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Manure Management for Water Quality

Costs to Animal Feeding Operations of Applying Manure Nutrients to Land

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Abstract

Nutrients from livestock and poultry manure are key sources of water pollution. Ever-growing numbers of animals per farm and per acre have increased the risk of water pollution. New Clean Water Act regulations compel the largest confined animal producers to meet nutrient application standards when applying manure to the land, and USDA encourages all animal feeding operations to do the same. The additional costs for managing manure (such as hauling manure off the farm) have implications for feedgrain producers and consumers as well. This report's farm-level analysis examines onfarm technical choice and producer costs across major U.S. production areas for hauling manure to the minimum amount of land needed to assimilate manure nutrients. A regional analysis then focuses on off-farm competition for land to spread surplus manure, using the Chesapeake Bay region as a case study. Finally, a sectorwide analysis addresses potential long-term structural adjustments at the national level and ultimate costs to consumers and producers.

Keywords: manure management costs, price and quantity adjustments, water quality, animal waste, manure nutrients, excess nutrients, confined animals, CAFO, manure nitrogen, manure phosphorus, manure use, assimilative capacity, nutrient management plan

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Executive Summary

U.S. farmers are world leaders in the production of animal products. The United States has the largest fed-cattle industry in the world, and is the world's largest producer of beef. The U.S. is also the world's largest producer of poultry meat and the third largest producer of pork products. Livestock and poultry production cuts widely across all elements of the farm sector; more than half of U.S. farms raise animals, and animal products account for about half of the total receipts for agriculture. In 2002, U.S. farmers produced nearly 86 billion pounds of meat and poultry products, more than 70 billion table eggs, and 170 billion pounds of milk products. But in supplying households with hamburgers, pork chops, and ice cream, livestock and poultry farms also generate more than 350 million tons of manure that must be disposed of.

When used as a fertilizer, livestock and poultry manure can provide valuable organic material and nutrients for crop and pasture growth. However, those same nutrients—nitrogen and phosphorus—can degrade water quality if they are overapplied to land and enter water resources through runoff or leaching. New regulations—enacted by the Environmental Protection Agency in February 2003—require the largest confined animal operations to meet nutrient application standards when disposing of their manure by spreading it on cropland.

The EPA regulations affect only those largest farms designated "concentrated animal feeding operations," or CAFOs. While making up only about 5 percent of animal feeding operations, they contain 50 percent of all animals and produce over 65 percent of excess nutrients. If all CAFOs meet the nutrient standards outlined in the new regulations, increases in production costs could be felt throughout the food and agricultural system. We evaluated these costs at the farm, regional, and national levels to provide a full perspective on potential economic impacts.

- *Complying with the EPA regulations will require CAFOs to spread their manure over a much larger land base than they are currently using, and most will need to move their manure off farm.* Only 18 percent of large hog farms and 23 percent of large dairies are currently applying manure on enough cropland to meet a nitrogen standard. Further, even if they spread manure over their entire land base, only 20-50 percent of all large hog farms operate enough land to meet land application standards, depending on whether a nitrogen or phosphorus standard is to be met. The new regulations will require even more large dairies to move their manure off farm; at best, just slightly more than one-quarter of all large dairies manage an adequate land base to spread their manure on and fewer than 2 percent have an adequate land base to meet a strict phosphorus-based standard. Similar results would be expected for beef and poultry.

- *Livestock and poultry farms' annual net income could decline by more than $1 billion (around 3 percent), but the precise outcome depends greatly on the extent to which cropland operators are willing to substitute manure for commercial fertilizers, and the degree to which revenue from sales of higher priced animal products mitigates increases in production costs.* Livestock and poultry producers' net income is predicted to decline by $1 billion if 40 percent or more of all U.S. cropland is available for spreading manure. On the other hand, if cropland farmers accept manure on only 20 percent of cropland, the per-animal cost to CAFOs for disposing of their manure would increase such that they would likely reduce their production. The net effect of increased manure transportation costs and decreased production levels, offset by increased prices for animal products, could result in a small (0.3 percent) increase in net revenues to livestock and poultry producers that remain in production.

- *Phosphorus-based standards are more costly than nitrogen-based standards.* A farm-level analysis of hog and dairy CAFOs suggests that their production costs could increase by twice as much, on average, under a phosphorus-based versus a nitrogen-based standard. The higher cost associated with the phosphorus standard reflects higher concentrations of phosphorus in manure than of nitrogen, relative to crop nutrient needs. More land is required to spread manure under a phosphorus standard than under a nutrient standard because less manure is needed per acre to satisfy crops' phosphorus needs. The cost gap between the nitrogen and phosphorus standards would shrink if regulations allow phosphorus to accumulate in the soil profile.

- *Production cost increases will vary by species and by region.* In general, costs will be lower in the Corn Belt than in other regions. Crop production is more prevalent there and livestock concentrations are lower, so manure does not have to be hauled as far off the farm to reach adequate land. Costs to hog producers, in particular, will depend greatly on where farms are located. Costs are highest in the Mid-Atlantic where hog densities are greater and cropland is not as common a land use in counties where hogs are raised. Under a phosphorus standard and with 20 percent of crop operators willing to take manure, hog farms in the Mid-Atlantic, South, and West would experience a 2- to 3-percent increase in production costs, while hog farmers in the eastern and western Corn Belt would be virtually unaffected. Large dairy farms tend to be more homogeneous across the regions we examined, so dairies in the North and South both experience similar increases in production costs (about 3 percent for a phosphorus-based standard when 20 percent of crop operators accept manure).

Crop producers are not subject to the new EPA manure management regulations, but are likely to experience indirect effects. Crops are linked to animal production in two ways. Many crops are used as livestock and poultry feed. Any changes in livestock and poultry production in response to the environmental regulations could result in shocks to the feed markets. On the other hand, cropland farmers could reap the benefits of using manure as a nutrient source. As adjustments filter through the food and agricultural system, consumers could also be affected.

- *Net returns in the crop sector could increase by more than $400 million as manure nutrients replace commercial fertilizer.* While small price increases for some crops are predicted, and would have a positive effect on revenues in the crop sector, the $400 million gain is primarily associated with savings due to reduced commercial fertilizer use. Of course, commercial fertilizer suppliers would feel some portion of that gain as a loss in revenues.

- *Sectorwide adjustments in livestock and poultry production, and related changes in feed crop production, could result in price shifts that would be felt throughout the food and agricultural system.* If farmers' willingness to accept manure is limited, prices for animal products could increase by up to 6 percent, while prices for feed crops (e.g., corn, oats, and soybeans) could increase by 1 to 3 percent. However, if manure is accepted on 40 percent or more of cropland in each region, prices for crops and animal products are all likely to remain unchanged. Results will also depend on domestic and international market dynamics (which influence price responsiveness).

- *Consumers could bear the cost of higher prices for animal products, but they could also benefit from improved water quality.* Although livestock and poultry producers could see higher net revenues if cropland farmers' willingness to accept manure is limited, that net benefit reflects increased consumer costs. The result is a net economic loss when consumer costs and producer benefits are added together. This analysis does not quantify the value of environmental benefits.

Although EPA regulations apply only to large operations, USDA policy encourages all animal feeding operations (AFOs) to adopt nutrient standards voluntarily, and provides financial assistance for doing so. Bringing all AFOs under the umbrella of farms meeting nutrient standards would increase the amount of manure needing transportation, and increase the demand for cropland to spread it on. In some regions, the competition for land could be severe.

- *For most farms trying to meet a nutrient standard, the most immediate problem is finding enough land to spread manure on.* Transporting manure to adequate land is the largest cost for meeting a standard. While many small and medium-size farms control enough land to meet nutrient standards, most are not applying manure on all of their cropland, thereby over-applying manure nutrients on the portion that receives manure.

- *Production cost increases for small and medium-size animal feeding operations are generally less than 1 percent*. This result holds under all scenarios we evaluated, including the entire range of assumptions about cropland farmers' willingness to accept manure, because small and medium-size AFOs generally have to move a much smaller portion of their manure off the farm.

- *If all AFOs meet a nutrient standard, costs to the livestock and poultry sector could exceed \$2 billion (7.1 percent),* and price increases to consumers would be greater than if only CAFOs met the standard. Although production cost increases could be relatively small at the farm level for small and medium-size AFOs, the increased demand for receiving cropland means that costs to CAFOs would be larger than if they were the only operations attempting to apply their manure at agronomic rates. In addition, the large number of AFOs suggests that even small costs at the farm level could translate into substantial costs sectorwide.

- *Competition for land for spreading manure could be severe in regions with high concentrations of animals.* Animal feeding operations in 2 to 5 percent of U.S. counties produce more manure nutrients than can be absorbed by all of those counties' cropland and pasture. Those counties are primarily in North Carolina, States surrounding the Chesapeake Bay (Virginia, Maryland, and Delaware), Southeastern States (such as Georgia, Alabama, and Arkansas), and in California. Consequently, operations in those regions would have to compete for available land if all manure were to be spread at agronomic rates. This could result in farther travel and higher costs.

- *The willingness of cropland operators to accept manure is critical in determining whether land application is feasible for disposing of all manure in regions with high animal concentrations.* For example, in the Chesapeake Bay Watershed, under a phosphorus-based standard, if less than 60 percent of cropland receives manure because of cropland operator preferences, there would not be sufficient land for spreading manure within a 90-mile radius of manure production.

- *Industrial processing of poultry litter might be a feasible alternative when the transportation costs for hauling manure to available land are high.* Analysis for the Chesapeake Bay Watershed suggests that cost savings from not having to haul manure long distances could be sufficient, on a per-ton basis, to cover the annualized capital costs of industrial facilities such as fertilizer plants. Whether such plants are economically viable in the long run is uncertain, but a closer look at such alternatives seems warranted by public agencies concerned with manure management and water quality.

- *AFOs are being encouraged by USDA to adopt nutrient standards voluntarily, so the estimated cost increases suggest that many AFOs will not have sufficient incentive to voluntarily meet nutrient standards without financial assistance.*

- *Financial assistance may be available to all animal operations, which would offset some of the costs associated with improved manure management.* USDA's Environmental Quality Incentives Program (EQIP) is designed, in large part, to provide relief to animal operations attempting to comply with EPA regulations. EQIP provides technical assistance, cost-share payments, and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm, with 60 percent of the program's funding ($1 billion per year) allocated to addressing livestock issues. To the extent that livestock and poultry producers' costs may be reduced through this or other conservation programs, the cost estimates and adjustments discussed in this report will be an overestimate.

Our analyses focused on land application of manure and the costs that animal producers might face in meeting nutrient application standards. Our findings have identified several issues that will require additional research, and indicated potential options for reducing the costs of meeting environmental goals.

- *Crop producers' willingness to accept manure is a very important determinant of manure-spreading costs.* A number of factors impede greater use of manure, including uncertain nutrient content, soil compaction associated with heavy manure application machinery, and odor. Research on how these impediments might be overcome, education on the benefits of using manure, and financial assistance for crop farmers using more manure could reduce farmers' manure management costs.

- *Advances in feed management in the near future may increase the options available to livestock and poultry producers for reducing nutrients in manure.* Further economic analyses could indicate the potential for such advances to reduce overall manure management costs, and how the use of such feed management options might be encouraged. We found that one such option, phytase in hog feed to reduce phosphorus concentrations, could reduce manure management costs for large hog farms under a phosphorus-based standard by up to 20 percent.

- *The costs of complying with manure management requirements could instigate structural and geographical shifts in the livestock and poultry sectors.* Our analysis indicates that the highest per-unit costs for meeting a nutrient standard are often borne by the largest operations. Sectors such as swine and poultry have seen a significant move toward integration, the use of production contracts, and larger farms, primarily because of the efficiencies these structural changes bring. The impacts of manure management costs on the potential benefits from this structure could influence whether such trends continue, whether smaller operations (non-CAFOs) not affected by current regulations become more competitive, and the degree to which location will be considered in expansion decisions.

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Chapter 1–Introduction

Livestock and poultry manure can provide valuable organic material and nutrients for crop and pasture growth. However, nutrients contained in animal manure can degrade water quality if they are overapplied to land and enter water resources through runoff or leaching. The nutrients of greatest water quality concern are nitrogen and phosphorus. Animal waste is a source of both.

A shift in the livestock and poultry industry over the past several decades toward fewer, larger operations has prompted public concern over the use and disposal of animal manure. Manure lagoon spills in North Carolina and *pfiesteria piscicida* outbreaks in North Carolina and Maryland have raised public concerns about the way manure is stored and handled. In response, State and Federal environmental protection authorities now require that manure be handled and applied to land so as to minimize runoff and leaching. However, such restrictions affect livestock and poultry production costs.

Producing feed on the farm, once a mainstay of animal production, is becoming rare. As animal operations grow larger, they increasingly buy feed from outside the farm. This is reflected in the reduced amount of available cropland per animal on livestock and poultry farms (Gollehon et al., 2001). Nevertheless, land application is still the predominant method for disposing of manure and recycling its nutrient and organic content (USDA-EPA, 1999). Concerns have consequently arisen that crops and other vegetation are not fully assimilating nutrients in manure, and that excess nutrients are increasingly likely to degrade nearby water resources. The land application rate—the quantity of manure spread on an acre of land—is believed to be the single most important manure management decision affecting the potential for contamination of water resources by manure nutrients (Mulla et al., 1999).

Recent policies and programs for increasing the efficient use of nutrients and protecting water quality from nutrient runoff all emphasize the importance of properly handling animal manure. The Unified Strategy for Animal Feeding Operations, jointly developed by the U.S. Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) in 1999, states: "Land application is the most common, and usually most desirable method of utilizing manure because of the value of the nutrients and organic matter. Land application should be planned to ensure that the proper amounts of all nutrients are applied in a way that does not cause harm to the environment or to public health. Land application in accordance with a comprehensive nutrient management plan (CNMP) should minimize water quality and public health risk" (USDA-EPA, 1999, pp. 8-9). A goal of the Unified Strategy is that all animal feeding operations—regardless of size—voluntarily adopt CNMPs for managing their nutrient resources, including both commercial fertilizer and animal manure.

However, rules promulgated in 2003 by EPA are designed to change the way animal operations are handled under the Clean Water Act. Under the new regulations, "concentrated animal feeding operations" (CAFOs) would be **required** to meet nutrient application standards as defined in a nutrient management plan. The plan would become a part of the National Pollutant Discharge Elimination System (NPDES) permits that all CAFOs need in order to operate. Violations of the permit are subject to fines and/or facility closure.

Implementation of nutrient standards for manure application will raise manure management costs for many farms. At the farm level, their implementation will, in many cases, require operators to find additional land on which to spread manure and to absorb the cost of transporting and applying animal manure to this land. If land off the farm is required, animal operations may incur additional rental payments or disposal fees. In most cases, though, the animal operation pays only the cost of hauling and applying manure.

In some areas of the country, large concentrations of confined animals would strain the ability of any individual CAFO to secure adequate land locally for spreading manure. The competition for land would likely elevate waste-handling costs since some operators would be forced to transport manure over longer distances for disposal. The willingness of crop producers to accept animal manure from livestock and poultry operations will also determine land supply and hauling distance. High transportation costs regionally could encourage the development and expansion of alternative uses of manure, such as for commercial fertilizer or energy production. High manure management costs could, under certain circumstances, induce animal operations to spread out geographically, to relocate to areas with more abundant land, or to reduce herd size.

Implementation of new requirements on animal waste management could affect not only producers, but consumers as well. A substantial spike in waste management costs could result in regional shifts in animal production and increased prices for animal products and certain feedgrains and other crops.

Objectives

Previous studies have suggested that restrictions on manure management similar to the ones promulgated by EPA will increase the costs of manure management. Systematic analyses across the different animal sectors would help to identify critical issues arising from implementation of the new rules. We present a multidimensional framework, based on farm-level, regional, and sectorwide analyses (see box, "Scope of Analysis"). The different scales are important because each addresses a different set of issues or questions.The interactions between the resource base and manure management are best examined at the farm level. However, the impacts of a national policy are felt across regions, and these impacts can be transferred across the economy through the market system. We use the most comprehensive data available to provide a fuller understanding of the costs of the new rules across farm types, regions, and a range of values for key policy variables. We specifically address competition for land on which to spread manure, an issue that has not been addressed in the literature, as well as the willingness of landowners to accept manure.

Chapter 2 reviews some of the structural changes that have occurred in the livestock and poultry sectors, animal agriculture's impact on water quality, State and

Scope of Analysis

As with all research, the strengths and limitations of this analysis are framed by the study objectives and reflected in the study's scope, methodology, and analytic assumptions. While motivated by Federal policy provisions first proposed in 1999, our study is not intended as a direct examination of either EPA's new CAFO regulations or USDA's nutrient management policies. Rather, the study provides an independent analysis of a key provision of these and other Federal and State animal waste initiatives—the land application of manure at agronomic rates. The study examines the costs and feasibility of reliance on land application for manure disposal and the effect of key factors (including policy provisions) on these costs.

The study includes three analytic components—farm-level, regional, and national analysis—to address a range of issues pertinent to the land application question (see table, p. 4). Each of these analyses focuses on issues best evaluated at its respective scale. The farm-level analysis examines onfarm technical choice and costs at the producer level for hauling manure to the minimum amount of land needed to assimilate manure nutrients. The regional analysis focuses on off-farm competition for land to spread surplus manure, using the Chesapeake Bay region as a case study. The sectorwide analysis addresses potential long-term structural adjustments at the national level and ultimate costs to consumers and producers.

While there are many differences in the scale, scope of analysis, economic variables, and assumptions about various facets of the animal industry, there are several unifying elements. Crop producer willingness to accept manure and its influence on producer costs is critical throughout the range of analyses. Our treatment of nutrient application standards, the primary policy tool, adheres to a strict definition of the standards throughout the study. Finally, the cost coefficients used to characterize the nutrient management policies, as well as the physical coefficients used to convert animal numbers to manure nutrients, are consistent among the three analyses.

Scope of Analysis

Item	**Farm-level model** (Chapter 3)	**Regional model** (Chapter 4)	**National model** (Chapter 5)
Analytic focus	Land required for manure spreading, and cost of hauling	Land required for manure spreading, and cost of hauling	National price, production, and welfare impacts
Geographic scope	Multistate regions	Chesapeake Bay Watershed	National
Unit of analysis	Farm	County/subcounty	USDA Farm Regions
Species considered	Swine, dairy	Swine, dairy, poultry, feedlot beef	Swine, dairy, poultry, all beef
Manure system types	Lagoon, slurry, dry (dairy)	Lagoon, slurry, dry/litter	Lagoon, slurry, dry/litter
Nutrient management costs included	Manure transport, application, nutrient content testing (soil and manure), management plan development		
Analytic tool	Farm-level manure hauling and application model	Regional manure hauling and application model	U.S. regional agricultural sector model (USMP)
Model structure	Simulation	Optimization, minimize net costs	Optimization, maximize net returns
Manure/Animal production	Fixed	Fixed	Estimated in model
Crop production	Fixed	Fixed	Estimated in model
Output prices	n.a.	n.a.	Estimated in model
Farm size class considered	Yes	No	Yes
Onfarm manure use tracked	Yes	Yes	No
Willingness-to-accept manure considered	Yes	Yes	Yes
Competition for land for spreading	No	Yes	Limited
Manure hauling distance	Estimated in model	Estimated in model	Weighted average
Nonland-based options	Phytase	Phytase, industrial treatment	n.a.

n.a. = not applicable.

Federal regulations to address those issues, and other research on the impact of environmental regulations on the animal sector. In chapter 3, survey data for hogs and dairy are used to estimate the short-term, farm-level implications of applying manure to land according to a nutrient standard across U.S. regions. This analysis best captures the interactions between a farm's resource base and manure disposal decisions, including how much land livestock farms would require beyond what they currently control, as well as the cost of hauling manure to this land. Both nitrogen- and phosphorus-based nutrient standards are assessed.

In chapter 4, regional policy implications are assessed for a case-study area of high animal concentrations. The analysis examines how the competition for land influences the costs of spreading manure from the viewpoint of a resource manager or policymaker trying to minimize manure transportation costs. Both nitrogen- and phosphorus-based standards are assessed. In chapter 5, the analysis is extended nationally to assess the broader impacts of improved manure management on the welfare of U.S. producers and consumers. A model of the U.S. agricultural sector is used to estimate impacts of manure management on prices, total production, and geographic distribution of production. The final chapter summarizes the findings and draws important conclusions for policymakers concerned with manure management and water quality.

Chapter 2—Background: Livestock and Poultry Industry Structure, Environmental Quality, and Regulatory Climate

The animal sector has undergone major changes in the last several decades. Economic factors pertaining to demand for meat products and organizational changes to enhance economic efficiency have resulted in larger confined production facilities that are often geographically concentrated. Increased facility size and regional concentration of livestock and poultry operations have given rise to concerns over the management of manure and potential impacts on environmental (particularly water) quality. This chapter reviews structural trends in the animal industry, potential impacts on water quality, and changes in the regulatory environment facing animal feeding operations.

Structural Change and Concentration of Animals

The number of farms with confined animals has declined dramatically and steadily from 435,000 in 1982 to 213,000 in 1997 (Gollehon et al., 2001). This decline occurred primarily in smaller operations (less than 300 animal units of 1,000 lb live weight). During the same period, the number of medium (300-1,000 animal units) and large operations (more than 1,000 animal units) grew. Medium-size operations grew by 4,400 farms to account for about 6 percent of all confined livestock and poultry farms in 1997, while large farms more than doubled to almost 4,000 farms (2 percent).

While total animal farms declined, the number of confined animals increased 10 percent between 1982 and 1997, indicating a significant increase in the average number of animals per farm. A decline in animals on small farms was more than offset by growth on medium-sized farms and large farms (Gollehon et al., 2001). In 1997, the largest 2 percent of all livestock farms produced 43 percent of all animals, by weight (Gollehon et al., 2001).

The driving forces behind structural change in livestock and poultry production are no different than those that affect many other industries: innovation and economies of size. Using new technologies and practices yields significant profits. To make use of these technologies and to capture economies of size often requires significant amounts of capital. Organizational innovations, such as production contract arrangements, enable growers to access the capital necessary to adopt innovative technologies and garner economies of size. The significant economic benefits from vertical coordination in the animal sector, particularly for poultry and swine, have led to both larger operations and a geographic concentration of animal production (Martinez, 2002; Martinez, 1999; McBride, 1997; McBride and Key, 2003).

The innovation and economies of size that characterize the livestock and poultry sector also served to separate animal production from crop production. Large, specialized facilities today focus on producing animals and purchase most of their feed from off the farm. This means there is less land on the farm on which to spread manure. The amount of land per animal unit across all animal types declined nearly 40 percent between 1982 and 1997 (Gollehon et al., 2001).

Increased animal concentrations and less land per animal have raised concerns that nutrients in manure are not being fully utilized by crops and are increasingly likely to enter ground and surface water. These concerns are heightened by events such as the lagoon rupture in Onslow County, NC, that released 25 million gallons of concentrated waste into the New River in 1995 (Mallin, 2000) and outbreaks of the toxic dinoflagellate *pfiesteria piscicida* in North Carolina and Maryland (Pease et al., 1998). Previous literature clearly points out that the value of manure is not sufficient for large confined feeding operations to manage according to agronomic needs, even before considering the environmental impacts (Roka and Hoag, 1996; Henry and Seagraves, 1960). Continued overapplication of nutrients on land increases the potential for environmental damage.

Confined Animals and Excess Nutrients

Land application has been and remains the predominant method for disposing of manure and recycling its nutrient and organic content (USDA-EPA, 1999). If manure is properly managed, plants assimilate most nutrients. When too much manure is spread on the land, nutrients build up in the soil and enter nearby water resources through runoff or leaching.

In 1997, a large percentage of recoverable nutrients from manure (nutrients that are available for application after collection and storage) were in excess of what the cropland controlled by animal feeding operations could assimilate, based on reported acreage and crop yields (Gollehon et al., 2001). Excess manure nutrients indicate a potential for environmental damages resulting from nutrient transport to water resources. Actual impacts depend on the magnitude of the nutrient surplus, whether manure nutrients leave the farm, the nutrient management practices used on the farm, the vulnerability of water resources to nutrient pollution, and agro-ecological conditions such as soil type and climate (Jones, 2001).

While small and medium-size livestock and poultry operations produce a large share of total nutrients, the largest operations generate the largest share of nutrients in excess of crop needs (Gollehon et al., 2001). This is consistent with a finding (Roka and Hoag, 1996; Henry and Seagraves, 1960) that large operations tend to view manure as a waste rather than a resource, and dispose of it on land closest to the facility. For example, the 6 percent of farms larger than 1,000 animal units (AUs[1]) were estimated to generate 65 percent of excess nitrogen and 68 percent of excess phosphorus (fig. 2-1) in 1997. The poultry sector produces the most total nutrients of any sector, even though it made up only 15 percent of confined animal farms. In 1997, poultry were estimated to generate 60 percent of all excess nitrogen on confined animal farms, and 61 percent of excess phosphorus (fig. 2-2). Dairy made up nearly half of confined animal farms, yet generated only 7 percent of excess nitrogen and 5 percent of excess phosphorus.

