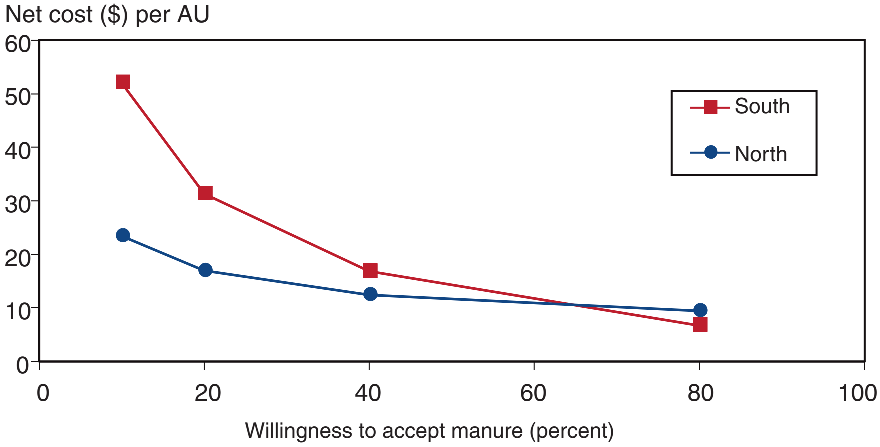
Figure 15
Average cost of applying manure from dairy farms following a nitrogen-based standard, by region



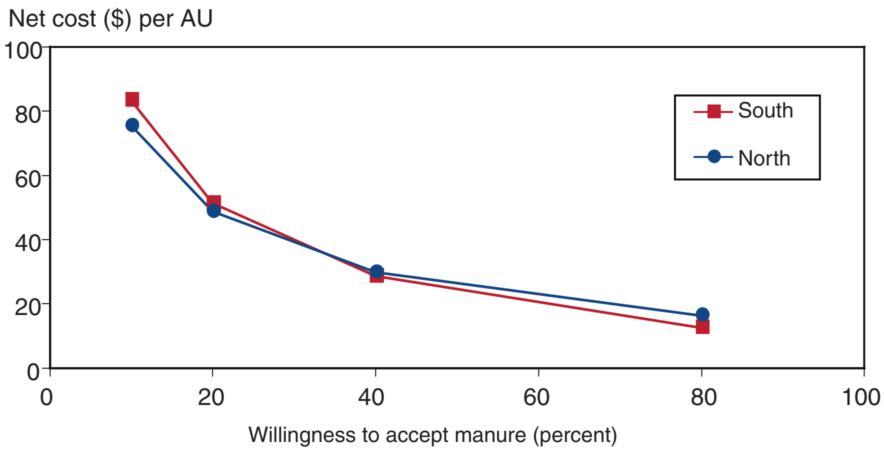
Source: Ribaudo et al., 2003.

Figure 16
Net cost of spreading manure following a phosphorus-based standard, by region