The calculations of onfarm nutrient excess may overstate excess manure nutrients actually applied because some manure is moved off production farms in some cases. However, because of transportation costs, the use of animal manure as a fertilizer may not be economically feasible on many non-livestock farms. Historically, a large share of the manure produced does not leave the farm on which it is produced (Bosch and Napit, 1992; Bouldin et al., 1984). Among the major field crops, the share of acres treated with manure ranges from about 15 percent for corn and 10 percent for soybeans to less than 3 percent for wheat (USDA, ERS, 2000a).

[1] An animal unit is defined by EPA as 1 slaughter and feeder cattle, 0.7 mature dairy cow, 2.5 swine weighing more than 25 kg, 30 laying hens or broilers if a facility uses a liquid manure system, and 100 laying hens if a facility uses continuous overflow watering.

However, total excess nutrients on confined livestock farms are more likely to be understated than overstated in this analysis because neither commercial fertilizer applications nor atmospheric deposition of nutrients are considered. Most crop farms without livestock, and many farms with livestock, use commercial fertilizers because they are less bulky, easier to apply, and have a more certain nutrient content than manure. For many producers, the convenience of commercial fertilizer often outweighs the value of manure as both a source of nutrients and a soil amendment that improves the physical and chemical properties of cropland.

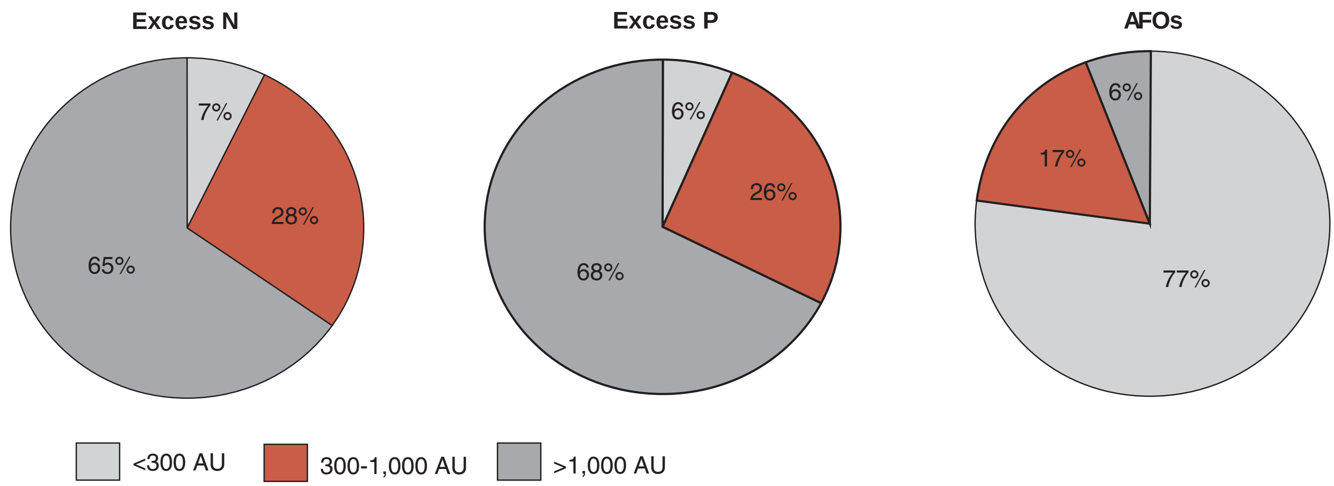
When animals are concentrated geographically, operators may have difficulty finding enough land off the producing farm to fully assimilate the nutrients in the manure. Many factors can limit the amount of land available for spreading, including land cover, topography, depth to water table, location of streams and wells, local regulations, transportation costs, and crop producer preferences. Gollehon et al. (2001) found that most counties had adequate cropland to handle the manure generated by all animal types raised on confined facilities in those counties, assuming that all crop and pasture lands were available to livestock producers. However, the assimilative capacity of nearby land was potentially limiting in some areas of high animal concentrations.

In 68 counties nationwide, the estimated manure nitrogen produced on confined livestock and poultry farms exceeded the assimilative capacity of all the county's crop and pasture land. These counties are primarily in North Carolina, northern Georgia, Alabama, central Mississippi, western Arkansas, and California. Many more counties (152) had county-level excesses of phosphorus. These counties are primarily in western Virginia, eastern Maryland, Delaware, eastern North Carolina, northern Georgia and Alabama, central Mississippi, western Arkansas, and southern California.

Manure Nutrients and Water Quality

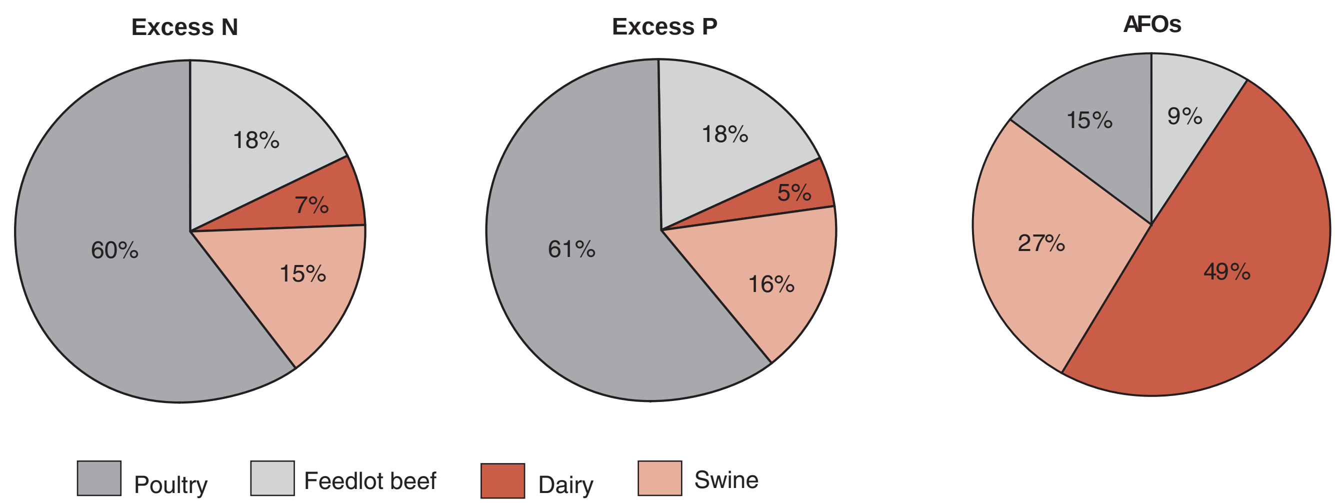
Nitrogen and phosphorus are significant pollutants of U.S. waters. Nutrient pollution is a leading cause of water quality impairment in lakes, rivers, and estuaries (U.S. EPA, 2000a). Nitrogen is easily soluble and readily transported to surface waters through runoff and tile drainage, and to ground water through leachate. Phosphorus is only moderately soluble and relatively immobile in soils, but erosion can transport

Figure 2-1
Excess nitrogen, excess phosphorus, and AFOs by size class



Source: Kellogg, 2002.

Figure 2-2
Excess nitrogen, excess phosphorus, and AFOs by animal type



Source: Kellogg, 2002.

considerable amounts of sediment-adsorbed phosphate to surface waters. If soils have been overfertilized, rates of dissolved phosphorus losses in runoff will increase due to buildup of phosphates in the soil.

Nitrogen and phosphorus accelerate algae production in receiving surface waters, resulting in a variety of problems including clogged pipelines, fish kills, and reduced recreational opportunities (U.S. EPA, 2000a). Besides harming aquatic ecosystems, nitrogen in water is also a potential human health threat, particularly to infants.

Nutrients in water resources originate from a number of sources, including industry, municipal waste treatment, agriculture, and atmospheric deposition. While well-publicized events such as those in North Carolina and Maryland fueled the public's perceptions of the problems from animal operations, a large number of watershed and plot studies have authenticated animal agriculture's impacts on water quality. States reported to EPA in 1996 that animal operations (feedlots, animal feeding operations, and animal holding areas) were a major factor in 5 percent of rivers and streams impaired by agriculture, and a contributing source in 15 percent more (U.S. EPA, 1998).[2] A USGS study of

[2] U.S. EPA's assessment relies on State self-reporting, which is incomplete and inconsistent between States (U.S. GAO, 2000). The Clean Water Act required that such a report be submitted to Congress every 2 years.

nitrogen loadings in 16 watersheds found that manure was the largest source in 6, primarily in the Southeast and Mid-Atlantic States (Puckett, 1994). In the Mississippi River's drainage basin, animal manure was estimated to contribute 15 percent of the nitrogen load entering the Gulf of Mexico (Goolsby et al., 1999). Nitrogen from the Mississippi River was found to be the leading contributor to a large zone of hypoxic (oxygen deficient) waters in the northern Gulf (Rabalais et al., 1999). A study of the relation between nitrogen concentrations in surface water and land use in the upper Midwest found that the level of nitrogen contamination is most strongly related to streamflow, acreage in corn and soybean production, density of cattle production, and population density (Mueller et al., 1993). Monitoring by USGS in the National Water Quality Assessment Program found that the highest concentrations of nitrogen in streams occurred in agricultural basins, and were correlated with nitrogen inputs from fertilizers and manure (USGS, 1999).

The State of Minnesota recently conducted an extensive environmental impact assessment of animal agriculture's impacts on water resources, and reviewed hundreds of studies conducted by scientists across the country (Mulla et al., 1999). Some of the main points they developed from the literature include:

- Livestock waste can contribute significantly to phosphorus loads in surface waters.
- Feedlot runoff contains extremely large loads of nutrients; if not properly collected before entering surface waters, this runoff can severely degrade surface-water quality.
- Nutrient losses in runoff from manured or fertilized fields were much greater than losses from unmanured or unfertilized control plots.
- Nutrient losses in runoff increased with the rate of manure or fertilizer applied.
- States with high concentrations of feedlots generally experience 20-50 lagoon spills and feedlot runoff events per year that degrade water quality.
- As the size of animal operations increases, nutrient imbalances also typically increase. This is mainly due to a lack of proper land area for spreading manure.
- As the density of animals in a watershed increases, the impact on surface-water quality grows. This is primarily due to increased production of manure nutrients, and inadequate crediting of nutrients in manure when farmers calculate their nutrient applications to cropland.

Environmental Regulations

In response to these concerns, a variety of Federal and State regulations have been enacted or proposed. The major Federal environmental law affecting animal operations is the Clean Water Act (CWA). Specifically, animal feeding operations (AFOs) may be covered by the National Pollutant Discharge Elimination System (NPDES) program established under the Act. NPDES permits are required by point sources (facilities that discharge directly to water resources through a discrete ditch or pipe) before they can discharge into navigable waters. The permits specify a level of treatment for each effluent source. Federal NPDES permits may be issued by any of the 44 States authorized to implement the NPDES program, or by EPA.

Agriculture is typically exempted from NPDES requirements. However, under regulations developed by EPA in 1974, certain AFOs can be designated "concentrated animal feeding operations" (CAFOs) and considered a point source under the NPDES program. EPA's regulations (contained in 40 C.F.R. §122.23 and Part 122, Appendix B) define an AFO as a facility where:

- Animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and
- Crops, vegetation, forage growth, or postharvest residues are not sustained in the normal growing season over any portion of the lot or facility where the animals are housed. (This does not include fields where manure might be spread.)

A CAFO is defined as an AFO that:

- Confines more than 1,000 animal units, or
- Confines between 301 and 1,000 AUs and discharges pollutants into waters through a manmade ditch, flushing system, or similar manmade device, or directly into waters that pass through the facility, or
- Is determined to be a significant contributor of pollutants to U.S. waters.

The CAFO definition contained an exemption for facilities that discharge only in the event of a 25-year, 24-hour storm event. The definition also exempted poultry operations that used dry manure handling systems. The Effluent Limit Guideline (which establishes the discharge goal for facilities requiring a permit) applicable to the NPDES permit for CAFOs is no discharge of pollutants to waters except in the event of a 25-year, 24-hour storm (40 C.F.R. § 412).

These provisions, notably, were applied only to the animal production facility. The rules presumed that manure removed from the production area was handled appropriately through land application. Land application of nutrients was traditionally treated as a nonpoint-source pollution issue, and as such, not regulated under the Clean Water Act. The high animal densities and potentially high levels of excess nutrients brought about by structural change in livestock production indicated that manure nutrients were being overapplied, but Clean Water Act regulations provided no direct response until recently.

Most States have implemented regulations for controlling the environmental impacts of AFOs that start to address the problems associated with modern production methods (table 2-1). Thirty-five states have some type of non-NPDES permit, license, or authorization program that covers CAFOs or AFOs. Of note, 34 States have a requirement covering manure application rates (prior to Federal requirements), and 27 States require the development and use of manure management plans.

Voluntary agricultural programs improve water quality by promoting various nutrient management practices. The Environmental Quality Incentive Program (EQIP) was initiated in the 1996 Federal Agriculture Improvement and Reform Act (1996 Farm Act) and amended by the 2002 Farm Security and Rural Investment Act (2002 Farm Act). EQIP provides technical assistance, cost-share payments, and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm. Animal feeding operations can receive financial assistance for waste management structures and for nutrient management. Contracts for financial assistance are for 1 to 10 years, with a maximum of $450,000 per farm over FY2002-2007. By statute, 60 percent of the available funding for the program is earmarked for practices related to livestock production. EQIP was funded at about $200 million per year from 1996 trough 2000. Funding is authorized to increase incrementally from $400 million in 2002 to $1.3 billion in 2007.

Changing Regulatory Landscape

In response to the changing structure of animal production, USDA and EPA announced in 1999 the Unified National Strategy for Animal Feeding Operations (USDA-EPA, 1999). The Strategy sets forth a framework of actions that USDA and EPA plan to take, under existing legal and regulatory authority, to minimize water quality and public health impacts from improperly managed animal manure. The Unified Strategy, when fully implemented, will set minimum standards for all State water quality protection programs.

The Unified Strategy establishes the goal that all AFO owners and operators develop and implement technically sound, economically feasible, and site-specific comprehensive nutrient management plans for properly managing the animal manures produced at their facilities, including onfarm application and off-farm disposal, if any. The Strategy cites land application as the most desirable method of using manure because of the value of its nutrients and organic matter (USDA-EPA, 1999). Nutrient management plans, adopted voluntarily or through regulation, would be tailored to address the individual needs and practices of each AFO.

To approach the goals of the Unified Strategy and to mitigate actual and potential water quality impacts from CAFOs, EPA revised the regulations for CAFOs at the end of 2002 (U.S. EPA, 2003). Some of the major changes for the NPDES permit and Effluent Limit Guidelines are:

- Eliminating the 25-year/24-hour storm exemption.
- Eliminating the exemption for poultry operations with dry manure handling systems.
- Making a nutrient management plan part of the NPDES permit, including land application of animal manure.
- Adopting a zero-discharge requirement with no overflow allowance for new swine, veal, and poultry CAFOs.
- Requiring installation of depth markers for open liquid impoundments (lagoons).

EPA estimates that up to 15,500 operations might qualify as CAFOs under the proposed regulations. Currently, about 12,000 operations are large enough

Table 2-1—State regulations for controlling animal manure

State	Permit type: Federal NPDES	Permit type: State NPDES	Permit type: State non-NPDES	Permit conditions: Effluent limits	Permit conditions: Management plan	Permit conditions: Land application plan
AL		X		X	X	X
AK	X					
AR		X	X	X	X	X
AZ	X		X			X
CA		X	X	X		X
CO			X	X	X	X
CT		X	X		X	X
DE		X	X			
FL		X	X	X		X
GA		X	X	X		X
HI		X				
IA	X	X	X	X		
ID	X		X	X	X	X
IL		X	X	X	X	X
IN		X	X		X	X
KY		X	X	X	X	X
KS		X	X		X	X
LA		X	X	X	X	X
MA	X					
MD		X	X			X
ME	X					
MI			X	X		
MN		X	X	X	X	X
MO		X	X	X	X	X
MS		X	X	X		
MT		X	X	X		X
NE		X	X	X	X	X
NC			X	X	X	X
ND		X	X			X
NH	X					
NJ		X				X
NM	X		X		X	X
NV		X				
NY	X				X	
OH		X	X		X	X
OK		X	X	X	X	X
OR		X	X			X
PA		X	X		X	X
RI		X				
SC		X	X	X	X	
SD		X	X	X		
TN		X		X		
TX		X	X	X	X	X
UT		X				X
VA		X	X	X	X	X
VT		X		X		X
WA		X	X	X	X	X
WI		X	X	X		X
WV		X		X	X	
WY		X		X	X	X
Totals	7	40	35	29	27	34

Source: U.S. EPA, 2002b, "State Compendium: Programs and Regulatory Activities Related to Animal Feeding Operations," www.epa.gov/owm/stcpfin.pdf

Permit conditions are requirements imposed through either NPDES or State non-NPDES programs.

to be considered CAFOs, but only about 2,500 actually have permits. This difference is due to the storm exemption, the poultry/dry manure exemption, and lax enforcement.

Of note, the new regulations require that CAFO nutrient management plans be based on the most limiting nutrient for applying animal manure and commercial fertilizer to cropland. This requirement essentially expands the coverage of the Clean Water Act from the production facility to the land where manure is applied. Plans would be nitrogen-based in areas where soil phosphorus is low. Where soils have high phosphorus content, plans would be phosphorus-based. A nutrient standard will limit manure application rates on most land, increasing competition for land where "spreadable" land (land capable of using manure as a plant fertilizer) is relatively scarce, and inflating overall manure management costs. This is especially true if nutrient management plans are phosphorus based. Animal manure contains more phosphorus than nitrogen relative to plant needs, meaning that less manure can be spread on a given acre under a phosphorus limit than a nitrogen limit (Mullins, 2000). Therefore, with a given amount of manure, more land would be required for spreading under a phosphorus limit than a nitrogen limit.

Changes in industry structure and environmental regulations raise important questions about the economic impacts of abiding by the new nutrient standards. These impacts are the subject of this report.

Overview of Previous Literature

The economic literature on the environmental aspects of manure from confined animal feeding operations has taken two tracks. One deals with the joint production of meat and manure and the incentives to take advantage of the nutrient content of manure. The other deals with the costs to the industry of meeting restrictions on manure management in order to achieve an environmental goal.

Henry and Seagraves (1960) presented the basic economics of transporting animal waste. They recognized the potential environmental problems from poultry litter as that sector was moving toward larger production facilities. The two most important factors that determine the net value of manure are its nutrient content and the distance it needs to travel before it is used. Nutrient content enhances manure's value, while transportation distance reduces it. The authors conclude that the unprofitability of moving litter long distances (because of an unfavorable weight-to-nutrient ratio) leads to nearby application. With higher application rates that surpass crop needs, the value of manure drops because crops cannot utilize the extra nutrients.

Roka and Hoag (1996) looked for evidence that swine producers factor the value of manure into their livestock management decisions. In their estimation, a farmer makes three decisions that affect the value of manure: choice of a treatment system, choice of area receiving effluent, and choice of crops grown. The authors found that the value of pork dominates a producer's hog marketing decisions, and that producers are relatively insensitive to the value of manure. Under the most favorable conditions, manure value is negative (-$2.94/head), yet production cycles or other management options were not changed in order to increase manure's value. Manure's negative value may prompt farmers to view it as a waste rather than a resource, and to overapply it on land nearest the production facility.

Gollehon et al. (2001) and Kellogg et al. (2000) demonstrate that large confined animal operations produce excess nutrients. Census of Agriculture data show the relationship between increased concentration in the livestock/poultry industry and the increase in onfarm "excess" manure nutrients, or nutrients above a crop's needs. They showed that excess nutrients have increased between 1982 and 1997, and that excess nutrients occurred primarily on large facilities.

Innes (2000) developed a conceptual model of livestock/poultry production and regulation to illuminate the issues of manure generation and management. The model represents the waste management decisions of private livestock producers, manure impacts on the environment, the effect of market forces, and implications for the design of efficient government regulatory policies. The model includes spills from animal waste storage (lagoons), nutrient leaching and runoff from fields, and direct ambient pollution from livestock operations, including odors, pests, and ammonia gases.

Innes used the model to evaluate how various regulations on livestock production affect economic efficiency, and found that the externalities associated with livestock production (e.g., water pollution and air pollution) result in too many large facilities that are also inefficiently large. Another finding is that regulations that focus only on waste handling result in inefficiencies in spatial arrangements of production. A solution to improve economic efficiency is to regulate livestock facility sizes and entry as well. Innes contends that when the government cannot directly regulate manure application, producers will always choose to spread more manure nutrients to nearby cropland than crops can use. In this instance, regulating observable producer choices that affect manure-spreading practices might enhance economic efficiency.

Farm-level assessments have dominated empirical research on how manure restrictions would affect livestock operations. These assessments generally rely on representative farm modeling to estimate costs of management changes needed to comply with an environmental goal. The models are generally optimized across various management options, including number of animals, storage system type, manure application rates, and crops grown.

Fleming et al. (1998) estimated the costs of spreading manure according to a nutrient application standard for various types of swine farms in the Midwest. This study emphasized the transportation costs of hauling manure to land for spreading. While not an optimization model for manure management, the model provides a means for estimating short-term costs of spreading manure. Fleming et al. also used the model to find an "optimal" herd size, balancing the costs of manure spreading with the benefits of manure nutrients for crop production. They concluded that manure nutrient returns are maximized where nutrient-hungry crops are grown close to a medium-size swine finishing facility and manure is stored in a nutrient-conserving manner (slurry tank). With a lagoon, the cost of delivering nutrients is always greater than the value of nutrients due to nutrient loss in storage. Basing manure applications on phosphorus levels was found to increase the value of manure nutrients, but also increased delivery cost because phosphorus-based application rates require more land for spreading. The authors also noted that the market value of hogs, not the value of manure nutrients, will generally drive swine production decisions.

Fleming and Long (2002) used the same model to evaluate the cost of restricting access to cropland with excess slope for the purpose of reducing surface runoff of nutrients and other contaminants. Reducing the amount of land available for application increases the costs of moving manure to suitable land. Swine producers in Kentucky would see increased manure management costs of 35 cents per head if manure nutrient applications were restricted to land with less than 12-percent slopes (7-percent reduction in suitable land area). Larger swine farms faced a much higher cost ($2.11 per head) because of the higher acreage requirements.

Schnitkey and Miranda (1993) estimated the longrun impact of phosphorus runoff controls on a representative hog-corn farm in the Midwest. Their model allowed adjustments in manure hauling distance, application rate, and number of animals on the operation. They found that placing runoff controls on livestock-crop producers would reduce both livestock supply and producer net income.

Yap et al. (2001) also used a representative farm model to estimate the economic impacts of phosphorus-based manure management for a north-central Indiana hog-grain farm. Adjustments to meet a phosphorus-based manure disposal policy included changes in cropping patterns, feed rations, manure disposal methods, and disposal locations. Like Schnitkey and Miranda, they found that moving from a nitrogen-based policy to a phosphorus-based policy reduced farmer net returns, even allowing for changes in feed rations, the use of a custom applicator, and hauling manure off the farm.

Huang and Magleby (2001) and Huang and Somwaru (2001) used individual farm models applied to survey data to estimate the costs of restricting the land application of manure for different size hog farms in two ERS-defined regions, the Heartland and Southern Seaboard.[3] Management options evaluated included adjustments in the amount of cropland receiving manure and in the manure application rate. The analysis looked at short-term impacts, assuming no change in operation size or management systems. (The models thus optimized on net returns from crop production alone rather than on net returns from both hog and crop production.) Both studies found that, for larger operations that are targeted by current policy, livestock production is the primary economic activity and, consistent with the findings of Roka and Hoag, these operations do not have the incentive to alter their operations to enhance the value of manure.

Bosch et al. (1997) used three representative farm models to estimate the economic impacts from reducing phosphorus in poultry litter (through the use of phytase in feed) in the Chesapeake Bay watershed. Under a phosphorus-based application standard, using phytase to reduce the phosphorus content of poultry litter was found to increase its nutrient value by allowing it to be applied to cropland at a higher rate. This higher application rate enables more of the crop's nitrogen need to be met by poultry litter, so less commercial nitrogen is applied. However, the value of lit-

[3] The Heartland region mainly covers Iowa, Illinois and Indiana, and parts of Ohio and Missouri. The Southern Seaboard mainly covers Virginia, North Carolina, South Carolina, Georgia, and Alabama. A description of ERS regions can be found at http://www.ers.usda.gov/Emphases/Harmony/issues/resourceregions/resourceregions.htm#new

ter as a nutrient source is less under a phosphorus-based plan than under a nitrogen-based plan, whether phytase is used or not. Under a nitrogen-based plan, poultry litter meets both the nitrogen and phosphorus needs of the crops, and no commercial fertilizer is needed.

Pease et al. (1998) used representative dairy and dairy-poultry farms in Virginia to simulate farm income effects of nutrient management policies. Current nutrient applications exceeded recommendations on many farms. Nitrogen application restrictions were found to increase net returns for many dairies, indicating that dairies were treating manure as a waste. A phosphorus restriction provided a greater reduction in nutrient losses, but greatly reduced dairy and dairy-poultry farm incomes. The farm costs were deemed unsupportable for most dairies.

Bosch et al. (1998) estimated the savings to hog farms with anaerobic lagoons when using phytase-treated feed and faced with phosphorus-based manure application limits. Phytase can reduce the phosphorus content of manure. Using representative farm models, the authors showed that phytase was economically beneficial to farms with limited land. Farms with a higher land-to-hog ratio were better off without using phytase. They also found that phosphorus-based nutrient standards were more costly to hog farms than nitrogen-based standards, even with the use of phytase.

Babcock et al. (1997) used an accounting approach to estimate the cost to Iowa hog producers of incorporating manure in order to reduce runoff, odor, and volatilization of ammonia. They found that the cost per head for requiring soil incorporation of manure depended on the amount of manure hauled, how it was stored (which affects nutrient content), and the number of producers not currently incorporating. Compliance was estimated to increase costs 17 cents/hog if incorporating slurry and 68 cents/hog if incorporating lagoon liquid. These costs were deemed sufficient to hurt Iowa's competitiveness if the restrictions were Iowa-specific.

While the farm-level studies described above generally incorporate restrictions on land availability, they do not consider the effects of competition from nearby farms also seeking land on which to spread manure. A regional analysis that considers competition for manure disposal off the farm was conducted in the Eucha/Spavinaw watershed (ESW) in Oklahoma (Wimberly and Goodwin, 2000). The study examined the cost of exporting surplus poultry litter from the ESW watershed by using an accounting framework. Competition from other, closer sources of litter put ESW at a competitive disadvantage to those other areas. The total spread costs for ESW litter ($17 to $26 per ton) were greater than the market price for litter in destination watersheds ($15 per ton) because of transportation costs.

National-level modeling has been limited. FAPRI (2001) used a national economic model to assess the financial impact of EPA's proposed CAFO regulations on the livestock and poultry sector. Costs estimated by EPA for the implementation of the proposed regulations were used as inputs in the model, although specific waste management technologies were not modeled. Instead, industry costs for meeting effluent limit guidelines and for meeting a land application standard were aggregated and assessed for different-sized animal feeding operations in different regions. The authors showed that the added costs associated with regulatory compliance would eventually be reflected in higher prices within the respective livestock sectors. Farm numbers were also found to decrease, with smaller producers facing the greatest financial stress.

In summary, the literature on managing manure with a consideration of environmental impacts hits on several recurring themes. Animal manure is costly to move relative to its nutrient value, limiting the area to which it can be economically applied. Large operations generally do not consider the nutrient value of manure in making livestock management decisions, thus treating manure as a waste. This leads to overapplication of manure on land nearest to the facility. Restrictions on manure applications in order to meet environmental goals will increase the cost of raising animals by increasing the amount of land that is used for spreading manure and the distance that manure must be hauled.

Chapter 3—Farm-Level Analysis: Nutrient Management and the Need for Land

The EPA regulations for manure nutrients applied to land according to a nutrient-based standard affect individual livestock and poultry farms. Meeting these standards may be difficult and costly if a farm has inadequate land and manure must be moved to other crop and pasture land. Many factors influence how high (or low) these costs might be.

We used data from the 1998 hog Agricultural Resource Management Survey (ARMS) and the 2000 dairy ARMS (USDA, ERS, 2002a) to demonstrate how the nutrient management goals of EPA and USDA might affect a particular livestock sector. For each sector, we examine the consistency of current land application decisions (referred to as the baseline) against nutrient standards that are based on agronomic needs. We then use a land application cost model to estimate the cost of spreading manure according to a nutrient standard while considering the availability of cropland and the willingness of non-livestock producers to accept manure as a source of nutrients.

We consider both nitrogen-based and phosphorus-based standards, as either might be required or recommended at any given location based on the phosphorus content of the soil (see box, "Nutrient Standards," p. 38). In the case of phosphorus-based standards, we assume a strict interpretation where the standard must be met every year on every acre receiving manure. This approach is very site specific, and we did not have the data necessary to fairly assess the costs of intermediate options that would fall between the nitrogen-based standard and the stricter phosphorus standard.

Net Costs of Meeting a Nutrient Standard for Hogs

The hog industry illustrates the changes in scale, structure, and location that have occurred in the confined animal sector since the 1960s. In 1982, there were 175,284 farms with confined hogs, totaling 6.3 million animals (USDA, ERS, 2002b). In 1997, the number of farms had shrunk to 63,723 (down 64 percent), while the number of hogs had increased to 8.2 million (USDA, ERS, 2002b) with many more hogs on large facilities. An estimated 51 percent of the recoverable nitrogen (nitrogen remaining after collection and storage) in hog manure and 64 percent of phosphorus was in excess of crop needs at the farm level in 1997 (Gollehon et al., 2001). Nutrient application standards for animal feeding operations are intended to address these excess nutrients.

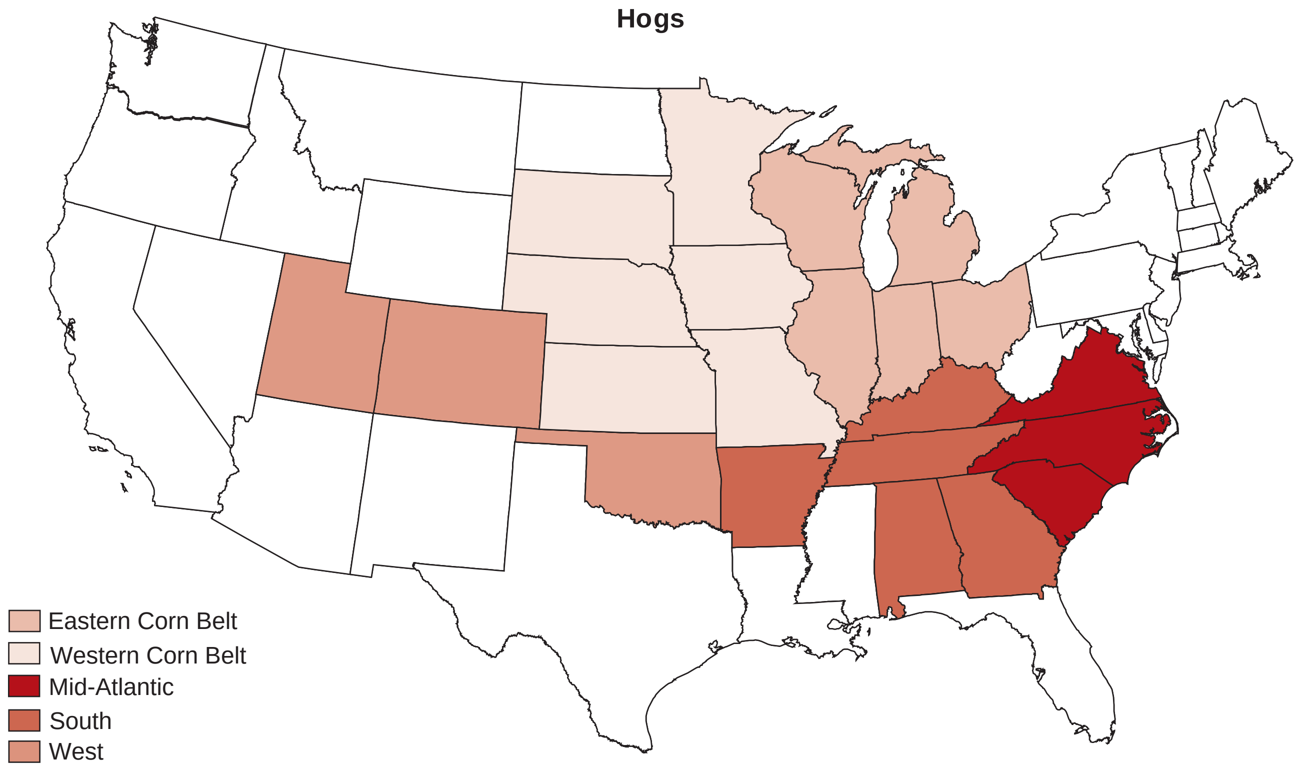
We grouped the survey data into five multistate regions: Eastern Corn Belt (IL, IN, MI, OH, WI); Western Corn Belt (IA, KS, MN, MO, NE, SD); Mid-Atlantic (NC, SC, VA); South (AL, AR, GA, KY, TN); and West (CO, OK, UT) (fig. 3-1). We looked at three size classes based on EPA's definition of animal units (where one AU is 2.5 hogs weighing more than 55 pounds): small operations (<300 AU), medium operations (300 - 1,000 AU) and large operations (>1,000 AU).

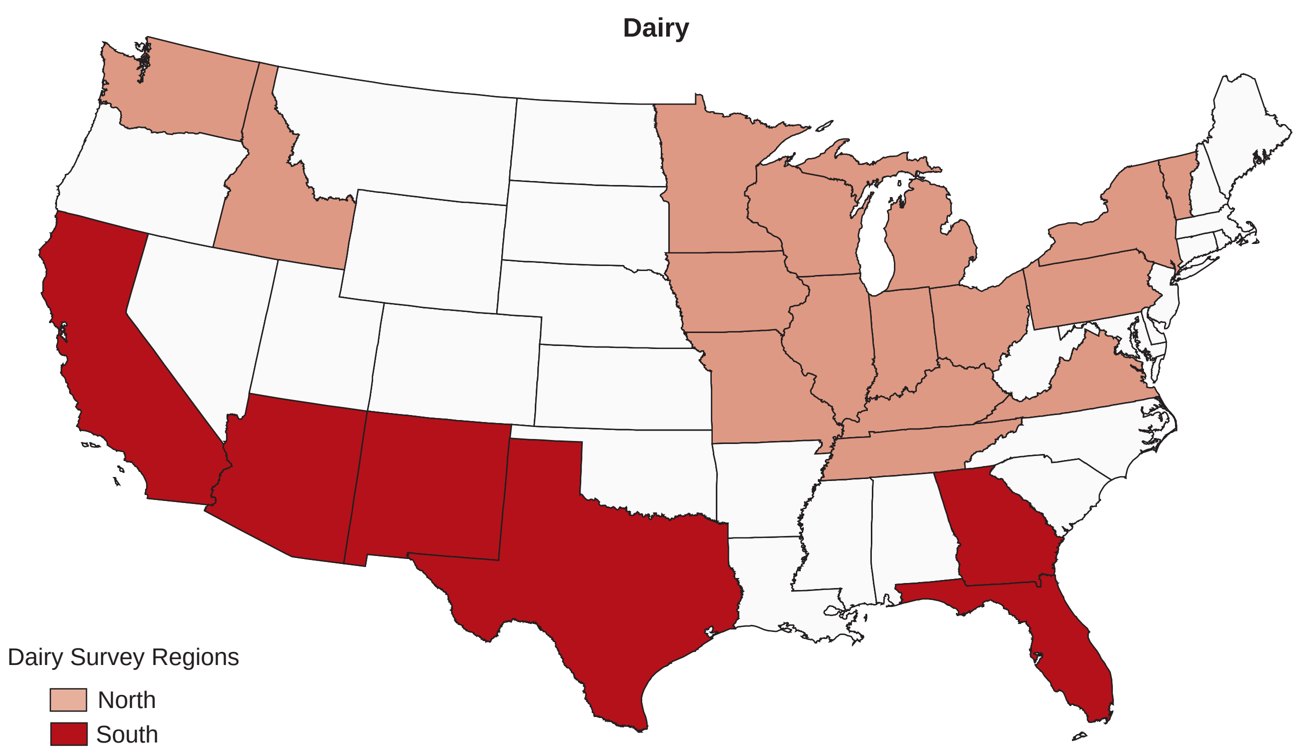
How Many Farms Are Potentially Meeting a Nutrient Standard?

How many farmers are spreading manure on enough land in the baseline scenario (1998) to meet a nutrient-based standard? We estimated the standard for each farm given the recoverable nutrients in the manure generated on the farm and the types of crops grown on the farm (see box, "Calculating the Nutrient Application Rate Under Nutrient Standards"). Even though the survey data are for hog farms, they include information on other types of animals raised on the farm as well. A nutrient standard will apply to all the manure on the farm, not just the manure from hogs, so we made our calculations accordingly. The standard-based nutrient application rate determined the amount of land needed for spreading the manure generated by the farm. We compared this estimate with the amount of land each farm reported on the ARMS survey as receiving manure.

Less than half the farms in any one size class were estimated to be meeting a nitrogen (N)-based standard in 1998 (table 3-1). Small farms had the highest percentage meeting an N-standard (45.8 percent) and large farms the lowest (18.0 percent). This was true across all five regions. The two Corn Belt regions had the highest percentage of farms meeting the standard in each size class. These results imply that most large farms will have to alter their manure disposal practices in order to comply with the new EPA regulations. Large hog farms in the Corn Belt would be better off,

Figure 3-1
Hog and dairy production regions used in this analysis





Calculating the Nutrient Application Rate Under Nutrient Standards

One of the key computations made by all three empirical procedures—farm-level, regional, and national—is determining the quantity of manure nutrients (nitrogen or phosphorus) that could be applied to suitable agricultural land without soil nutrients building up and threatening water quality. Minimizing nutrient loss is the standard that farms are to meet in applying manure and other nutrients, either voluntarily or as a result of regulation. The maximum nutrient application rate (in pounds per acre) that can meet this standard depends on the animal species, the manure handling and storage system, the manure application system, and the type of crops receiving manure. We calculated rates that were tailored to the geographic scale of each analysis.

Calculating the nutrient application rate starts with the nutrients contained in the harvested portion of the crops grown. The amount of a nutrient (N or P) removed by harvest for each of 24 crops was calculated using an average nutrient content per unit of crop output and the production level as outlined in Kellogg et al. (2000). The amount of P removed by harvest becomes the P application standard that farmers are assumed to meet. To account for unavoidable losses in the soil that make some nitrogen unavailable to plants, a "nutrient recommendation" was calculated by multiplying nitrogen removed in harvest by 1.43 (Kellogg et al., 2000). This becomes the N application standard.

but more than three-quarters would still have to make adjustments. While most small and medium farms are not directly affected by the EPA regulations, more than half might benefit from a more efficient use of the nutrients available to them. Apparent “wasting” of manure nutrients on these farms may be due to ignorance of the nutrient value of manure or to the greater costs of spreading manure on additional land versus commercial fertilizer costs.

Fewer farms are spreading manure on cropland to meet a phosphorus (P)-based standard, since the high P content of manure relative to crop needs significantly reduces the quantity of manure that can be applied on an acre of land. No large farms in the Eastern Corn Belt, Mid-Atlantic, or West met the P-based standard, and only 12.8 percent of all small farms did so (table 3-1). Given this, a P-based standard would affect many more farms than an N-based standard. These estimates consider the fact that some farms currently add the enzyme phytase to feed to reduce manure’s phosphorus content.

Farms applying manure at rates greater than a nutrient standard are not fully utilizing the nutrients in their manure. Somewhat surprisingly, most hog farms indicated on the ARMS survey that they had additional land on which manure could be spread. This is consistent with reports that large, specialized animal feeding operations treat manure as a waste rather than a valuable resource. The percentage of farms estimated to meet N- or P-based standards increases substantially when all land on each farm suitable for receiving manure is used for spreading. If all suitable land were used, about twice as many farms would be meeting an N-based standard (table 3-1). Nevertheless, more than half of all large farms still could not meet an N-based standard, and about 80 percent could not meet a P-based standard. A higher percentage of farms in the Corn Belt can meet N- or P-based standards using their own land than in any other region, across all size classes.

One pattern that emerges from these results is that farms in the two Corn Belt regions seem better able to meet a nutrient application standard than farms in other regions. For one, average hog densities, in terms of AUs per acre currently being used for spreading manure and AUs per acre of available land, differed significantly between the regions (table 3-2).[4] Densities on land receiving manure in the Mid-Atlantic region were about 5 times those in the two Corn Belt regions. A similar difference exists for land operated by the farm that could receive manure. Hog farms in the Corn Belt tend to be more integrated with crop production than in other regions, so they generally have more cropland available on the farm for spreading manure (McBride and Key, 2003).

Another reason for the Corn Belt’s relative advantage in meeting regulations is the difference in application standards compared with the other regions (at the 5-percent level of significance) (table 3-2). Its mix of crops grown and differences in crop yields enable a higher nutrient application rate. Thus, more manure can be applied to an acre of land in the Corn Belt, and less land is needed to meet a given standard.

The apparent ability of hog farms in the Corn Belt regions to meet an N-based or P-based application standard using available land is more dramatic when

[4] This difference is statistically significant at the 5-percent level. Specifically, the joint hypothesis test of equal uptake in all regions was rejected with a 95-percent probability.

Table 3-1—Percentage of hog farms meeting N-based and P-based standards, by region and size, 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

Eastern Corn Belt includes IL, IN, MI, OH, WI. Western Corn Belt includes IA, KS, MN, MO, NE, SD. Mid-Atlantic includes NC, SC, VA. South includes AL, AR, GA, KY, TN. West includes CO, OK, UT.

Source: 1998 ARMS hog survey.

Table 3-2—Manure storage system, hog density, and nutrient application standard, by region

Region	Percentage of farms using using lagoons*	Animal units per receiving (manure) acre	Animal units per acre operated	Average nitrogen application (lbs/acre)	Average phosphorus application (lbs/acre)
Eastern Corn Belt	18.2	8.4	3.7	152.6	41.7
Western Corn Belt	24.5	7.2	2.5	154.0	42.6
Mid-Atlantic	97.7	41.4	32.4	123.8	38.8
South	79.8	10.8	5.8	98.8	39.0
West	89.1	28.2	7.6	92.2	32.6

*Remainder are slurry systems.

Eastern Corn Belt includes IL, IN, MI, OH, WI. Western Corn Belt includes IA, KS, MN, MO, NE, SD. Mid-Atlantic includes NC, SC, VA. South includes AL, AR, GA, KY, TN. West includes CO, OK, UT.

one considers the dominant waste handling technologies in each region. Slurry systems are prevalent in the Corn Belt regions, while lagoons dominate elsewhere (table 3-2). Slurry systems preserve more of the nutrients in manure than do lagoon systems, which lose a significant amount of nitrogen to the atmosphere and phosphorus to the sludge at the bottom. More land would therefore be needed per animal under a slurry system than a lagoon system to meet a nutrient standard. However, Corn Belt hog farms generally had more than enough land to compensate for differences in manure storage.

How Much More Land Would Be Needed To Meet Nutrient Standards?

We used the 1998 hog ARMS data to estimate the amount of additional land each farm would need to meet N- and P-based standards. This indicates how costly it may be for hog farms to meet the standards. The acreage needed to assimilate manure produced on the farm 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 will have to spread on a larger area, which may necessitate moving manure off the farm to cropland and pasture operated by other farmers.

Additional acreage needed to meet an N-based standard is greatest for large farms (209.4 acres on average, or 393.6 acres minus 184.2 acres, or an increase of 114 percent) (table 3-3). Small farms, on average, are spreading on enough land. Medium farms would need, on average, to spread on an additional 36 acres (33 percent). Large farms in the West would need to spread on the most additional acres (600 acres, or 428 percent). In contrast, large farms in the Western Corn Belt would need to spread on an additional 106 acres (40 percent).

If a phosphorus-based standard is required, producers will have to spread on even more land. Large farms, on average, would have to spread on over 1,000 additional acres of land to meet a P-based standard. Even small and medium farms would have to increase receiving land significantly to meet a P-based standard. As with N-based plans, large farms in the West would have to increase the amount of land receiving their manure the most (1,853 acres on average, or over 1,300 percent). In contrast, large farms in the South would have to spread on an additional 693 acres, on average, or 396 percent.

Many farms have additional land on which to spread manure. This is important because manure management costs could increase greatly if much manure has to be moved off the farm and if other cropland operators willing to use manure must be found. Additional land on farms suitable for spreading manure enables the average farm for most regions and size classes to meet an N-based standard. Large farms in the Mid-Atlantic (150 acres, or 61 percent), South (302 acres, or 109 percent), and West (478 acres, or 185 percent) would have to spread on the most off-farm acres to meet the standard. Farms in the Corn Belt regions, where integrated livestock/crop production is more prevalent, have a distinct advantage in this regard.

The additional land available on farms will have less impact in meeting a P-based standard because of the amount of land such a standard requires. Farms in the Corn Belt regions and the South benefit most from having additional land that could be used for spreading manure. Large farms in the West would still need an additional 1,734 acres, on average, and large farms in the Mid-Atlantic an additional 918 acres.

One way to reduce the phosphorus content of manure and the amount of land needed for spreading is to use reformulated feed containing the enzyme phytase (see box, “Reducing Manure Nutrients Through Feed Management”). Phytase enables nonruminants (such as hogs) to better utilize phosphorus in grain, thus reducing the need to add di-calcium phosphate or other inorganic phosphorus additives common in hog feed mixes. The addition of phytase to poultry and hog feed can reduce the phosphorus content of manure by up to 45 percent (Harper, 2000). We assumed the phosphorus content of manure would be reduced by 30 percent on those farms indicating in the ARMS survey that they used feed containing phytase. Few farms indicated they used phytase—3.5 percent of small farms, 9.7 percent of medium farms, and 15.6 percent of large farms. If all farms used phytase to reduce the phosphorus content of manure, about 26 percent less land would be needed to meet a P-based standard (table 3-3).

What Are the Net Costs of Meeting the Standard?

The cost of spreading manure on additional land bears heavily on how the operation might adjust to new regulatory requirements. Assuming no other technologies are implemented for reducing the amount of surplus manure nutrients on the farm, the costs would include developing a nutrient plan to meet the standard, testing manure for its nutrient content, testing the soil on fields receiving manure, and transporting and applying manure to the necessary land base. Since animal manure has value as a crop fertilizer, the extent to which animal manure replaces commercial fertilizer on

Table 3-3—Average acreage being used for spreading and average acreage needed to meet nutrient standard on hog farms, by region and size, 1998

Region	Acres being used	Acres available on the farm[1]	N-based standard baseline	Acres needed P-based standard, phytase	P-based standard, all phytase
Eastern Corn Belt			*Acres*		
<300 AU	66.6	365.2	53.8	193.9	140.1
300-1000 AU	110.7	705.2	145.0	466.6	352.4
>1,000 AU	179.6	756.7	349.0	1,143.5	863.7
Western Corn Belt					
<300 AU	75.9	451.4	61.6	229.2	161.9
300-1,000 AU	119.4	535.5	147.4	493.2	355.2
>1,000 AU	262.8	789.5	368.7	1,206.8	882.0
Mid-Atlantic					
<300 AU	16.1	144.0	57.6	172.3	135.5
300-1,000 AU	39.2	134.5	151.7	331.1	242.7
>1,000 AU	68.7	247.3	397.9	1,166.0	851.5
South					
<300 AU	39.5	342.3	49.8	115.3	82.2
300-1,000 AU	57.6	688.2	127.7	366.4	266.0
>1,000 AU	139.7	276.7	578.8	833.1	693.3
West					
<300 AU	40.7	163.0	127.5	170.7	120.2
300-1,000 AU	59.2	5.7	138.6	272.3	218.9
>1,000 AU	139.4	258.6	736.6	1,992.6	1395.2
Nation					
<300 AU	68.5	404.5	59.6	208.2	148.4
300-1,000 AU	110.2	556.9	146.2	471.5	344.0
>1,000 AU	184.2	603.5	393.6	1,196.9	882.1

[1]Acres owned or leased suitable for receiving manure. Eastern Corn Belt includes IL, IN, MI, OH, WI. Western Corn Belt includes IA, KS, MN, MO, NE, SD. Mid-Atlantic includes NC, SC, VA. South includes AL, AR, GA, KY, TN. West includes CO, OK, UT.

Source: 1998 ARMS hog survey.

Reducing Manure Nutrients Through Feed Management

Animal diet modification to reduce the nitrogen and phosphorous content of excreted manure offers an additional way of helping producers to meet nutrient standards for land application. Researchers have made key advances during the past decade, although most of these measures have not been widely implemented due primarily to technical and economic reasons. Least-cost diet formulation typically has not incorporated ingredients to decrease nutrient excretion as there has been little or no economic (or regulatory) incentive to do so (CAST, 2002).

There are a number of interrelated approaches for reducing manure nutrients through diet modification. While some of these approaches are more relevant for certain species, feed management can reduce nutrients in all animal types.[1] Approaches include:

- Developing more accurate nutrient requirements of animals by sex and by growth phase;
- Accounting for the digestibility of nutrients in feed;
- Feeding the most digestible ingredients economically possible (increase feed efficiency);
- Increasing phase-feeding, which alters the diet with increasing age of animals;
- Minimizing safety margins for feed nutrient content that have traditionally been high;
- Substituting phytase and synthetic amino acids for alternative ration components.

[1] Current research findings identify potential nutrient reductions by animal type: poultry - 40-percent N and P; swine - 50-percent N and 60-percent P; dairy - 35-percent N and 50-percent P; and cattle - 30-percent N and 50-percent P. However, reductions that can be obtained in full production systems have not been fully assessed (CAST, 2002).

cropland constitutes a cost saving from land application. For this analysis, we assume that animal producers pay for the transportation of manure off the farm, and that they receive a payment from the crop operator equal to the nutrient value of the manure. We assume that hog producers do not pay a fee for being able to spread manure on cropland operators' fields. Total costs minus nutrient benefits are the net costs of spreading manure.