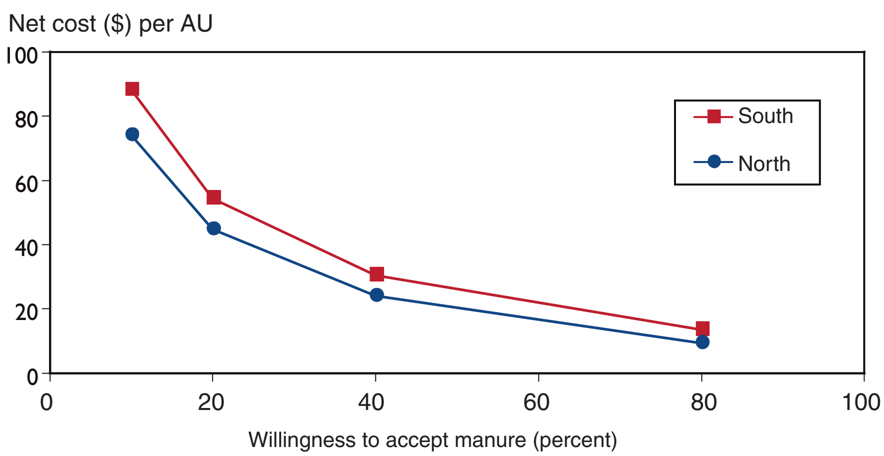
<300 AU



300-1,000 AU



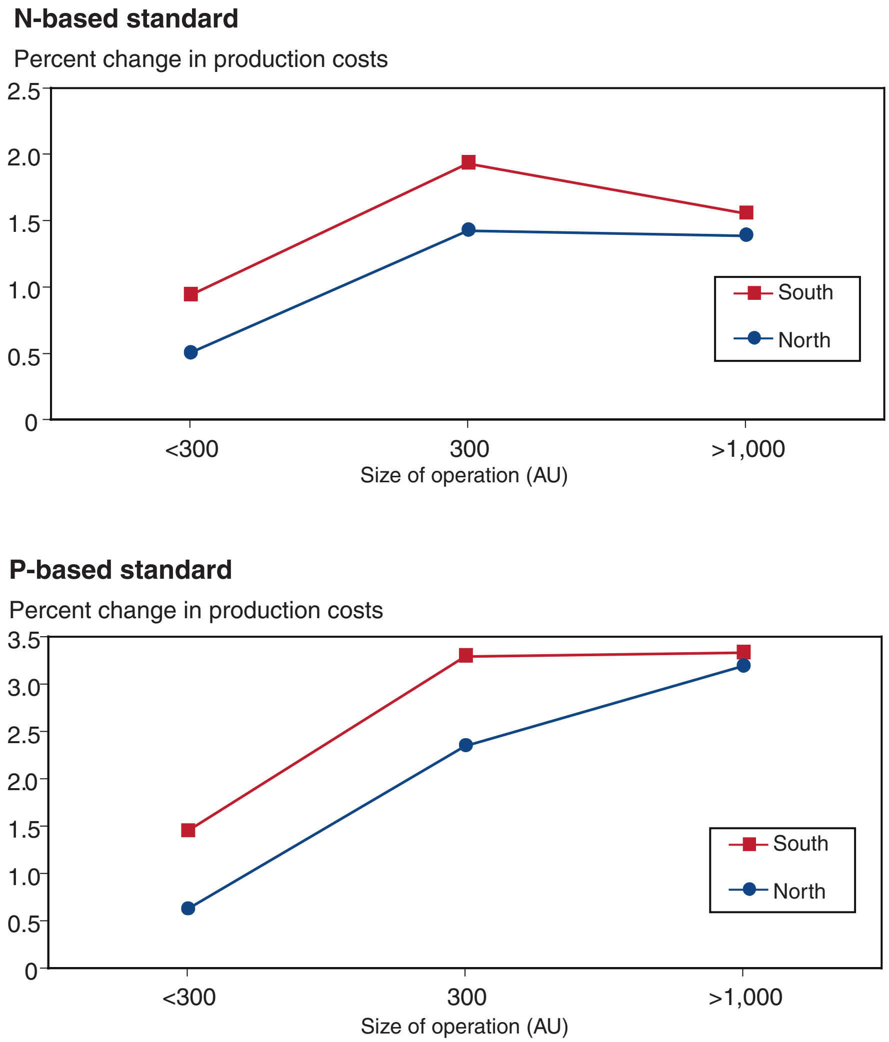
>1,000 AU



Source: Ribaudo et al., 2003.

Figure 17

Increase in production costs for meeting a nutrient standard with a willingness-to-accept-manure of 20 percent for dairy farms, by size



Source: Ribaudo et al., 2003.

manured acres on the farm or by removing manure to cropland on other farms, or they will need to reduce nutrient loadings through changes in feeding. The Ribaudo et al. (2003) estimates suggest that the likely costs required to meet NMPs, while substantial in the aggregate, are nevertheless relatively small fractions of total production costs. If those findings are accurate, they suggest that the cost advantages held by large farms will not be erased, or even substantially modified, by the types of regulations captured in nutrient management plans (in some cases, they are enhanced slightly). In that case, such regulations are unlikely to lead to major structural changes in the industries.[20]

[20]There may nevertheless be significant geographic changes in livestock feeding driven by differences in production costs, some of which may in turn be driven by future urban development, State and local moratoria on large operations, or persistent geographic differences in NMP compliance costs. Our evidence suggests that these factors may influence the location but not the size structure of production.