We used a model developed by Fleming et al. (1998) to estimate the change in net land application costs associated with meeting a nutrient standard (see appendix 3-A). This model estimates the net costs of spreading manure while accounting for the economic benefit of replacing commercial fertilizer with manure nutrients and for the availability of suitable land in the surrounding countryside. We first estimated a baseline net cost, using the acreage reported in the survey as receiving manure.[5] We then estimated the net cost of applying manure to the land required by an N- or P-based standard. The difference between the net cost of spreading on required acreage and net cost of spreading on baseline acreage is the net cost of meeting the nutrient standard. To this we added the costs of developing a nutrient management plan, testing manure, and testing the soil. The net costs we report are those attributable only to hogs. Net costs of handling manure from other animal types on the farm are factored out, based on their share of total farm manure nutrients. All farms bear the cost of developing a nutrient management plan and conducting nutrient tests, even if they were spreading on an adequate amount of land in the baseline.

A particularly attractive feature of the model is that it accounts for land use in the surrounding area and the willingness of cropland operators to use manure as a source of crop nutrients. Both factors influence the distance that manure must be hauled to reach an adequate amount of land. There is little basis for choosing a level of willingness-to-accept-manure (WTAM). Currently, cropland operators supplement commercial fertilizer with manure as part of their crop fertilization regime on 17 percent of corn acreage and 2-9 percent of soybean acreage (USDA, ERS 2000a, p. 36). We examined net costs over a WTAM range between 10 percent and 80 percent (see box, "Willingness to Accept Manure").

Nitrogen. At any given level of WTAM, the net cost of meeting an N-based application standard would generally be highest (on an animal unit basis) for small operations (fig. 3-2). This result is surprising if one considers only manure hauling and application costs, since almost half of small farms were already meeting the N-based standard. However, plan development and testing costs, which are independent of the number of animals, are higher (on an animal unit basis) for small operations than for larger operations. Net unit costs are therefore relatively high. Medium operations enjoy lowest unit costs, since plan and testing costs are spread over more animals and fewer farms have to move manure off the farm. Net unit costs for large operations are higher than for medium operations. Even though the plan and testing costs per AU are lower, hauling costs increase greatly due to the need to move more manure off the farm.

Crop producer willingness to accept manure has a profound impact on net costs. The cost of hauling manure to suitable land decreases as more cropland operators are willing to take manure. The effect is greatest when farms must move significant amounts of manure off the farm. This is why the Corn Belt regions do not see as great a decrease in net costs as the Mid-Atlantic or West as willingness-to-accept increases. A larger share of land needed to meet an N-based plan is located on the farm in the Corn Belt than other regions.

In some scenarios (primarily for the Corn Belt regions), the average net costs of meeting an N-standard are negative, meaning that the benefits from replacing commercial fertilizer with manure nutrients outweigh the costs of testing, hauling manure to the field, and applying it. Nutrients applied in excess of crop needs have no value because they are not beneficial to the crop. By reducing excess application, more commercial nutrients are replaced by manure nutrients and the value of manure increases. When a farm has enough of its own land for spreading, the nutrient value may outweigh the additional manure management costs.

This result begs the question of why farmers do not currently increase net returns by making better use of manure nutrients. There are several possible reasons. Farmers may not know the nutrient value of manure, which can only be determined through testing. There may be other constraints or costs to using manure, including uncertainty, storage, labor, and equipment. These costs are not accounted for in the simulation model. The literature cited in chapter 2 indicated that some animal operations (primarily larger ones) treat manure more as a disposal item rather than a resource with value and apply it to land closest to the facility without regard to its nutrient value. Determining

[5] We assume that land on the farm is in a contiguous block. This assumption results in an underestimation of the cost of hauling manure on the farm.

Willingness To Accept Manure

When onfarm manure production is greater than the capacity of the farm to utilize it, manure must be moved off the operations where it is produced in order to meet nutrient standards. Most will move to nearby crop farms that will accept the manure for its nutrient value and soil enhancing properties. The number of crop farms that lie within a feasible transportation range depends on the type of manure, its water content, and each farmer's perception of the value of manure. The willingness of neighboring crop farms to accept manure will have an important bearing on the animal industry, both in terms of the availability of land for manure spreading and the transportation expense to access a needed amount of land.

There are several potential drawbacks to land application of manure that could discourage greater use on cropland. These factors include uncertainty associated with the nutrient content and availability, high transportation and handling costs relative to commercial fertilizer, soil compaction from spreading equipment, dispersion of weed seeds, concerns about added regulatory oversight, and public perception regarding odor and pathogen issues (Risse et al., 2001). The willingness of crop producers to accept manure will depend on each farmer's weighting of the benefits of a natural source of nutrients and organic matter against the costs of manure application.

whether a change in application rates actually increases a particular farm's net returns would require further analysis.

Net costs in the Corn Belt regions are consistently lower than net costs in other regions across all sizes and all levels of willingness-to-accept (fig. 3-2). Three reasons explain this result. First, hog operations in the Eastern and Western Corn Belt tend to be more integrated with grain production than in other regions, so there is generally more land available per animal unit on the operation for all size classes (as demonstrated in tables 3-1 and 3-3). Second, grain production is a more pervasive land use in these regions, so availability of suitable land off the farm is much higher than in other regions, reducing the distance manure must travel. For example, NRI data indicate that 78 percent of the land in counties containing confined hog operations in the Corn Belt regions is suitable for spreading (cropland and pasture), compared with only 20 percent of the land in the Mid-Atlantic. Third, allowable nutrient application rates are generally higher in the Corn Belt regions because a large share of the crops grown use significant amounts of nitrogen (notably corn), and crop yields tend to be higher (table 3-2).

Phosphorus. For most levels of WTAM, large and medium hog farms would have to pay a higher net cost per AU for meeting a phosphorus-based nutrient standard than a nitrogen-based standard (fig. 3-3). More land is needed for spreading manure, which increases the number of farms needing to spread off the farm as well as average hauling distance relative to the N-standard. However, small farms in all regions but the Mid-Atlantic and South would see lower net costs relative to the N-standard. Small farms, on average, had enough land to meet the P-based standard. Spreading manure according to a P-based standard does not oversupply N or P, meaning that all manure nutrients are fully valued. The resulting nutrient benefits outweigh the costs of spreading on more land, as well as the fixed costs of developing and implementing a nutrient plan. Only in the Mid-Atlantic would small farms generally have to look off the farm for land, and net costs would increase under a P-based standard. The slight increase in net costs for small farms in the South is probably due to the mix of crops grown and the availability of suitable cropland off the farm.

Large farms would generally face higher net costs per AU than either small or medium farms under a P-based standard, reflecting the large amounts of land that would be needed off the farm and the steep increase in hauling costs. Contrast this to what would happen under the N-based standard, where small farms would tend to bear a higher net cost. However, this result depends on the willingness of landowners to accept manure. Increasing willingness to accept manure benefits large farms the most. At high acceptance levels, large farms in most regions would have lower unit net costs than small farms (fig. 3.3).

The two Corn Belt regions would meet the P-based standard for the lowest net costs, just as they did the N-based standard. The availability of land on and off the farm gives these regions an advantage over the others in implementing a P-based standard.

Farms can reduce their hauling and application costs by using phytase-treated feed. The cost of phytase is mostly covered by the decreased need for phosphorus supplements (Bosch et al., 1998). Large operations would benefit most if phytase were used to reduce the phosphorus content of manure (fig. 3-4). For example, the average net cost for a large operation in the Mid-Atlantic facing a willingness-to-accept of 10 percent

Figure 3-2

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

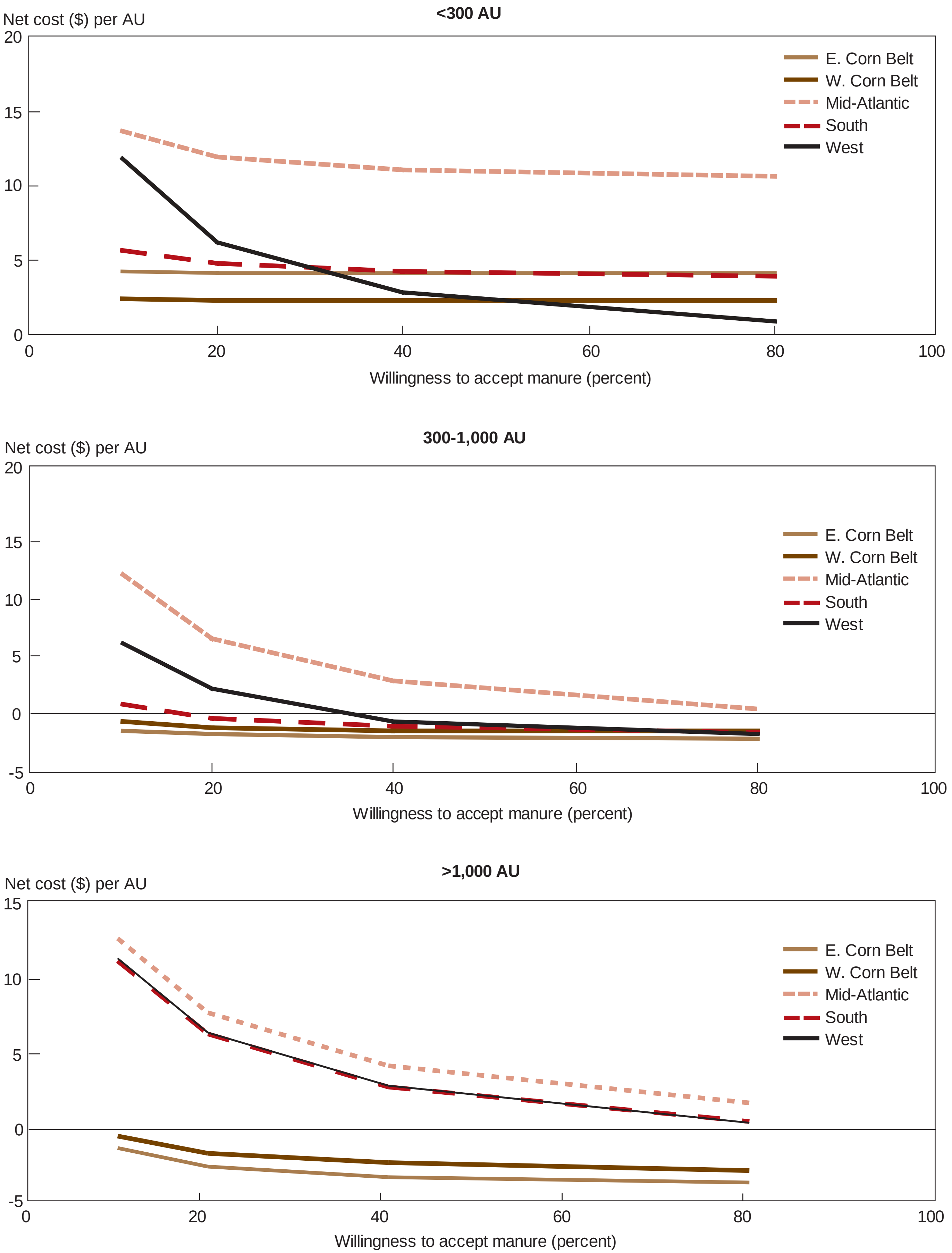
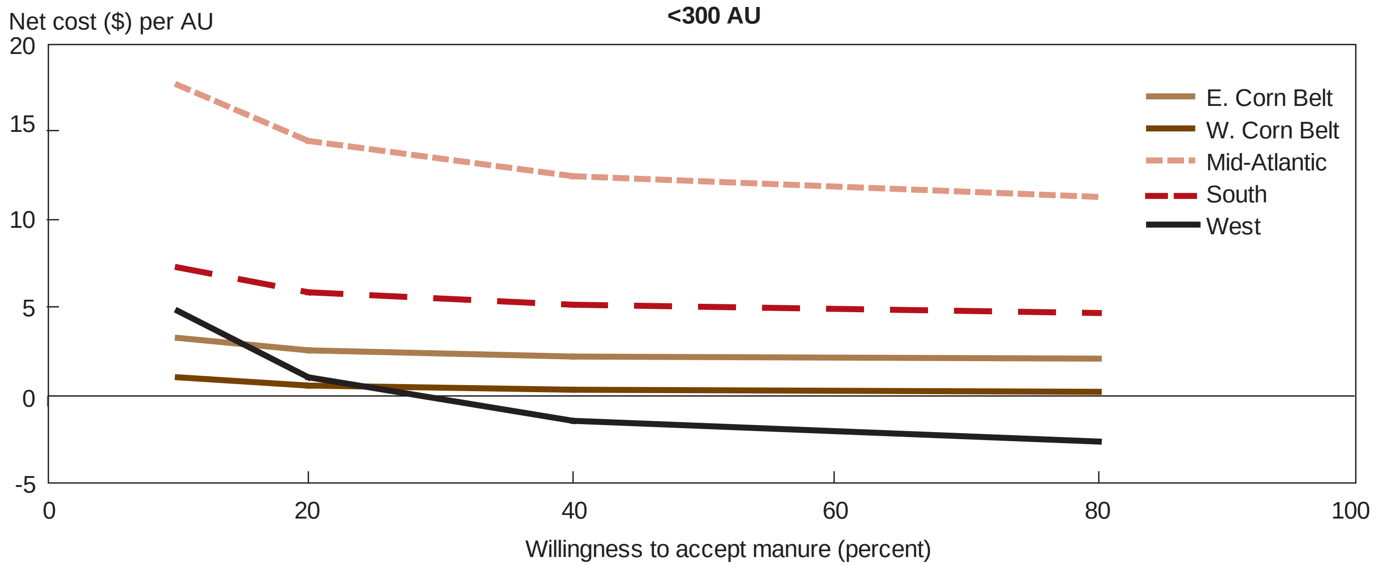
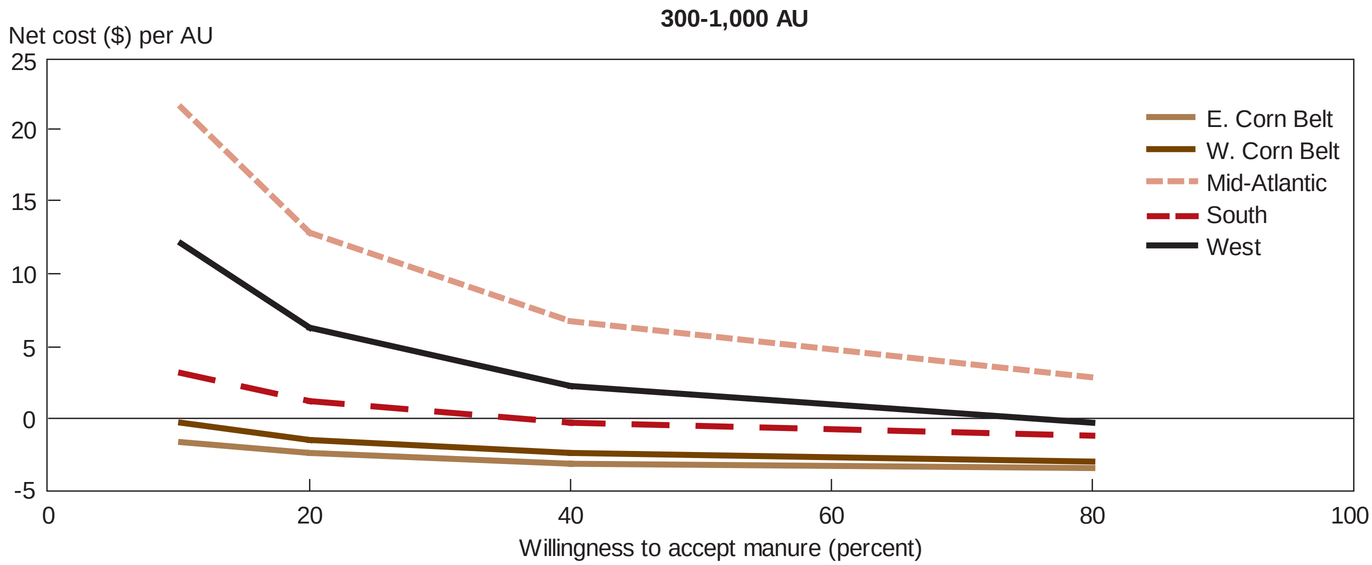


Figure 3-3

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





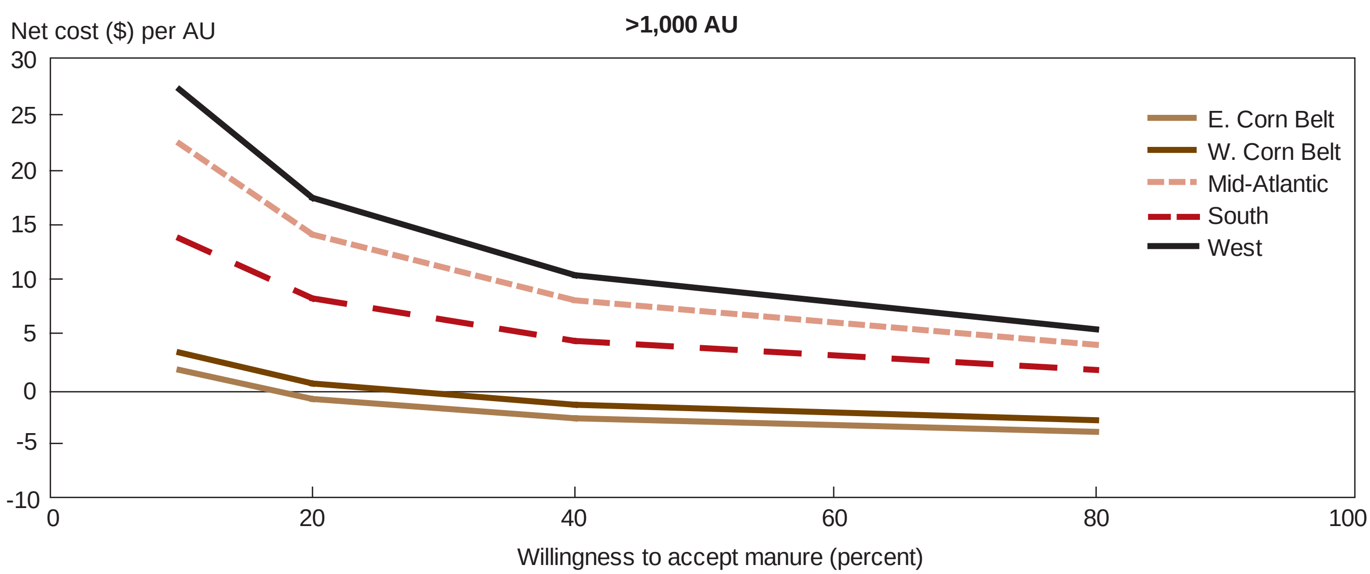
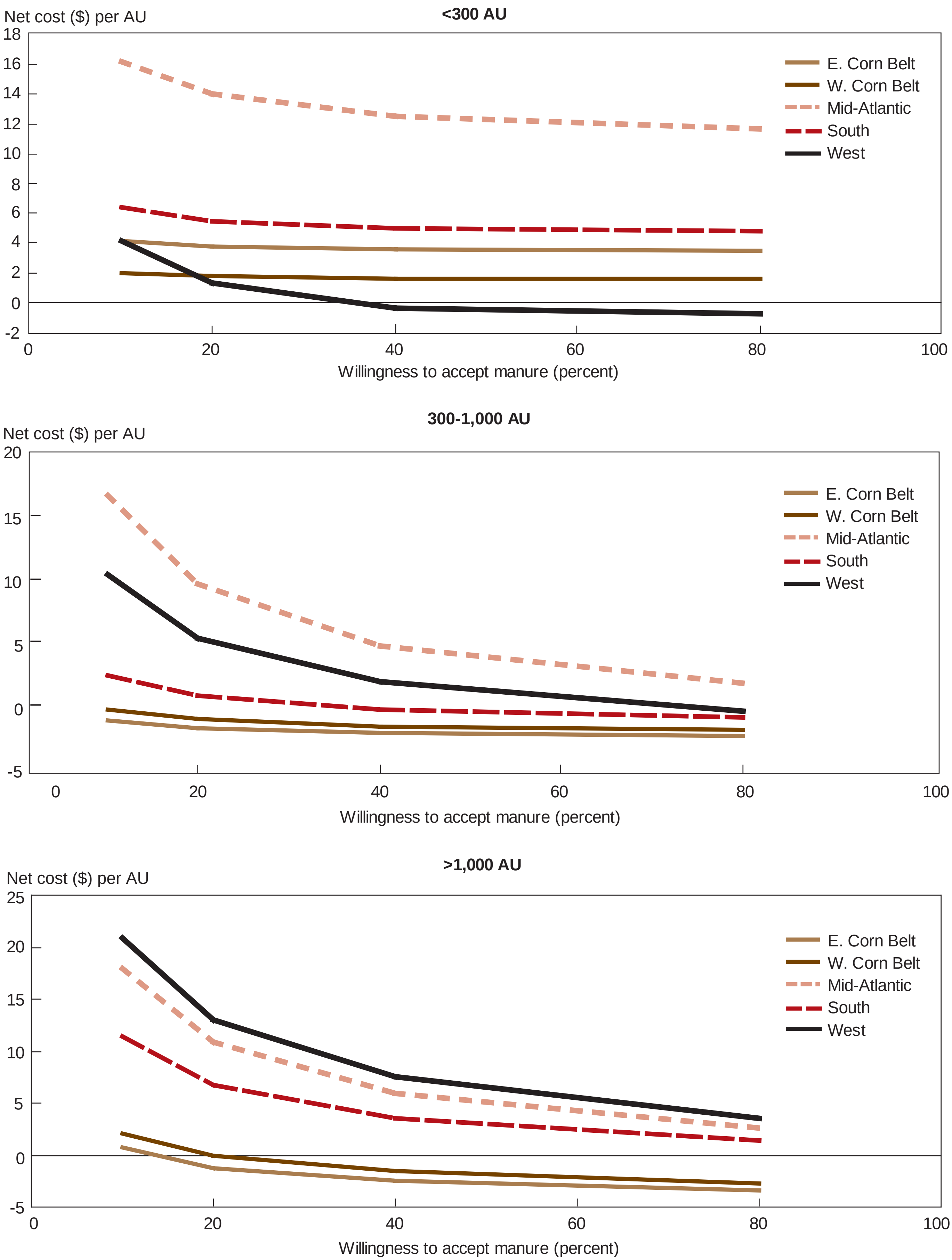


Figure 3-4

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



would decline from about $22.40 to $17.90 per AU (20 percent). Operations with adequate land for meeting a P-based standard would benefit the least. In some cases, manure application costs would actually increase because reducing manure's phosphorus content reduces its nutrient value. The benefits from phytase would also decrease as off-farm willingness to accept manure increases.

Cost Considerations in Context

Now that we've examined manure management costs for farms of different sizes and regions, how do estimated compliance costs compare to hog production costs, or transport/application costs compare to plan development/testing costs? Data from the 1998 hog ARMS survey indicate that hog production costs (operating costs plus allocated overhead) ranged from $360 to nearly $1,000 per animal unit, depending on the region, size of operation, and type of operation (farrow-to-finish, farrow-to-feeder, etc.). At a high WTAM (80 percent) the production costs for meeting either an N- or P-based standard would increase 1 percent or less across regions, sizes, and type of standard. At lower WTAM (10 -20 percent), production costs for large hog operations are noticeably higher 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 decreases with operation size in the Corn Belt regions, where land is generally more plentiful on and off the farm (fig. 3-5). For large farms, the impact on production costs is negligible. In the other three regions, percentage increases in production costs decline with size from small to medium farms as fixed costs are spread over more animals, but increase greatly for large farms due to higher transportation costs as manure is moved off the farm. The greatest impact on production costs is in the South, with a 2.1-percent increase for large farms.

Meeting a P-based plan pushes costs up in all settings. Increases in production costs are still generally 1 percent or less for high levels of WTAM (80 percent). At a WTAM of 20 percent, the impacts on costs are again smallest in the Corn Belt regions (fig. 3-5). As with the N-based plan, small farms would see the greatest impact on production costs. The impact on production costs for large farms in the Corn Belt regions are negligible. In the other three regions, costs increase significantly between medium and large farms. Production costs increase the most in the West (3.5 percent), and more than 2 percent in the Mid-Atlantic and South. Costs are higher still if WTAM is less than 20 percent.

Spreading manure to meet a nutrient standard entails two broad categories of costs: hauling/application costs and plan costs. The latter consist of developing a nutrient management plan, testing manure nutrients, and testing the soil. Hauling and application costs dominate the costs of spreading on adequate land to meet a nutrient standard, for all size classes, regions, and assumptions about willingness to accept manure. Plan costs take on greater importance for small farms. With a very high willingness-to-accept-manure of 80 percent, 26 percent of the costs of meeting an N-based plan for small farms in the Eastern Corn Belt were plan costs (the highest observed). Plan costs are less than 10 percent of the costs of meeting a nutrient standard for medium and large operations in all regions and all levels of WTAM.

Net Costs of Meeting a Nutrient Standard for Dairy

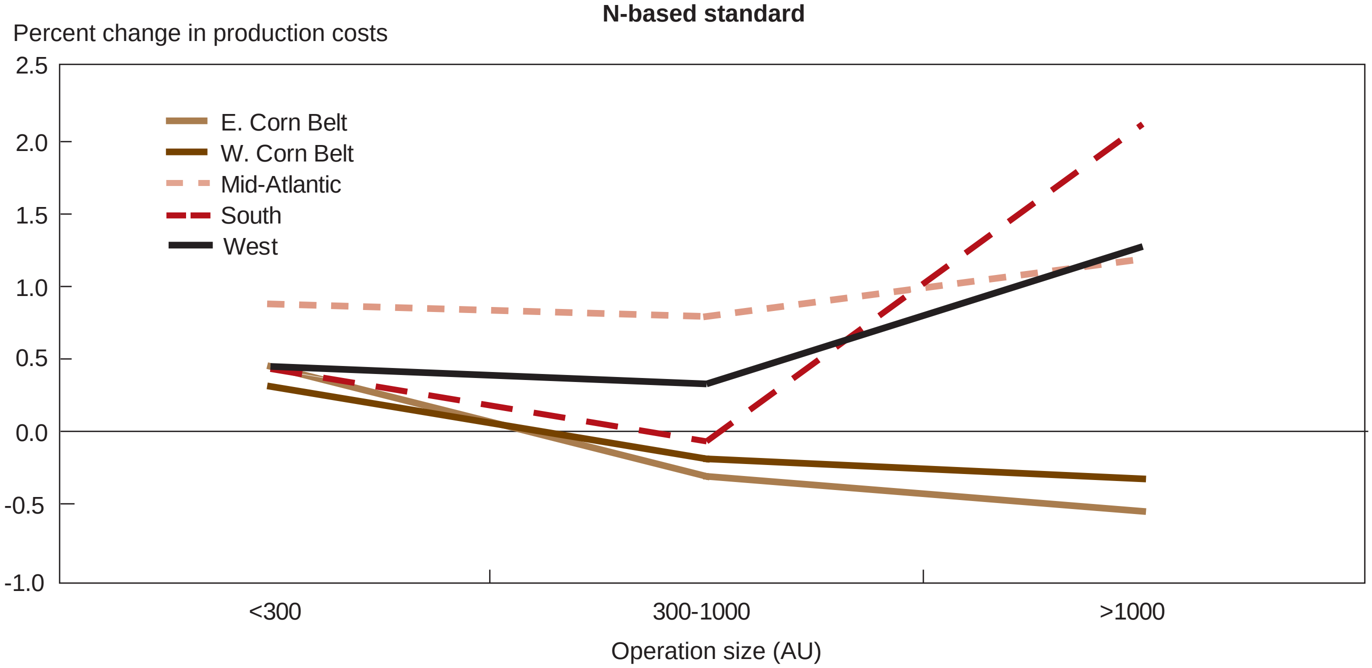
Dairy proves an interesting comparison to the hog sector. The dairy sector has not seen the same degree of concentration as in the hog industry. In 1982, there were 161,563 farms containing 11.4 million confined dairy cows (USDA, ERS, 2002b). By 1987, the number of confined dairy farms had fallen by nearly half to 86,354. However, unlike the increase in hog numbers, the number of confined dairy cows dropped to 9.9 million (13.1 percent) (USDA, ERS, 2002b). Excess nutrients do not appear to be as much of a problem for dairy as for hogs, on average. About 22 percent of dairy manure nitrogen (34 percent of dairy manure phosphorus) that could be applied to cropland was in excess of crop needs, versus 51 percent N and 64 percent P for hogs.

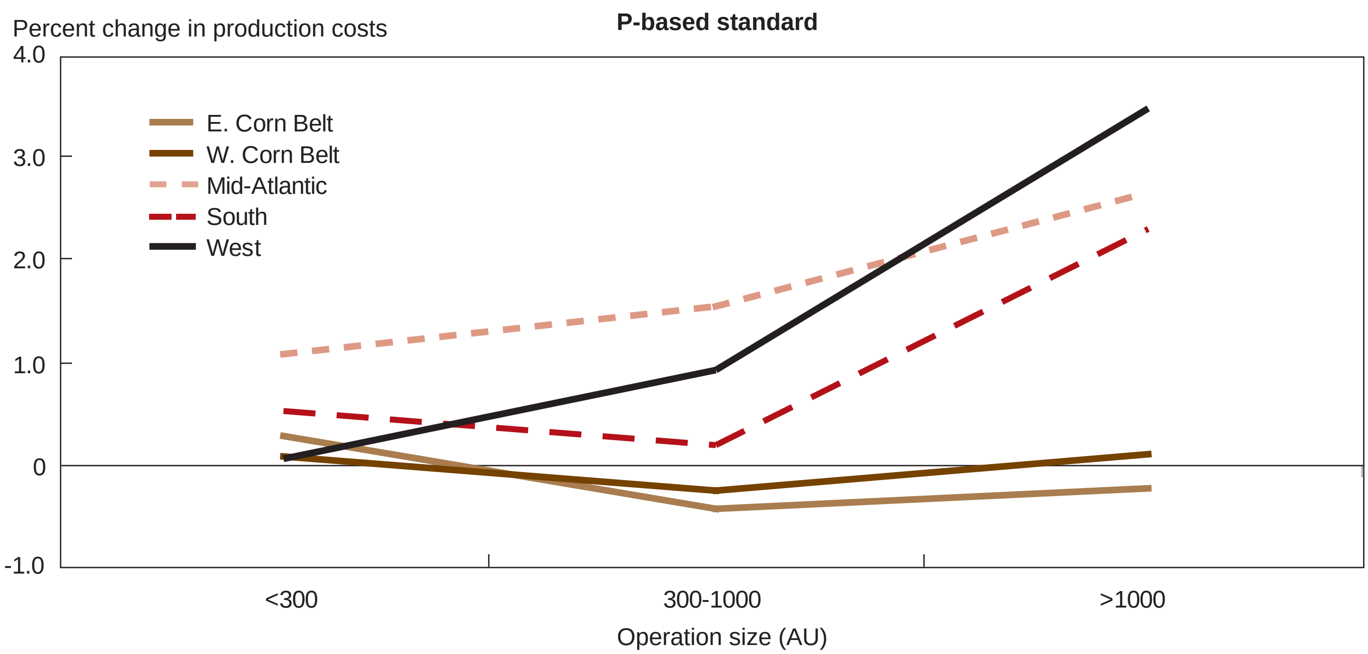
The dairy ARMS data were divided into two regions, North and South (fig. 3-1). We examined three size classes based on EPA's definition of animal unit (one AU is 0.7 mature dairy cow): small (<300), medium (300-1,000 AU), and large (>1,000). Small dairies dominate the North, while dairies in the South are distributed fairly evenly between the three size classes (table 3-4).

How Many Farms Are Potentially Meeting a Nutrient Standard?

Nationally, 23 percent of dairies with more than 1,000 AUs were applying manure on an adequate amount of land to meet an N-based nutrient standard (table 3-4). The percentage of medium-sized farms meeting an N-based standard was slightly higher at 27.5 percent, while over 70 percent of small farms were meeting the

Figure 3-5
Increase in production costs for hog farms under a nutrient standard with a willingness-to-accept-manure of 20 percent, by size





standard. A higher percentage of dairies in the North was meeting an N-based standard for all size classes.

Fewer farms were spreading manure at rates consistent with a P-based standard. Nationally, less than 1 percent of large dairy farms were applying manure to enough land to meet a P-based standard (table 3-4). Medium farms (6 percent) and small farms (27 percent) did a little better, but a large share of farms would have to increase the amount of land used for spreading manure to meet a P-based standard. None of the large operations in the North or medium operations in the South were meeting a P-based standard.

As with hogs, dairy farmers were not generally using all their suitable land to spread manure. Using this additional land would greatly help dairy farms, particularly small ones, to meet nutrient standards (table 3-4). Many large farms, however, would still need to find additional land off the farm to meet either an N-based or P-based plan. Small and medium-size northern dairies are much better able to meet nutrient appli-

Table 3-4—Percentage of dairy farms meeting N-based and P-based standards, by region and size, 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

South includes AZ, CA, FL, GA, NM, TX. North includes ID, IL, IN, IA, KY, MI, MN, MO, NY, OH, PA, TN, VA, VT, WA, WI.
Source: 2000 dairy ARMS.

cation standards on their own land than in the South, where most farms could not meet either standard even if all available cropland were used.

Differences in dairy farm characteristics explain some of our findings. Dairy densities, in terms of both AUs per acre used for spreading and AUs per acre of cropland operated by the dairy farm, are significantly higher in the South (at the 5-percent level of statistical significance) (table 3-5). This probably reflects the dominance of small operations (which tend to have more land per animal) in the North. Both nitrogen and phosphorus uptake rates were significantly higher in the South, reflecting crop mix and yields (at the 5-percent level) (table 3-5).

Manure storage systems again affect both the nutrients available for crops/pasture and the amount of land required to meet a nutrient standard. About two-thirds of the dairies in the South use liquid systems (lagoons) for storing manure, while about two-thirds in the North use solid manure storage systems (table 3-6). Manure from a solid system has a higher nutrient content per unit or volume.

How Much More Land Would Be Needed?

Nationally, large farms would have to increase the amount of land used to spread manure the most (about 314 acres for N-based standards or almost 100 percent) (table 3-7). In the South, small (91 acres or 173 percent), medium (214 acres or 166 percent), and large farms (351 acres or 113 percent) would all have to spread manure on additional land to meet an N-standard. Farms in the North are using more land for spreading, on average, and do not need as many additional acres (no increase for small farms, 3 percent for medium, and 70 percent for large). Having to meet a phosphorus-based plan would require farms, especially large ones, in each region to increase the amount of land used for spreading manure.

Using all suitable onfarm land would meet the manure disposal needs of many farms, primarily in the North. Only the large farms in this region would need to find land off the farm to meet an N-based standard. On average, farms of each size class in the South would need to move manure off the farm to meet an N-based standard. Land needs increase 87 percent for small farms, 200 percent for medium farms, and 107 percent for large farms (table 3-7).

If farms are required to meet a P-based standard, the amount of land needed off the farm would increase substantially. Large farms in the South would have to locate an additional 1,681 acres off the farm (526-percent increase), on average, and large farms in the North an additional 1,588 acres (405 percent).

What Are the Net Costs of Spreading on Adequate Land?

Net costs of meeting an N-based manure application standard would be highest for medium-sized dairies (fig. 3-6).[6] Small operations would have the lowest net costs for most levels of willingness-to-accept-

[6] Net costs per animal unit for dairies are higher than net costs per animal unit for hogs. The main reason is that more manure is produced by one dairy AU than one hog AU. This is a consequence of EPA not using a weight-based criterion for defining animal units.

Table 3-5—Cow density and average nutrient application standard, by region, 200

Region	Animal units per receiving (manure) acre	Animal units per acre owned	Average nitrogen application standard (lbs/acre)	Average phosphorus application standard (lbs/acre)
South	7.4	4.6	223.1	67.8
North	1.9	0.8	185.5	54.5

South includes AZ, CA, FL, GA, NM, TX. North includes ID, IL, IN, IA, KY, MI, MN, MO, NY, OH, PA, TN, VA, VT, WA, WI.
Source: 2000 dairy ARMS.

Table 3-6—Dairy manure storage technology, by region, 2000

Region	Farms using liquid systems	Farms using solid systems	Farms using mixed systems
		Percent	
South	66.4	12.5	21.1
North	29.2	64.5	6.3

South includes: AZ, CA, FL, GA, NM, TX. North includes: ID, IL, IN, IA, KY, MI, MN, MO, NY, OH, PA, TN, VA, VT, WA, WI.
Source: 2000 dairy ARMS.

Table 3-7—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	Acres needed: P-based standard
South		*Acres*		
<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.
South includes AZ, CA, FL, GA, NM, TX. North includes ID, IL, IN, IA, KY, MI, MN, MO, NY, OH, PA, TN, VA, VT, WA, WI.
Source: 2000 dairy ARMS.

manure. Northern dairies would have lower net costs in most cases, but only for small dairies is the difference notable (e.g., $39 vs. $19 at 10-percent willingness-to-accept). Many more small southern dairies would have to haul manure off the farm to meet the N-based standard (67 percent in South vs. 9 percent in North). The difference in net costs for all dairy farms decreases sharply as willingness-to-accept increases and off-farm hauling costs decrease. At no point does the average net cost of manure become negative as it did for hogs.

Meeting a P-based standard would increase the net costs of spreading manure for all size classes and regions because of the increase in the amount of land needed for spreading (fig. 3-7). Large and medium farms in both the North and South have similar net unit costs that are higher than those for small farms. As with N, increased willingness to accept manure would significantly reduce the net cost of spreading manure.

Figure 3-6
Average cost of applying manure from dairy farms following a nitrogen-based standard, by region

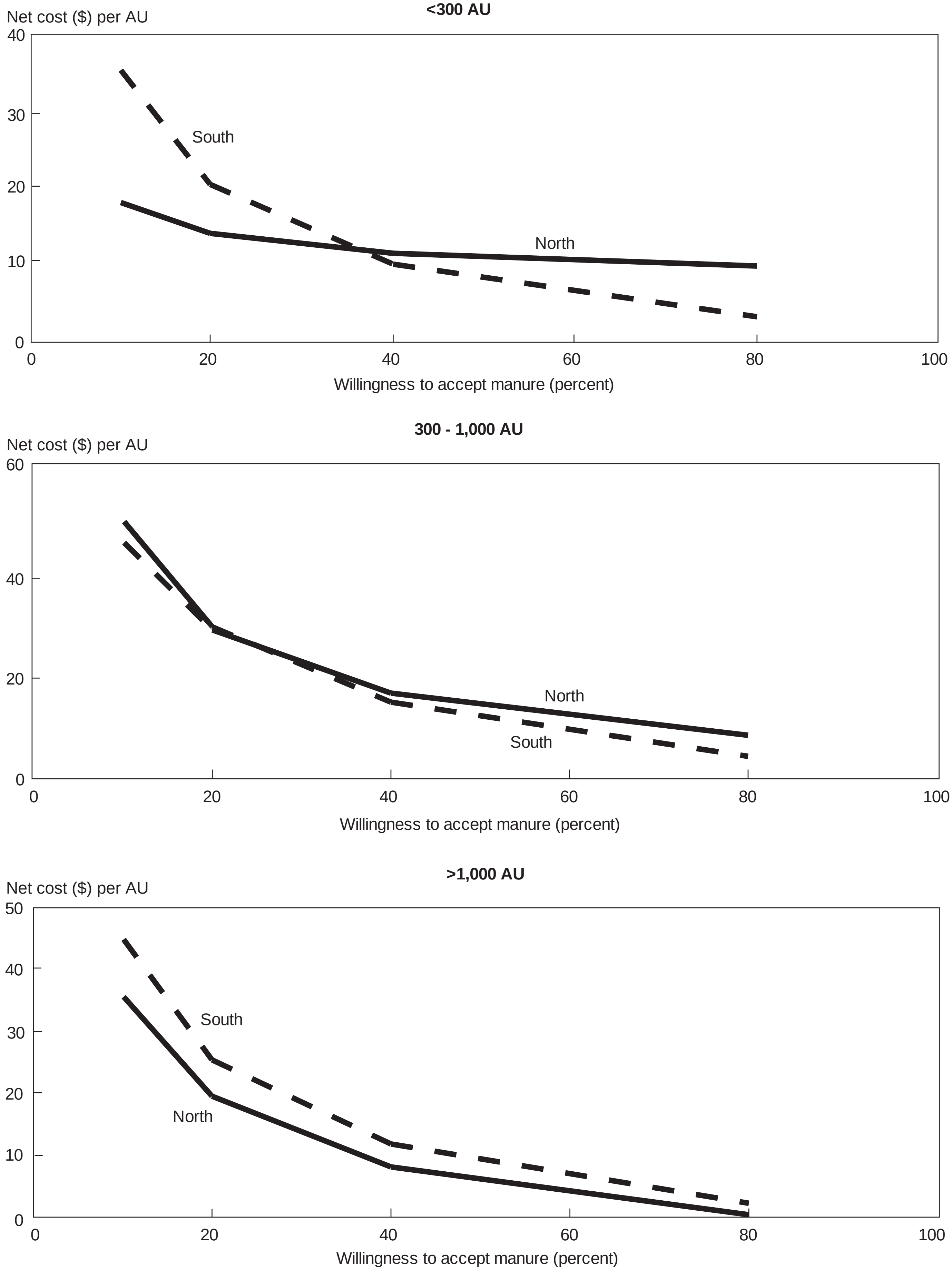
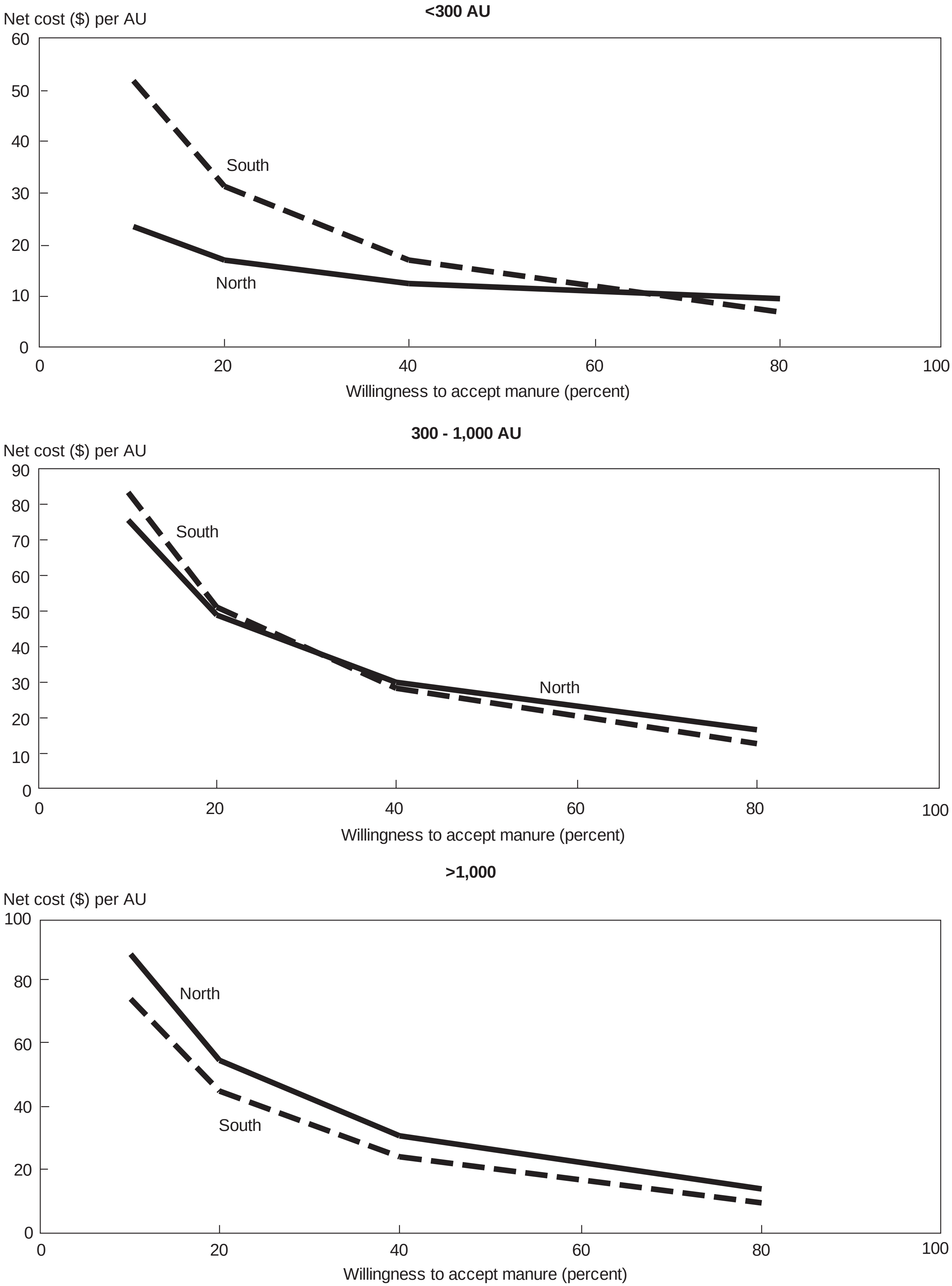


Figure 3-7

Net cost of spreading manure from dairy farms following a phosphorus-based standard, by region



Cost Considerations in Context

Applying manure to meet a nutrient standard would have a smaller impact on production costs in dairy than it would for hogs, on an animal unit basis. Based on the 2000 dairy ARMS, average dairy production costs (operating costs plus allocated overhead) ranged from about $1,400 to $2,700 per animal unit per year, depending on the size of the operation and the region. With high willingness-to-accept-manure (80 percent), impacts of a manure nutrient application standard on production costs would be about 1 percent or less for all regions and size classes.

At lower levels of WTAM, percentage increases in production costs would be greater, but still of small consequence. At a WTAM of 20 percent, meeting an N-based plan would increase large dairies' costs by about 1.5 percent in each region (fig. 3-8). Small operations would see the smallest increases, ranging from 0.5 to 1 percent. Production cost increases would be slightly higher in the South across all size classes.

Meeting a P-based standard with a WTAM of 20 percent would increase production costs more than meeting an N-based standard. Costs would increase about 3.25 percent for large operations in each region and for medium farms in the South. Cost increases for small farms would range from 0.5 percent in the North to 1.5 percent in the South.

Hauling costs are much more important than plan development/testing costs when a nutrient standard is imposed. Hauling costs constitute more than 90 percent of the costs of meeting a nutrient standard for all size classes, regions, and assumptions about willingness-to-accept-manure. This is a bit higher than for hogs, due to dairy's higher manure output per animal unit.

Summary

Proposed manure management restrictions on nitrogen and phosphorus applications would require many large swine and dairy operations to seek additional land for manure spreading. Most small operations (87 percent for hog farms and 90 percent for dairies) have enough land to spread their own manure on and meet a nitrogen standard. In contrast, large farms have less land per animal unit than small farms, so a smaller percentage has adequate land to meet a nitrogen standard (49 percent for hog farms and 27 percent for dairies). Costs for meeting a standard are closely related to how much manure must be moved off the farm to surrounding cropland.

Fewer farms have enough land if a phosphorus standard must be met, because manure application rates are lower than for a nitrogen-based plan. A majority of small farms have enough land (69 percent for hog farms and 65 percent for dairies). However, only 21 percent of large hog farms and 2 percent of large dairies have enough land to meet a phosphorus standard.

Implementing a nutrient management plan for meeting a standard (plan development and testing) and hauling/applying manure to fields both add to the cost of producing animals. These costs will vary by species, by the size of the operation, and by region. The average costs of meeting a standard (per animal unit) across farm sizes and regions range from -$4/AU to $27.3/AU for hogs, and $0.2/AU to $88.3/AU for dairy.

Large farms, those typically designated as CAFOs by EPA, would generally see greater percentage increases in production costs from meeting nutrient standards than would smaller farms. At low levels of willingness-to-accept-manure (10 percent), production costs can increase more than 5 percent for large hog producers in some regions if a P-standard is enforced (costs ranging from $1.6/AU to $27.3/AU). Costs are lower in the Corn Belt regions where land to receive manure is more readily available both on and off the farm. Similar results are seen for large dairies—costs range across regions from $74.1/AU (North) to $88.2/AU (South) with a WTAM of 10 percent. For small operations, production costs generally increase less than 1 percent at any level of WTAM (costs ranging across regions from $1/AU to $17.6/AU for hog farms and $23.4/AU to $52/AU for dairies with a WTAM of 10 percent).

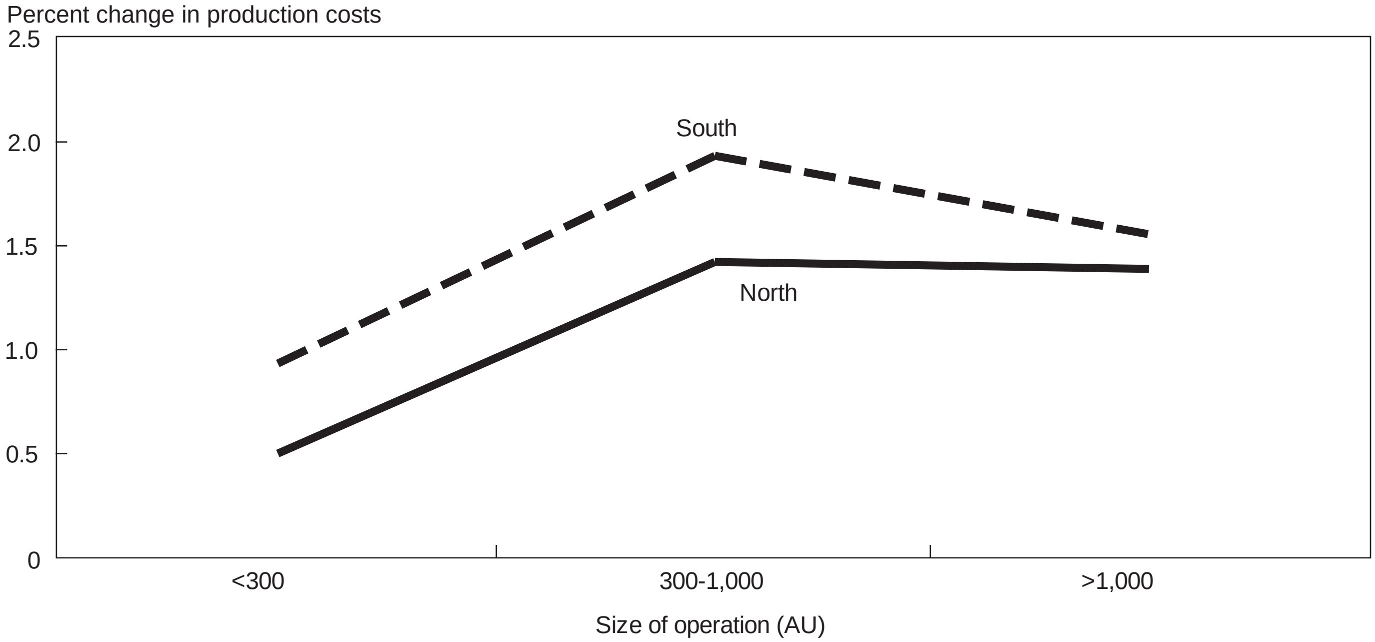
Willingness of cropland operators to accept manure greatly influences the net costs to livestock and poultry producers of meeting any nutrient standard. For example, the average cost of meeting an N-standard for large hog farms in the Mid-Atlantic would drop from $11.20 per AU to $0.50 per AU (96-percent decrease) if WTAM increases from 10 percent to 80 percent. Manure transportation costs decline as crop producers are more accepting of manure. Research on their acceptance of manure as a nutrient source would identify constraints that might be overcome through technical assistance, financial assistance, and education.

Our results do not reflect changes in management other than spreading manure on additional acres. Incorporating other management changes would likely lead to a different set of results. For example, farmers might grow crops that take up more nutrients, change manure handling systems, and reduce herd size. These

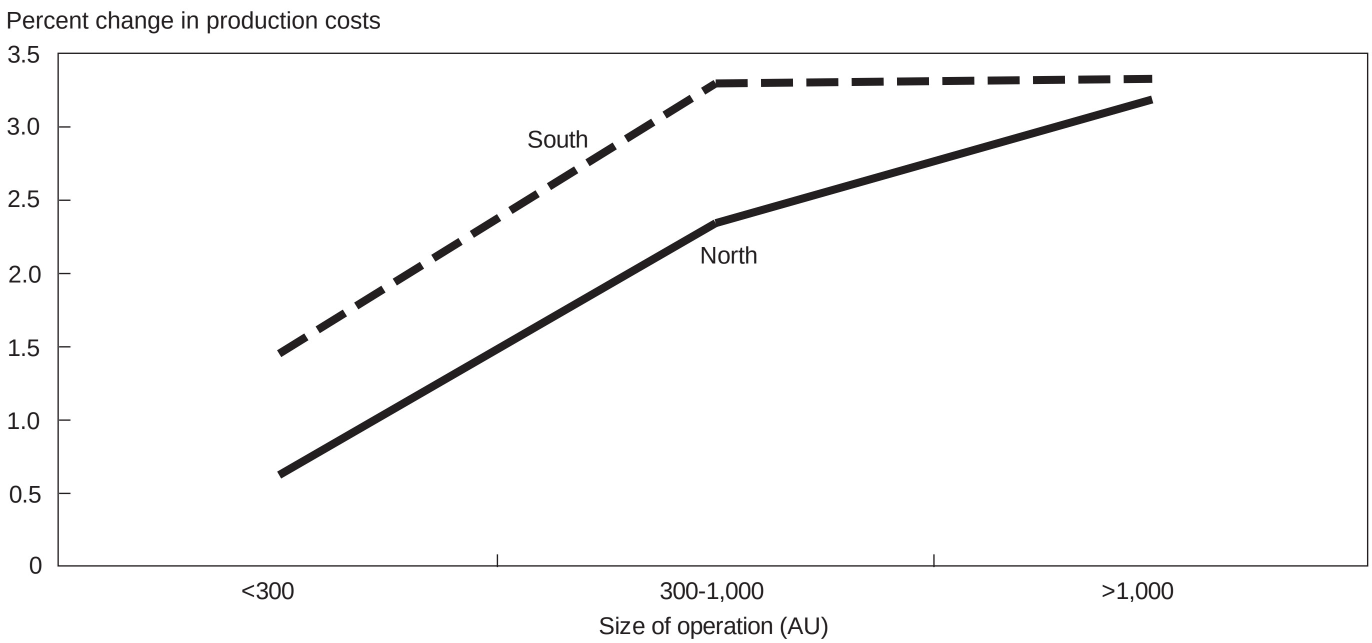
Figure 3-8

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

N-based standard



P-based standard



changes would occur over time, and at some expense. The results reported here can be viewed as an initial adjustment that might foster further changes, as farmers evaluate the net costs of manure spreading and consider alternative or additional changes.

The farm-level analysis assumed that the only factor constraining farmers from spreading on cropland off the farm is the willingness of cropland operators to accept manure. In regions where animal concentrations are particularly high, animal operations may be in competition with each other for available cropland. This would drive up the costs of spreading manure, as animal operations are forced to transport manure longer distances. Such regional issues are addressed in the following chapter.

Appendix 3-A

Fleming Model for Estimating Net Costs of Following a Nutrient Standard

Costs of Transporting and Spreading Manure

The Fleming model has two components. The first component estimates the cost of transporting and spreading the manure to receiving land. To estimate costs, the model requires three types of information: (a) a base charge (for mixing, loading, and applying manure); (b) a mileage charge (for transporting the manure); and (c) the number of miles manure is hauled. Charges reflect those used by custom applicators. We assume that time and equipment would be the same for farmers applying manure themselves. For solid manure or slurry that is directly applied without being stored in lagoons, the mileage charge represents driving time from the production facility to the field. For lagoon liquids that are sprayed on cropland, the mileage charge represents the cost for the assembly and use of any additional equipment needed to deliver wastes to the field.

The cost equation is:

$$\mathrm{DC} = Q\mathrm{H}\left[r_B + \mathrm{Z} r_A \left(\left(\frac{N_M Q\mathrm{H}}{640\alpha\beta\gamma \mathrm{N}_C} \right)^{1/2} - 1 \right) \right] \tag{1}$$

DC = delivery and application cost

Q = quantity of manure hauled per head (gallons)

H = number of animals

r_A = unit mile charge (dollars per gallon per mile)

r_B = base charge (dollars per gallon)

Z = 2 for slurry systems (round trip for hauling vehicle), 1 for liquid waste (no return trip required)

N_C = nutrient standard for limiting nutrient (N or P, depending on which nutrient the standard is based on) (pounds per acre)

N_M = nutrient content of manure (pounds per gallon) for target nutrient (N or P)

α = proportion of surrounding land that is cropland or pasture

β = proportion of cropland that is suitable for receiving manure

γ = proportion of crop acres where manure is accepted by farmers

The term is the required acreage (RA) for spreading the waste at a rate that meets the nutrient standard.

Fleming et al. point out that acreage suitable for receiving manure is rarely available adjacent to the site where animals are produced, and that some amount of "searching" for suitable cropland will be required. We assume that manure is only applied to cropland or pasture. Only a portion of surrounding land will be cropland or pasture (α). The rest will be in other land uses, such as forest or rangeland. In addition, only a portion of cropland will be suitable for receiving manure (β) (hereafter referred to as "spreadable land"). We assume that vegetable crops and some pastureland does not receive manure.

Only a portion of spreadable land will actually be available because not all landowners will be willing to take animal manure (γ) (see box, "Willingness To Accept Manure," p. 21). The less willing landowners are to use manure, the more costly it will be to find available spreadable land.

The equation $\frac{N_M QH}{\alpha\beta\gamma N_C}$ thus defines the "searchable area" (SA).

Fleming et al. developed an algorithm for estimating the average distance traveled to spread manure in the searchable area. The searchable area is assumed to be a square, contiguous block. Within this area one or more crop fields are randomly selected for manure applications. Fields are assumed to be of the same size. Thus, a grid is formed where the outside edge defines the searchable area, and the cells are the individual fields.

Given this grid, it is possible to calculate average distance by measuring the distance from each point to each other point, sum these distances up, and divide by the number of points in the grid. The shortest possible distance traveled will be 0. The greatest distance will be traveled when the entrance to a receiving field is on the perimeter of SA opposite the source. Maximum one-way mileage is two times the square root of SA divided by 640 (acres in a square mile).

As SA is divided into smaller and smaller fields, the distribution of mileage traveled approaches a normal curve. From statistics, the median point of a distribution will approach the mean as that distribution converges to the shape of a normal curve. Hence, the median distance, the sum of the minimum and maximum distance traveled divided by two, is a good approximation of average distance traveled and is easier to calculate (Fleming et al., 1998). Therefore, average distance traveled to spread manure over spreadable land that accepts manure is

$$\left(\frac{N_M QH}{640\alpha\beta\gamma N_C}\right)^{1/2}.$$

Generally, the first mile is included in the base charge, so this distance is subtracted from average distance when the mileage cost is calculated.

Benefits from Replacing Commercial Fertilizer

Manure nutrients have value if they replace commercial fertilizer on cropland. The equation for calculating this benefit is:

$$TB = QH \sum_{i=n,p,k} P_{M,i} + aRA \qquad (2)$$

$$N_{M,i}\mathrm{AR}_T \le N_{Ci,} \text{ for T = n or p and i = n, p}$$

$$a = 0 \text{ if } N_{M,i}\mathrm{AR}_T < N_{C^i} \text{ for i = n, p}$$

$P_{M,i}$ = price of commercial fertilizer for nitrogen (n) and phosphorus (p)

$N_{M,i}$ = nutrient content of manure for n and p

a = commercial fertilizer application cost (expressed in dollars per acre)

RA = required acreage for spreading

AR_T = application rate for manure (gallons per acre) based on the target nutrient T

In this equation, nutrients in manure are valued at the price of commercial fertilizer only to the extent that the plant uses the nutrient. If a nutrient is applied beyond plant needs, the over-application has zero value. We assume that spreadable land not receiving manure is receiving commercial fertilizer at agronomic rates. The elimination of the cost of applying commercial fertilizer is only considered a benefit if all the crops' nutrient needs are met by manure and commercial fertilizer is no longer applied. If one nutrient in manure is not sufficient to cover crop needs, then commercial fertilizer must be applied to make up the deficit, and the application cost must be paid.

The difference between costs of spreading manure on acceptable acres and benefits from reduced fertilizer costs are the net costs of spreading manure at agronomic rates. We used data from USDA's Agricultural Resource Management Survey (ARMS) to estimate the net cost of land-applying manure for each farm in the survey. ARMS provided data on the county in which a farm is located, the number of animals (H), the type of manure storage system, whether manure was surface applied or incorporated, the total amount of cropland on the operation, the crops grown, and crop yields. Quantity of manure or lagoon liquid hauled per animal (Q), hauling and application charges (r_A and r_B), nutrient content of manure or lagoon liquid (Nm), fertilizer prices (Pm), and fertilizer application cost (α) were obtained from published sources (Kellogg et al., 2000, Iowa State Extension, 1995; Jones and Sutton; Sutton et al.).

Spreadable area for each operation was divided into two components: land available on the farm and land available on surrounding land in the county. We assumed that animal operators would spread manure on their own cropland first, the amount of which was available from ARMS. We assume the operator's willingness to accept (γ) for his or her own land to be 100 percent. We also assume that the farm's land is in a contiguous block. This assumption probably results in an underestimate of baseline hauling costs. Once their own land is fully used, farmers are assumed to spread manure on surrounding land in the county. We assume that the percentage of surrounding land that was suitable for receiving manure is the same as for the entire county in which the farm is located. We use data from the 1997 National Resources Inventory to estimate the percentage of searchable area off the farm that is cropland or pasture (α) and the percentage of cropland or pasture actually suitable for receiving manure (β). Manure and cost coefficients used in the model are summarized in table A-1.

Table A-1—Coefficients and prices used in cost model

	Hogs	Dairy
Volume of manure:		
Lagoon	5.98 gal./lb liveweight/yr.	
Slurry pit	Feeder pigs - 73 gal./head/yr. Market hogs - 438 gal./head/yr. Breeder sows - 584 gal./head/yr.	
Solid		100.52 lb/1000lb. liveweight/day
Nutrient content:		
Lagoon nitrogen	0.004 lbs./gal.	Slurry and lagoon concentrations for each farm are determined by estimating volume of manure, nutrient content of solid waste, and volume of wastewater. Wastewater is estimated with a function that includes precipitation, wash water, slab runoff, and reported manure storage system.
Lagoon phosphorus	0.003 lbs./gal.	
Slurry pit nitrogen	Feeder pigs - 0.035 lbs./gal. Market hogs - 0.070 lbs./gal. Breeder sows - 0.025 lbs./gal.	
Slurry pit phosphorus	Feeder pigs - 0.020 lbs./gal. Market hogs - 0.035 lbs./gal. Breeder sows - 0.025 lbs./gal.	
Solid storage nitrogen		Milk cow - 0.580 lb/day/AU Dry cow - 0.360 lb/day/AU Heifer/calves - 0.307 lb/day/AU
Solid storage phosphorus		Milk cow - 0.131 lb/day/AU Dry cow - 0.048 lb/day/AU Heifer/calves - 0.041 lb/day/AU
Costs:		
Unit mile charge	Hauled - $0.00123/gallon-mile Pumped - $0.001025/gal.	Hauled - $0.00123/gallon-mile Pumped - $0.001025/gal. Solid - $0.13/ton-mile
Base manure handling charge	Slurry hauled - $0.0079/gal. Incorporated - $0.0088/gal. Lagoon liquid pumped - $0.0057/gal. Incorporated - $0.0071/gal.	Slurry hauled - $0.0079/gal. incorporated - $0.0088/gal. Lagoon liquid pumped - $0.0057/gal. incorporated - $0.0071/gal. Solid - $6.00/ton
Fertilizer application cost	$5.75/acre	$5.75/acre
Fertilizer prices	Nitrogen - $0.185/lb. Phosphate - $0.13/lb.	Nitrogen - $0.185/lb. Phosphate - $0.13/lb.

AU = animal unit

Chapter 4—Regional Analysis: Costs and Distribution of Manure Management

The costs associated with meeting USDA goals and EPA regulations for improved manure management depend not only on individual farm conditions—addressed in our farm-level analysis (chapter 3)—but on the *interaction* among animal operations, within the broader context of off-farm resource conditions. The farm-level analysis implicitly assumes that there are no other sources of manure in the area surrounding the surveyed farms that might also need land for spreading. This chapter addresses manure management from a regional perspective, focusing on the challenges all animal feeding operations (AFOs) may face in finding suitable land for manure application when there are many producers in the same region needing to apply manure off the farm.

The geographic distribution of animal manure and land available for manure application varies significantly across the Nation. Kellogg et al. (2000) and Gollehon et al. (2001) identified areas where confined animals produce more manure nutrients than can be assimilated on cropland and pastureland in the county of production, when applied at agronomic rates. Notable among these areas were several county clusters within the Chesapeake Bay watershed (fig. 4-1).

The Chesapeake Bay is among the largest and most biologically rich estuaries in the world. The declining health of this ecosystem in recent decades has prompted Federal and State initiatives to reduce nutrient loading from tributaries that drain the watershed. Nutrient loads to waters in the region have resulted in eutrophication and related ecological shifts that harm wildlife and aquatic resources (Preston and Brakebill, 1999).

The Chesapeake Bay watershed (CBW) spans over 160 counties in 6 States, and includes 66,600 farms with an estimated 8.5 million acres of land available to receive manure. The CBW included approximately 15,900 farms with confined animals in 1997, with an average daily inventory of about 1.6 billion pounds of feedlot beef, dairy, swine, and poultry (USDA, 1999). These animals produce roughly 93,000 tons of recoverable manure nitrogen and 44,000 tons of recoverable manure phosphorus annually. Even if confined animal operations fully utilized the crop and pasture land under their control for manure application (and data from the farm-level analysis suggest they do not) only about 40 percent of the manure nitrogen and 30 percent of the manure phosphorus produced could be assimilated onfarm. Clearly, applying manure at agronomic rates would require moving significant quantities of manure off animal production farms.

In areas of the Chesapeake Bay watershed where confined animal production is concentrated, implementation of EPA and USDA manure policies poses tremendous challenges. If the manure produced exceeds potential local use, producers may choose to: (1) transport the manure ever-greater distances until enough land can be found for application, (2) alter feed management to reduce nutrient output, or (3) apply technologies that transform the manure to a value-added product that is more readily transportable and usable. Beyond this, the only recourse is to reduce the number of animals in the watershed. Florida recently reduced its numbers via a Dairy Buyout Program to slow nutrient runoff from dairy farms in the Lake Okeechobee watershed (Schmitz et al., 1995).

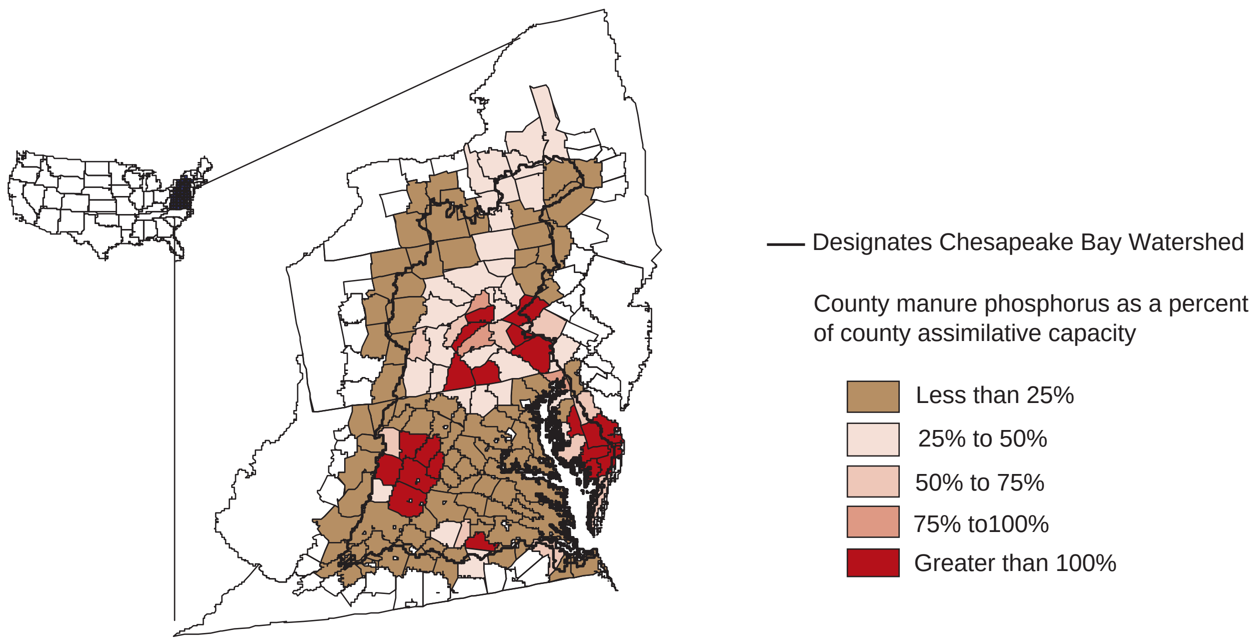
In this chapter, we present an analysis based on a regional model of manure management that accounts for the competition for spreadable land among animal producers in the Chesapeake Bay watershed (CBW). We assume that all AFOs are trying to meet the nutrient management goals laid out in the USDA-EPA Unified Strategy. The model and its results reflect a regional planning perspective emphasizing the cost determinants and feasibility of alternative strategies at the watershed scale.

Modeling Manure Management in the Chesapeake Bay Watershed

We first evaluate the feasibility of a land application strategy, allowing for out-of-county transport and considering alternative levels of willingness of landowners to use manure. Our model is designed to minimize the total regional costs of manure management, transport, and application for use on agricultural lands in the CBW, given the existing structure and scale of the animal industry and existing manure storage technology. The regional specification captures the element of competition by modeling access to spreadable land, ensuring adequate area for land application of all

Figure 4-1

The Chesapeake Bay Watershed with manure phosphorus relative to county assimilative capacity for modeled counties, with counties outside the watershed used for manure application



Source: Gollehon, et al., 2001

manure produced in the region, and computing the associated hauling costs. Explicit modeling of competition for land on which to spread manure differentiates the model from existing farm-level models.

The model was developed to: (1) provide a mechanism to track manure and related nutrient flows within the basin, from AFOs to site application and use; (2) compute the regional costs of applying manure to land, given the manure movement dictated by the nutrient flow; and (3) provide a framework for evaluating proposed land application regulations and alternative nutrient management policies (see box, "Nutrient Standards").

The county is the primary modeling unit. The county-level specification provides consistency with Census of Agriculture data and other data, and permits differentiation of institutions and regulatory conditions across county and State political boundaries within the watershed. County and local data are used to capture heterogeneity in technologies and land quality conditions across the region, though our model may not represent the conditions on any particular farm. Details of the model are in Appendix 4-A, "Modeling Manure Management in the Chesapeake Bay Watershed."

Applying Manure to Land in the Chesapeake Bay Watershed

Feasibility of Land Application

Land application of manure under a nitrogen (N)-standard would require about 2.5 million acres of crop and pasture land in the CBW and surrounding counties, or almost 40 percent of the 6.6-million-acre agricultural (crop and pasture) land base. A phosphorus (P)-standard would require about 4.8 million acres of crop and pasture land, or almost three-fourths of the agricultural land base.

Confined animal farms in the CBW having to meet either an N or a P standard would run out of land on which to spread manure within the modeled transportation radius if WTAM falls below certain thresholds (bar chart portion of figure 4-2).[7] The willing-

[7] The structure of the model necessitated identifying the allowable transport options by specifying the counties available for receiving manure from each county that could possibly export manure. Counties within a 60-km radius of the county boundary were identified in most areas. In areas with high manure production, a 150-km radius was used. The actual transport distance is generally greater since the distance within both the source and destination county is considered and adjustments are made to convert radius distance to road distance.

Nutrient Standards

USDA's Natural Resources Conservation Service (NRCS) has devised policy and developed a conservation practice standard for nutrient management that address the requirements for land application of manure nutrients (USDA, NRCS, 1999a). Land application is the preferred method of utilizing manure because these materials can supply large amounts of nutrients for crop growth, thereby reducing the need to apply commercial fertilizers. Nutrient management criteria are established by the NRCS conservation practice standard to provide adequate nutrients for crop growth and to minimize the potential for adverse environmental effects.

NRCS' nutrient management policy and conservation practice standard criteria are implemented by animal feeding operations through the development and implementation of site-specific nutrient management plans, as defined in the NRCS General Manual, Title 190, Part 402 (1999c); and the NRCS Conservation Practice Standard, Nutrient Management (Code 590) (1999a). The primary criteria within these policy documents are that land application rates of nutrients be based upon Land Grant University nutrient application recommendations. NRCS policy permits manure application rates that are determined using either a nitrogen or phosphorus standard. Manure application rates that are based on a nitrogen standard would supply all the nitrogen recommended for the crop. Manure applied at a nitrogen standard will usually result in overapplication of phosphorus. NRCS policy permits use of the nitrogen standard on sites for which there is a recommendation to apply phosphorus, or when the use of a risk assessment tool has determined that the site has acceptable risk for offsite transport of phosphorus. (The Phosphorus Index is currently the most widely used risk assessment tool for this purpose.)

Manure application rates that are based on a phosphorus standard supply only the amount of phosphorus that is recommended, based on current soil tests or a function of the phosphorus content of plant biomass removed at harvest. Manure applied based on the phosphorus standard will not usually supply the recommended amount of nitrogen, necessitating the application of additional nitrogen from other sources. When using the phosphorus standard, NRCS policy permits an application of phosphorus equal to the amount of phosphorus contained in the biomass of multiple years of crops grown on the site, provided that the nitrogen recommendation rate for the first year is not exceeded. This allows farms that have enough land to continue to apply manure on the basis of a nitrogen standard, but rotate manure applications to other sites so that a single site receives manure infrequently. Consequently, operations with sufficient land can meet nutrient management criteria without actually applying manure at rates based on a phosphorus standard. This generally is advantageous to the producer because it can be difficult to achieve a phosphorus rate of application with existing manure application equipment. Operations without sufficient land, however, will eventually need to apply manure based on a phosphorus standard on all available onfarm acres as the phosphorus levels in the soil build up. Alternatively, producers may export the manure off-farm for land application or alternative use. For the model results in this report, nutrient management criteria were represented by two scenarios: application at N-standard rates for all farms and application at P-standard rates for all farms. Neither is intended to reflect expected implementation strategies, because in practice there will be some farms that can meet criteria with N-standard rates and others that will need to adopt the more restrictive P-standard rates. In a related study on the costs of implementing comprehensive nutrient management plans, NRCS estimated that about 30 percent of livestock operations would need to use P-standard rates to meet nutrient management criteria; the remaining 70 percent have sufficient land available to apply manure based on a nitrogen standard. We did not have the data on soil characteristics and historical land use to determine in our analyses the share of land that would need to meet a P-standard. The two scenarios used in the present study are intended to establish upper and lower bounds on the costs associated with implementing nutrient management plans.

ness-to-accept-manure (WTAM) threshold at which available land reaches its capacity for assimilating manure nutrients is estimated at 60 percent for a P-standard and 20 percent for an N-standard. Current use of manure on field crops is in the 10- to 20-percent range nationally. Several options exist for disposal of surplus manure that cannot be absorbed on available land:

- Increasing landowner willingness to accept manure through technical and financial assistance can expand the spreadable area while reducing hauling distances.

- Greater reliance on off-farm processing to create manure-based products both reduces the quantity of manure requiring agricultural land application and expands the spreadable area to nonagricultural lands, such as golf courses and lawns.

- Farms in the region can increase manure-nutrient uptake through both cropping pattern adjustments and yield enhancements from improved management and technologies, such as irrigation.

- Animal producers can reduce the nutrient content of manure through improved rations and the use of additives, enabling increased manure applications per acre for a given nutrient standard (see box "Reducing Manure Nutrients Through Feed Management," p. 19).

- Changes in animal industry structure, such as reductions in the number of animals and plant relocations, can directly reduce the quantity of manure that exceeds land application levels.

The total cost of manure disposal in the CBW represents the cost of applying manure to land (addressed in our model) ***plus*** costs of managing manure that cannot be land applied under assumed hauling distance limits. Our focus on land application here expands to include options like off-farm processing and feed ration adjustments. Other options—involving incentives to increase WTAM and adjust cropping patterns—will require additional programs of research.

Finally, reductions in manure via a smaller animal sector will require careful evaluation from both a producer and rural economy perspective. The national sector analysis in this report (see chapter 5) does estimate the potential loss in returns to agricultural producers from reductions in animal numbers, although these estimates do not consider impacts on the associated rural economy. Reducing animal stocks such that all manure could be land applied lowers projected net returns in the CBW by $47 million (15 percent of total returns to the animal industry in the CBW) under an N-standard and $164 million (51 percent) under a P-standard, assuming a 10-percent WTAM. This estimate is based on net return estimates from the national sector analysis (chapter 5). Actual costs to address the manure that cannot be land applied will depend on the combination of options utilized in the region.

Regional Costs

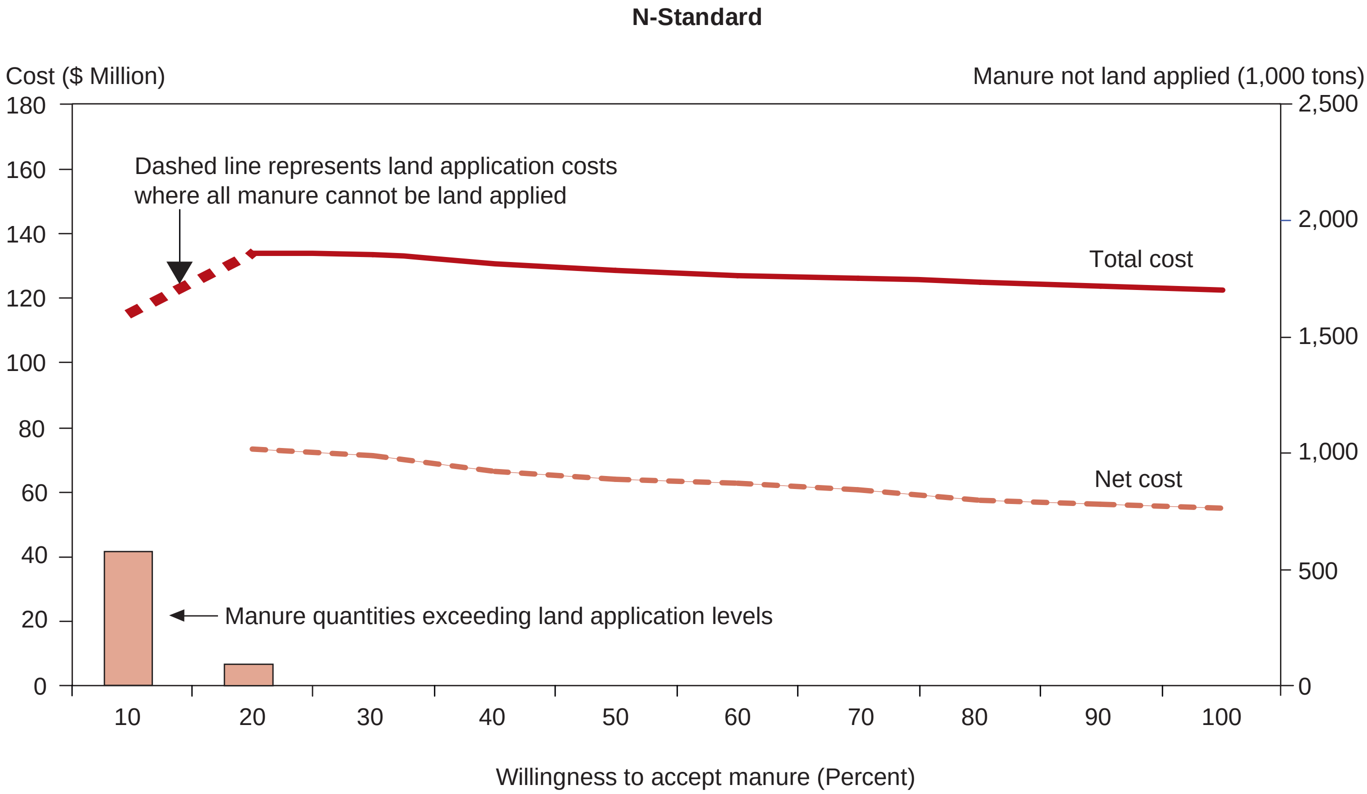
Regional costs considered in this analysis—consistent with the farm-level analysis in chapter 3—include selected nutrient management costs (plan development, soil testing, and manure testing), manure transport (onfarm and off-farm), and application (field spreading and incorporation). We also estimated the savings from reduced chemical fertilizer purchases and application to compute a net regional cost of manure land application.

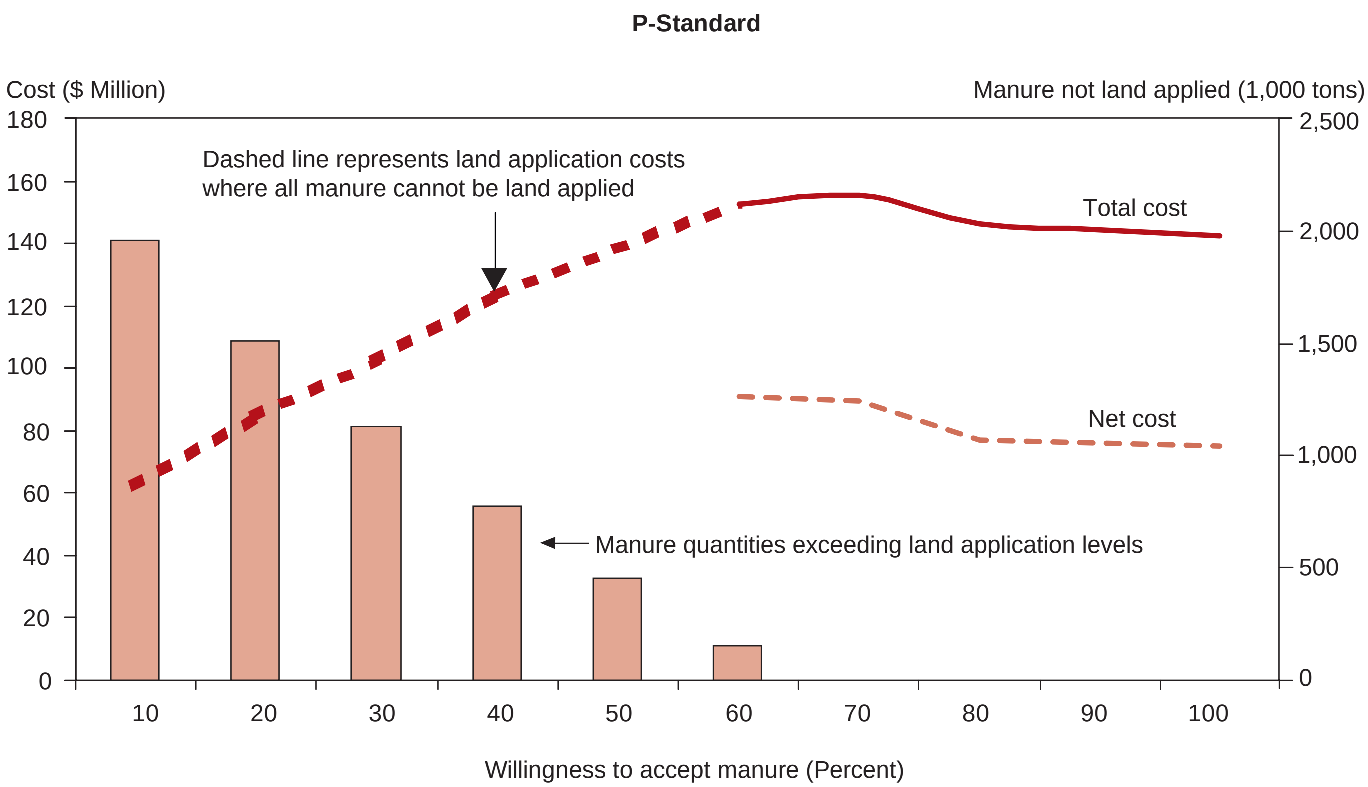
The total regional cost for management, transport, and application under an N-standard was estimated at $134 million at a WTAM of 20 percent (current national levels for select crops are believed to be between 10 and 20 percent) (fig. 4-2). At the 20-percent WTAM level, 2 percent of manure would exceed approved land application levels. Costs decline as WTAM increases, falling to $123 million under an N-standard with all crop and pastureland available for spreading (WTAM = 100 percent). If WTAM is less than 20 percent, the share of manure exceeding land application limits increases, and the costs for management, transport and application would decline. These estimates do not include disposal costs for manure that is in excess of what can be applied to crop and pasture land in the modeled area.

The total costs of management, transport, and application under a P-standard follow a pattern similar to the N-standard. However, costs under the P-standard would be greater and would peak at a substantially higher WTAM due to the lower per-acre application rates and increased hauling distances (fig. 4-2). At a WTAM of 20 percent, about 40 percent of manure production would be in excess of available land's ability to assimilate phosphorus. It is not until WTAM reaches 60 percent that almost all manure produced in the watershed can be land applied. Estimated management, transport, and application costs peak at $155 million with a WTAM of 70 percent (no excess manure). At a WTAM of 100 percent, land application costs would total $143 million. At WTAM levels below 60 percent the quantity of manure in excess of land application increases, and the cost of manure management, transport, and application associated with crop and pasture land use declines. Clearly, at lower WTAM levels, much of the full regional cost of addressing manure nutrients will depend on the disposition of the manure that is not land applied within the CBW.

[8] Savings in chemical fertilizer were based on nutrient costs of nitrogen and phosphorus in the region's most common commercial form and are sensitive to assumptions on fertilizer prices, forms, and application efficiencies. Only the manure nutrients that could be utilized by crops were assigned value. In meeting a N-standard, adequate phosphorus would also be applied and the value of a reduced field operation was credited as "savings." However, nitrogen requirements are not met under a P-standard. It was assumed that additional commercial nitrogen would be applied, so the chemical fertilizer savings when meeting a P-standard included no savings in field operations. There is currently little data on either the current level of substitution of manure for chemical fertilizer or the degree to which potential benefits of improved manure management may already be captured.

Figure 4-2
Effect of willingness-to-accept manure on manure exceeding land application levels, net and total land application costs in the Chesapeake Bay Watershed





Net land application costs are the estimated costs of management, transport, and application for land-applying manure, less the savings from reduced chemical fertilizer purchases and reduced fertilizer application costs.[8] Chemical fertilizer savings were substantial, offsetting 45-55 percent of the total costs of land application for nitrogen and 40-47 percent of the total costs for phosphorus (fig. 4-2).

Regional Cost Components

An analysis of regional manure management must consider costs that occur off-farm, including out-of-county, which may represent a major share of the costs associated with meeting nutrient standards on AFOs. This information may help inform programs that compensate producers for specific cost components, such as transport.

Transporting manure for land application—both onfarm and off-farm—represents the largest component of total costs for manure management, transport, and application in the Chesapeake Bay watershed. Transport costs account for 64 to 67 percent of total costs ($78-$89 million) under an N-standard, and 63 to 67 percent ($90-$102 million) under a P-standard (table 4-1).[9] Application costs were fairly constant across WTAM levels, at near $34 million (25-27 percent) for an N-standard. For a P-standard, application costs were near $40 million, or about 28 percent of total costs. Manure management costs (quasi-fixed costs of plan development, nutrient testing, etc.) were between 7 and 9 percent of total costs for both an N- and P-standard.

Regional costs of land application can also be reported by the location of receiving lands—onfarm, off-farm within the farm's county, or off-farm and out-of-county. Onfarm transport and application costs of manure represent the largest component of total costs in the watershed. Onfarm costs account for between 65 and 75 percent of costs, or about $85 million, under an N-standard (fig. 4-3). Onfarm costs were fairly constant across WTAM levels, since nearly all land on farms with confined animals was used for manure application regardless of the WTAM level of crop producers.[10] Confined animal farms were assumed to have a WTAM for their own manure of 100 percent.

Off-farm manure transfers to suitable crop and pasture land account for 25 percent of the transport and application costs at a WTAM level of 100 percent. The costs devoted to off-farm transfers would increase from $28 million to $43 million (25 to 35 percent) as the WTAM declines, with a shift from mainly within-county costs to primarily out-of-county costs (fig. 4-3). Few counties in the CBW need to transport manure out of county (see fig. 4-1).

A regional presentation masks many of the local cost conditions; most of the region's total out-of-county costs may occur in relatively few counties. For example, in one major exporting county, off-farm transfers accounted for 80 percent of total costs, with out-of-county hauls accounting for 76 percent of the total county cost. Within-county transport costs would decline from $19 million to $10 million while inter-county transport costs would increase from $9 million to $32 million if WTAM dropped from 100 percent to 10 percent, clearly underscoring the importance of willingness to accept manure on the transport patterns and associated costs.

The distribution of on- and off-farm transport costs for the P-standard follows a similar pattern to the N-standard, except that modeled costs peak at a WTAM level of 70 percent (fig. 4-4). Onfarm costs of transport and application were about $80 million (60 percent of total costs) over the WTAM range of 70 to 100 percent. Intracounty costs would decline as WTAM declines. In contrast, intercounty costs increase from $36 million to $54 million as WTAM falls from 100 to 60 percent (fig. 4-4). Out-of-county transport costs for a P-standard are greater even at a 100-percent WTAM than for an N-standard at a 20-percent WTAM. This difference is rooted in the lower allowable per-acre application rate for P, so that fewer tons of manure can be applied on land in the county. This results in lower costs for intracounty hauling but higher intercounty costs. At the lower application rate, more acres are required in total and suitable land will be farther from the manure-producing farm.

One of the major impacts of a reduced willingness to accept manure is the need to move manure farther. The average distance that manure would be transported on manure-producing farms in the CBW is estimated at 0.35 miles.[11] The average distance a farm's excess manure would be transported off the farm, but within-county, ranged between 3.8 miles and 7.3 miles

[9] These costs do not include the capital improvement costs that may be desirable or necessary to improve onfarm manure storage and handling systems to meet policy goals.

[10] While onfarm use of manure nutrients is roughly constant across scenarios, onfarm costs decline with lower WTAM levels when all manure cannot be land applied. This is attributable to the increased onfarm use of higher nutrient and lower cost forms of manure under the regional cost-minimization framework.

[11] The method used to compute onfarm transportation distance likely understates the actual distance, because the algorithm assumes the farm's acres are in a conterminous, square block. Some farms manage separate land parcels spread over large areas.

Table 4-1—Total and net land application costs in the Chesapeake Bay watershed, by nutrient standard and willingness to accept manure

Nutrient standard	Cost category	Willingness to accept manure 10	20	30	40	50	50	70	80	90	100
Nitrogen						*$ Million*					
	Transport costs	--	89.23	88.19	86.02	84.36	83.08	82.17	80.45	79.65	78.87
	Application & Incorporation costs	--	34.24	35.01	34.32	33.98	33.59	33.6	33.88	33.61	33.19
	Management costs	--	10.41	10.43	10.45	10.46	10.45	10.46	10.49	10.5	10.49
	Total land application costs	--	133.88	133.63	130.79	128.8	127.12	126.23	124.82	123.76	122.55
	Less: Chemical fertilizer savings	--	-60.77	-62.55	-64.22	-64.78	-64.45	-65.58	-67.21	-67.55	-67.71
	Net land application cost	--	73.11	71.08	66.57	64.02	62.67	60.65	57.61	56.21	54.84
						Percent of total costs					
	Transport costs	--	66.6	66.0	65.8	65.5	65.4	65.1	64.5	64.4	64.4
	Application & Incorporation costs	--	25.6	26.2	26.2	26.4	26.4	26.6	27.1	27.2	27.1
	Management costs	--	7.8	7.8	8.0	8.1	8.2	8.3	8.4	8.5	8.6
	Total land application costs	--	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Less: Chemical fertilizer savings	--	-45.4	-46.8	-49.1	-50.3	-50.7	-52.0	-53.8	-54.6	-55.3
	Net land application cost	--	54.6	53.2	50.9	49.7	49.3	48.0	46.2	45.4	44.7
Phosphorus						*$ Million*					
	Transport costs	--	--	--	--	--	102.04	101.90	94.03	91.51	89.98
	Application & Incorporation costs	--	--	--	--	--	39.52	42.01	41.1	41.39	41.25
	Management costs	--	--	--	--	--	11.24	11.34	11.38	11.41	11.42
	Total land application costs	--	--	--	--	--	152.8	155.25	146.51	144.31	142.65
	Less: Chemical fertilizer savings	--	--	--	--	--	-61.77	-65.62	-69.43	-68.38	-67.62
	Net land application cost	--	--	--	--	--	91.03	89.63	77.08	75.93	75.03
						Percent of total costs					
	Transport costs	--	--	--	--	--	66.8	65.6	64.2	63.4	63.1
	Application & Incorporation costs	--	--	--	--	--	25.9	27.1	28.1	28.7	28.9
	Management costs	--	--	--	--	--	7.4	7.3	7.8	7.9	8.0
	Total land application costs	--	--	--	--	--	100.0	100.0	100.0	100.0	100.0
	Less: Chemical fertilizer savings	--	--	--	--	--	-40.4	-42.3	-47.4	-47.4	-46.7
	Net land application cost	--	--	--	--	--	59.6	57.7	52.6	52.6	53.3

-- indicates that more than 5 percent of manure could not be land applied. The resulting cost distribution is not a realistic reflection of likely costs.

Figure 4-3

Effect of willingness to accept manure on costs of applying manure to land in the Chesapeake Bay Watershed, by location of land receiving manure

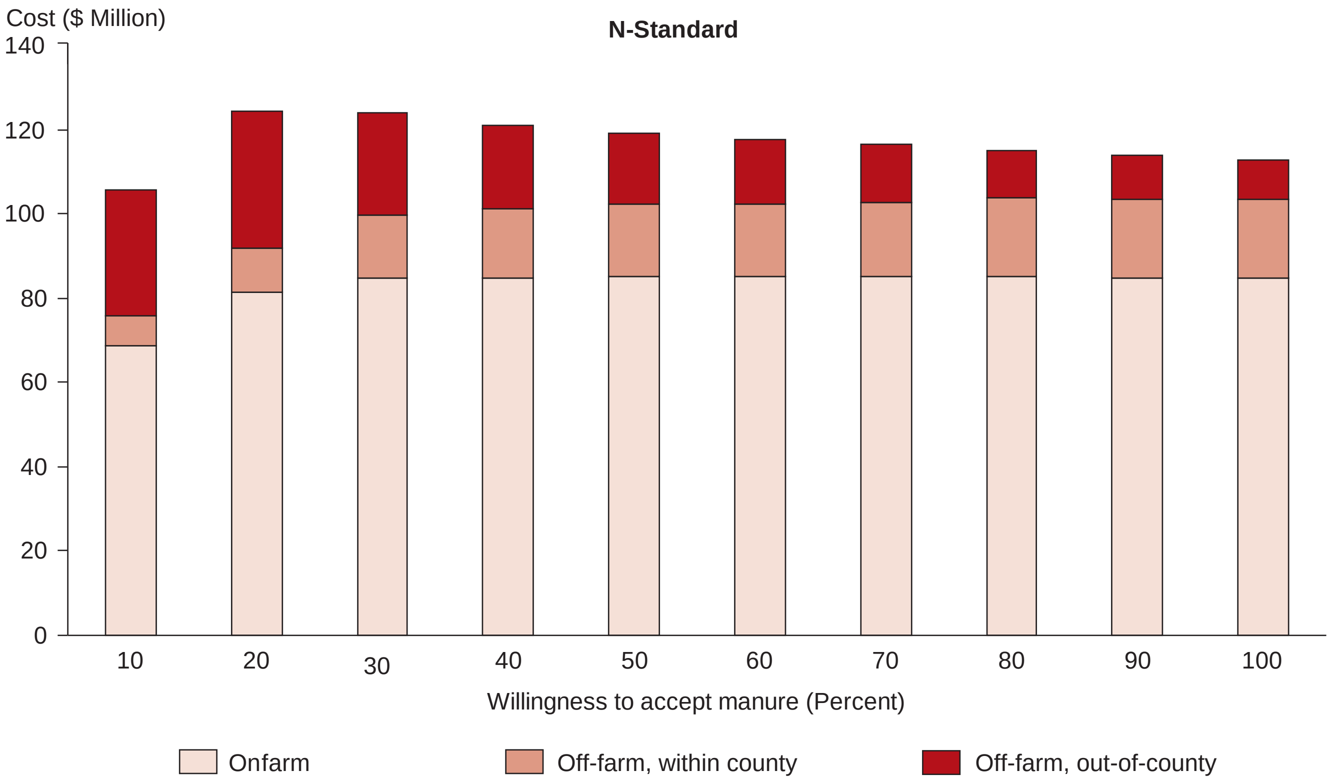
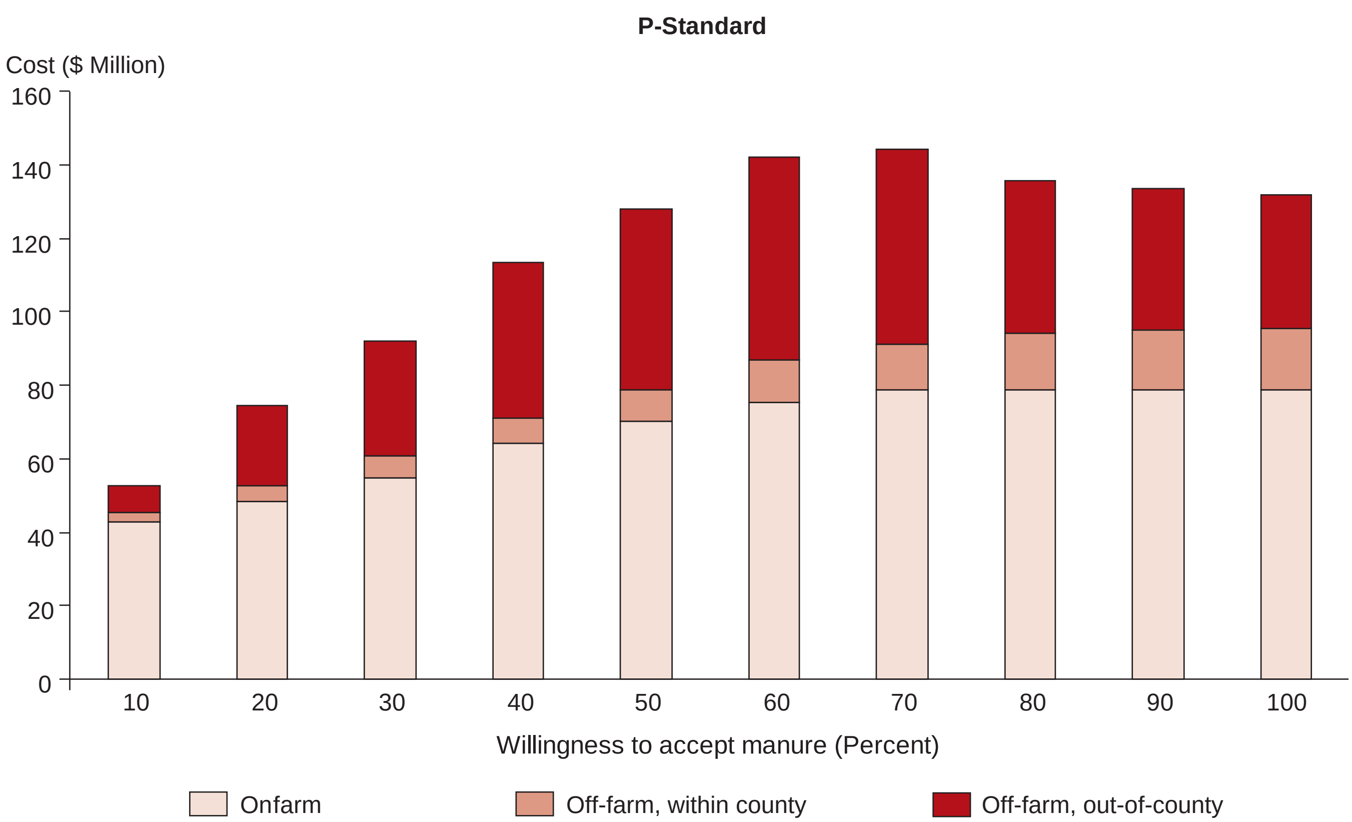


Figure 4-4

Effect of willingness to accept manure on costs of applying manure to land in the Chesapeake Bay Watershed, by location of land receiving manure



for both an N- and P-standard. Out-of-county transport distances are substantially greater, with significant differences between N- and P- standards. Under an N-standard with WTAM of 100 percent, the average intercounty hauling distance was 23 miles. Average intercounty transport distance would increase to near 75 miles at a WTAM of 20 percent. Average intercounty transport distances under a P-standard, at about 40 miles under a WTAM of 100 percent, is almost double that of the N-standard. Average intercounty transport distance would increase to near 120 miles at a 60-percent WTAM.

Our regional model is able to track the relationship between distance and the land that is potentially available for manure application. As farms utilize all of the nearby land for manure application, competition for receiving land intensifies and increases the average distance manure must be moved. The farm-level analysis (chapter 3) estimated that the average distance a large hog farm in the Mid-Atlantic region (which includes most of the Chesapeake Bay watershed) would have to transport manure to reach enough suitable land was about 2.6 miles under an N-standard with a WTAM of 20 percent. The maximum transport distance for any one farm was 21 miles (without considering other farms in the same area also needing land for manure application). Compare this with the *average* intercounty distance of 75 miles from the regional CBW model. When the needs of all confined animal farms are considered simultaneously, the transport distance can increase considerably.

This analysis presumes a working mechanism that allows manure to move from AFOs to crop producers who can use the manure. This could be a manure broker who collects manure from farms and sells it to crop producers, or simple agreements between individual animal producers and their neighbors. Increasing the manure transport distance beyond a producer's own farm and nearby lands highlights the importance of having a manure of consistent nutrient composition that can be delivered and applied in a timely fashion. A market system that will allow the level of manure transfers needed to land apply all the manure in the CBW does not currently exist. Such a system may emerge to link manure producers with manure recipients once the new regulations are implemented and farms meet nutrient application standards.

Additional Cost of Meeting Phosphorus Standard

While the regional costs of applying manure to land were greater under the more stringent P-standard, the cost of shifting from an N- to a P-standard depends on the WTAM level assumed. At a WTAM of 100 percent, the regional costs to meet a P-standard would be about $20 million more than the N-standard. The additional costs to meet a P-standard would increase as the WTAM declines, with total costs about $26 million greater than under an N-standard at a WTAM of 60 percent. At WTAM levels below 60 percent, the increased costs cannot be determined because of the growing quantity of manure that is in excess of land application capacity.

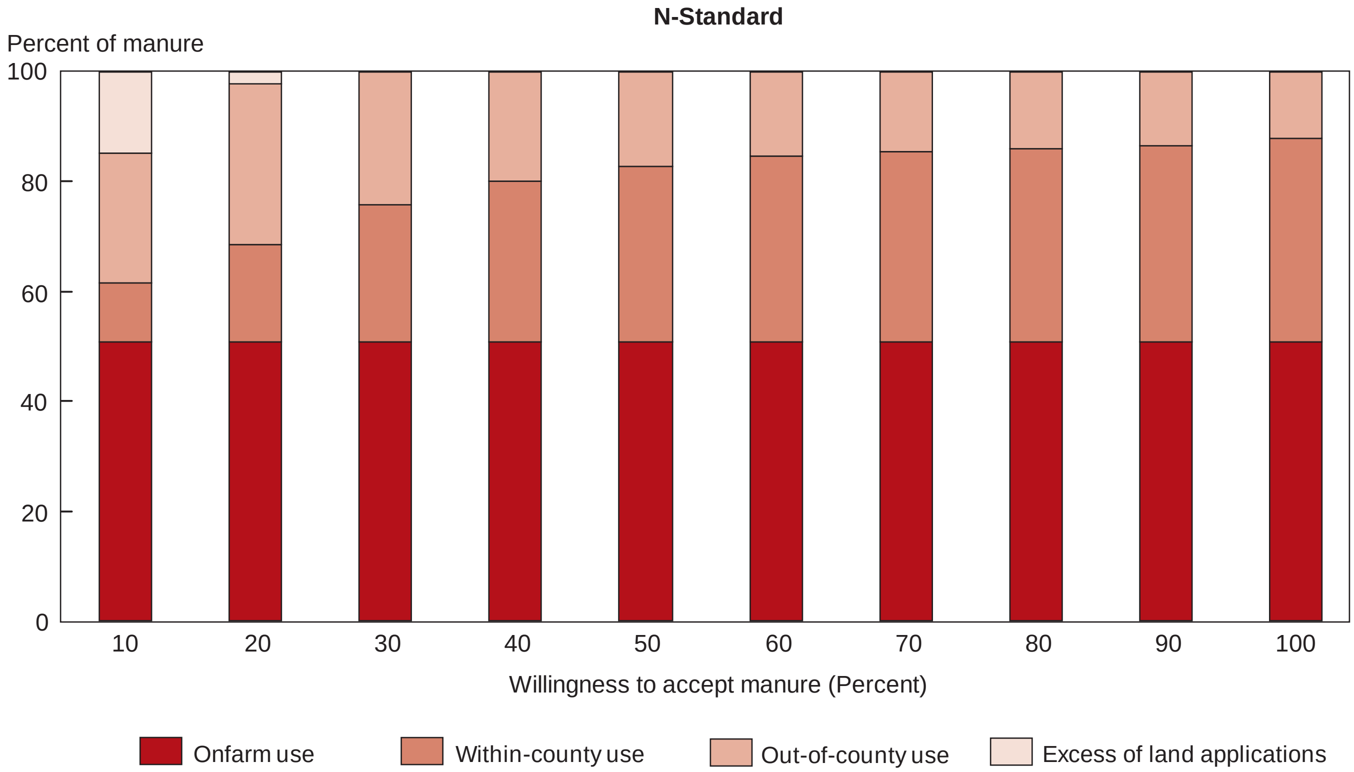
The higher costs of meeting a P-standard are mostly from the greater costs for off-farm manure transport. Off-farm transport costs under a P-standard would be $25 million higher at 100-percent WTAM, growing to $35 million at a 60-percent WTAM. Costs of increased movement of manure off-farm are partially offset by the reduced costs for manure utilized onfarm, since less manure could be applied onfarm. Also potentially reducing the costs of adopting a P-standard are reductions in the costs of applying manure. When soil phosphorus threshold values are acceptable, NRCS policy permits producers to apply multiple years of manure-P in a single-season application (see box, "Nutrient Standards," p. 38). Such flexibility in implementation of nutrient management policy could reduce the acres receiving manure in any given year. Curtailing manure spreading operations to meet the P-standard more flexibly could reduce costs relative to our estimates by as much as $6 million, or 30 percent of the total cost of shifting from an N- to a P-standard, assuming all receiving acreage is eligible based on soil phosphorus thresholds.

Regional Manure Disposition

Costs of meeting the nutrient standards largely reflect the transport distances associated with the quantities of manure applied onfarm, within-county, and out-of-county. Under an N-standard, just over half the manure would be applied onfarm, 37 percent in the farms' county, and the remaining 12 percent to land outside the farms' county at a 100-percent WTAM (fig. 4-5). As the WTAM declines, manure moved off the farm would be transported farther—as reflected by the increased share transported to farms outside the county—reaching 24 percent at a WTAM level of 30 percent. At a WTAM level of 20 percent, about 2 percent of manure in the watershed would be in excess of land application capacity, given the transportation limits in the model.

Meeting a P-standard would decrease the quantity of manure applied onfarm (relative to an N-standard) to less than 40 percent of total manure. The share of

Figure 4-5
Effect of the willingness to accept manure on its disposition in the Chesapeake Bay Watershed, including excess manure



manure applied in the farms' county would also decline to 24 percent. As expected, the share of manure transported out of the farms' county would increase substantially, with 37 percent of the manure transported to land outside the farms' county under a 100-percent WTAM (fig. 4-6). The share of manure transported across county lines would continue to increase as the WTAM level declines, reaching 41 percent of manure produced at a 60-percent WTAM.

The growing share of intercounty manure transport as well as the increasing distance for average intercounty movement is shown spatially in figure 4-7. At a WTAM level of 100 percent, three areas of manure export prevail—the Shenandoah Valley of Virginia and West Virginia; the Delmarva Peninsula area of Delaware, Maryland, and Virginia; and areas of south-central Pennsylvania, especially Lancaster County. The composition of manure export counties remains fairly constant as WTAM levels decline, though the number of counties that are net importers of manure increase, as does their distance from the export counties.

Manure produced in the region is not uniform, but varies in quality depending on the animal type and manure system (see box, "Manure Handling Systems," p. 47). Manure characteristics influence where manure is applied because the standards are nutrient based and high-water manure adds weight and cost. One would expect that manure with a high water content ("wetter" manure) would be transported a shorter distance than "dryer" manure, all else being equal. In the CBW, lagoon waste is the wettest form of manure, while poultry litter is the driest. Slurry is intermediate in terms of water content.

Generally, the wetter the manure, the more likely it would be used onfarm (fig. 4-8). (The model is responding to the cost per ton of material and minimizing the transport of water long distances.) Over half of the dry manure would be transported off the farm under all WTAM levels under both an N- and P-standard. Another outcome of cost-minimizing is that when available land capacity for receiving manure is reached, manure transported is that with the lowest water content.

Alternatives to Land Application

Numerous alternatives to spreading manure on land—broadly classified as "output-using" or "supply-reducing"—exist or are under development, but their applicability varies with animal species, region, and stage of development. Output-using technologies redirect the manure off-farm as an input for industrial uses. These technologies may transform the manure into a

Figure 4-6
Effect of the willingness to accept manure on its disposition in the Chesapeake Bay Watershed, including excess manure

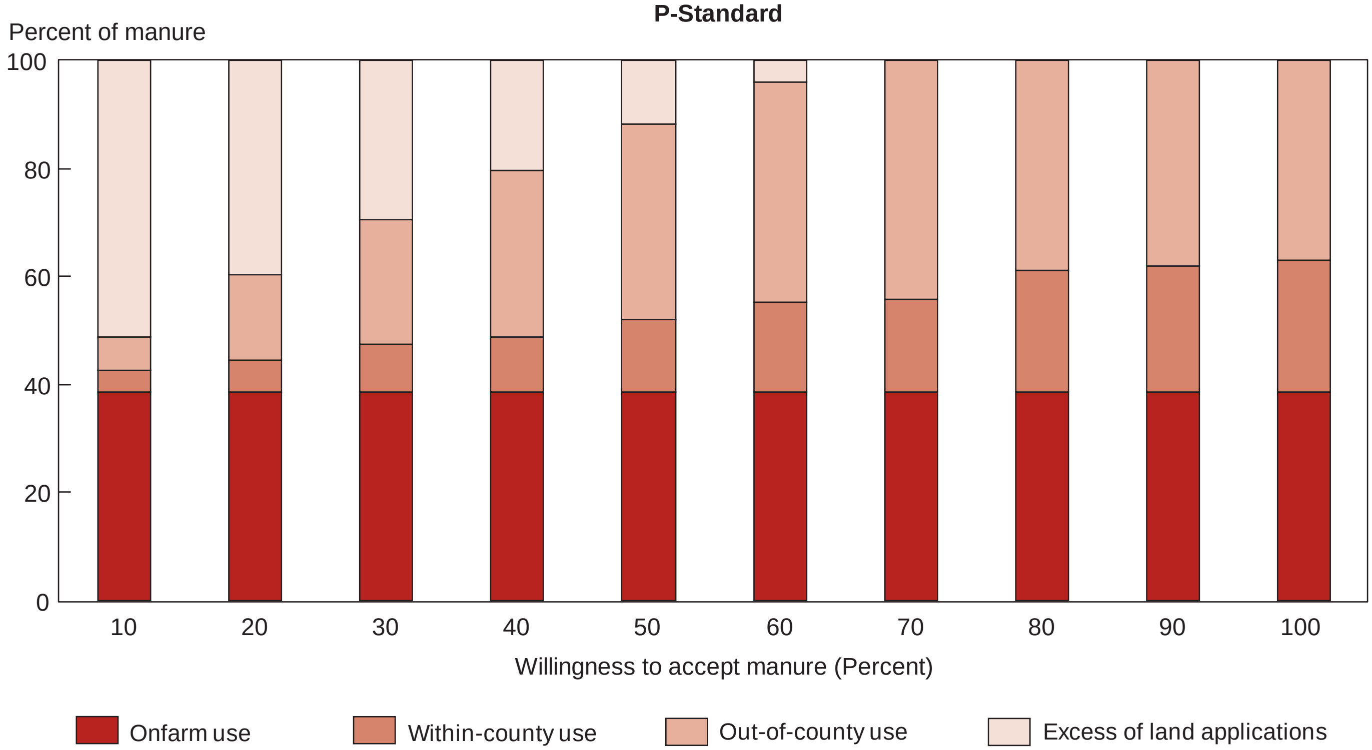
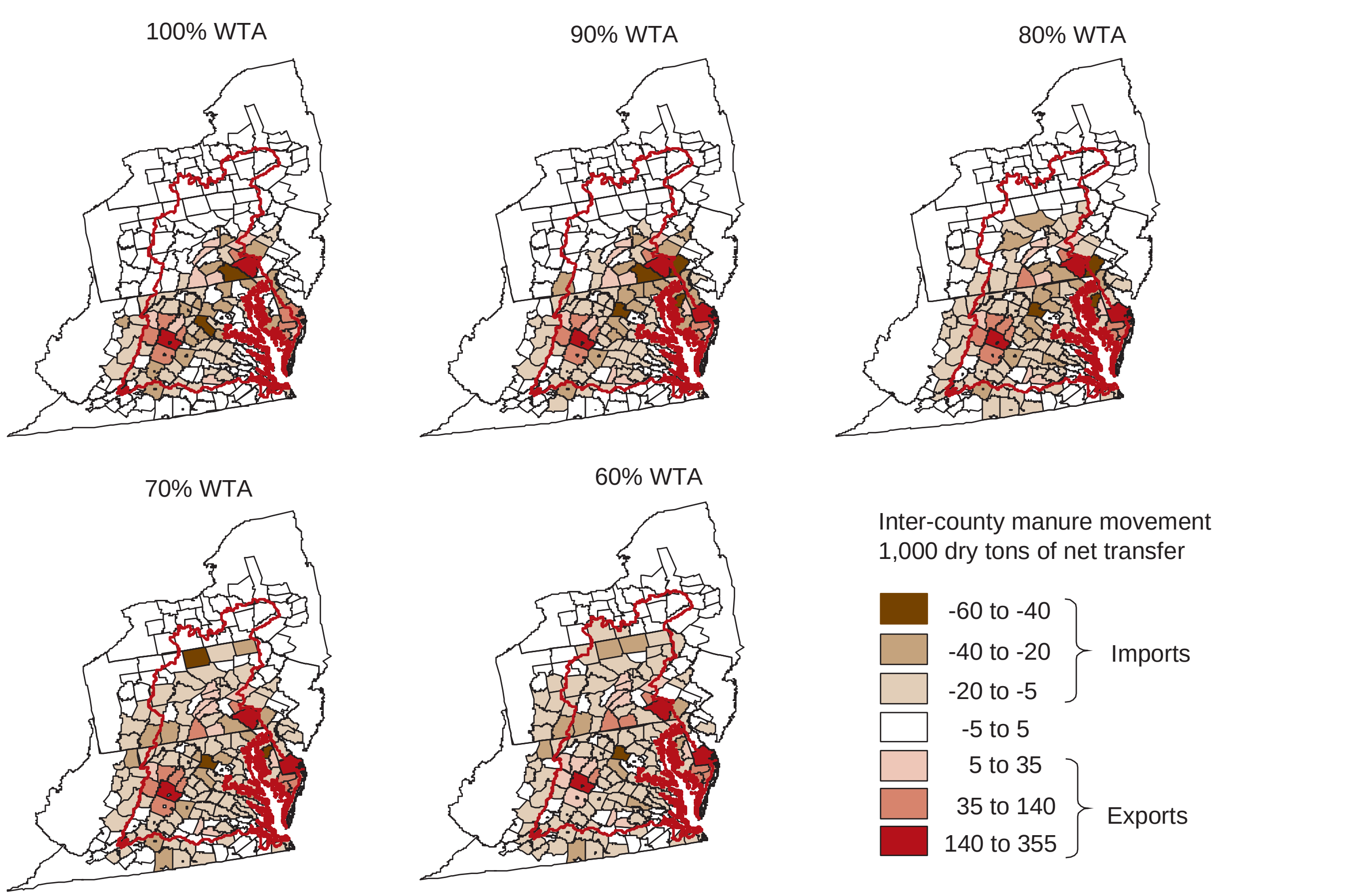


Figure 4-7
Effect of willingness to accept manure on its spatial distribution under a P-standard, 1997



Manure Handling Systems

Alternative manure handling systems play an important role in the regional model. The systems were the basis for the estimation of the wet manure transport weight and associated costs. Systems also formed the basis for the different ways manure can be transported and applied (truck, tractor and spreader, or irrigation system). Three alternative manure handling systems were included in the regional model: lagoon systems (open, uncovered storage), slurry systems (covered storage), and dry systems (primarily poultry in the CBW). All poultry in the CBW were assumed to use a dry litter system. The manure handling systems for swine and dairy in the CBW were determined from the systems reported in the ARMS for those animal types (USDA, 2002a). Feedlot beef was assigned the same system proportions as dairy. Manure handling systems were linked to an animal type and were not allowed to adjust in the current regional model.

Manure waste from lagoon systems was specified as 99 percent water; slurry systems - 95 percent water; poultry dry systems - 30 percent water, and dry systems for other livestock types - 50 percent water (USDA, NRCS, 1999b). An additional bedding adjustment, representing tons of bedding per ton of dry manure, was included for some dairy (30 percent of manure) and all poultry (10 percent of manure) production. The share of dairy systems utilizing bedding was based on ARMS data.

more homogeneous and stabilized fertilizer product, or may burn manure for power generation. Manure with relatively low moisture content, such as broiler litter, is generally better suited for use in industrial processes than "wetter" manure from lagoon and slurry systems. A supply-reducing technology reduces the amount of nutrients excreted per unit of animal output, resulting in fewer pounds of nutrients needing disposition. This can be achieved through dietary modifications.

Output-Using Technology

Industrial uses of manure in the Chesapeake Bay watershed have historically focused on composting poultry litter. The amount of poultry litter in the CBW processed by industrial facilities has increased significantly with the recent construction of two large-scale industrial facilities using poultry litter, PerdueAgriRecycle™ and Harmony Farms Shenandoah Valley (HSV).[12] These two operations transform litter into pelletized organic fertilizer, blended fertilizer products, and energy for use in fertilizer manufacturing. Other industrial processes that could divert litter from land spreading are in the planning or construction stage (see box, "Industrial Processes for Using Manure," p. 50). For example, a large-scale, capital-intensive project to generate electricity by burning poultry litter has been proposed, but its high cost and other issues have thus far prevented its development.

PerdueAgriRecycle™, in Seaford, Delaware, is permitted to process 94,000 tons of litter annually into pelletized organic fertilizer for agricultural and landscaping uses. HSV, in the Shenandoah Valley of Virginia, is designed to process 60-65,000 tons per year of poultry litter as both an energy source and a feedstock in the manufacture of a blended organic-inorganic fertilizer for the golf course and landscaping markets. Manure diverted to plants such as these would no longer be in competition for land, reducing the total regional costs of applying manure to land.

Based on proposed alternatives, we estimate that the diversion of poultry litter to industrial alternatives would be 200,000 tons per year in the near term (2002-2004) and 376,000 tons within 5 years, or 0.30 and 0.65 percent of the manure produced in the region.[13] Near-term estimates include the two new plants and existing composting facilities. Future estimates reflect projected growth in composting operations, full use of existing plants' capacity, and the completion of industrial uses currently in the planning or construction stage.

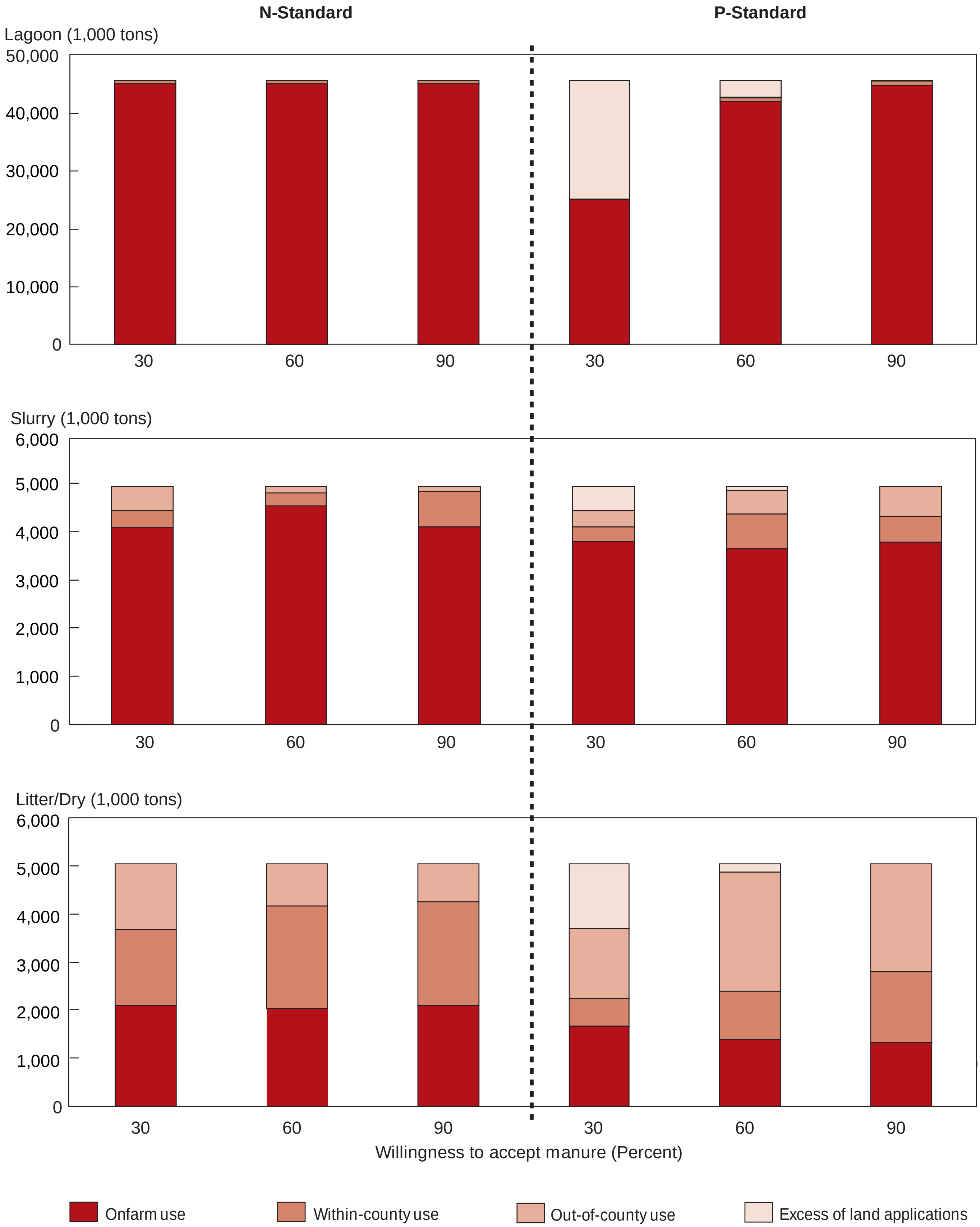
Diverting poultry litter to industrial uses would reduce total land application costs under an N-standard in the CBW by \$2-\$3 million per year in the near term, and \$3.6-\$4.8 million per year as additional projects are completed, for a total drop in regional costs of 5-6 percent depending on the WTAM level. Processing litter into fertilizer and energy would reduce total regional costs by \$10-\$15 per ton, mostly due to savings in off-farm transport and land application. However, factoring in the value of nutrients in manure not going to the land, savings are reduced to \$0.55-\$5.75 per ton (table 4-2).

Under the more stringent P standard, total land application costs would decline by \$4.6 million to \$7.3 million (3 to 4 percent) per year depending on the quantity of poultry litter diverted to industrial facilities at the

[12] No endorsement by USDA of the process or product is implied or inferred.

[13] Quantity estimates of poultry litter production based on the Agricultural Census are 710,000 tons in the Delmarva area (Lichtenberg et al., 2002) and 550,000 tons in the Shenandoah Valley (Pelletier et al., 2001).

Figure 4-8
Disposition of manure in the Chesapeake Bay Watershed, by manure handling system and willingness-to-accept, 1997



90-percent WTAM level. Processing litter into fertilizer and energy would reduce total costs by $20-$23 per ton, from savings in transport and application costs. Net cost savings are $8-$11.50 per ton after accounting for the value of manure nutrients no longer being applied to land in the CBW (table 4-3).

The estimates of manure diverted to industrial uses at a WTAM level of 60 percent absorbed enough manure to enable land application of all remaining manure. However, some of the costs actually increase because more manure was applied than without industrial alternatives, and wetter manure is being transported greater distances due to the diversion of poultry litter to industrial options. At the current industrial level, costs increase but the region is able to spread all manure not sent to an industrial alternative at a 60-percent WTAM. With expanded industrial capacity, there was a cost savings of $7 per ton in transport costs ($6 considering fertilizer value adjustments). The transport cost savings at a 60-percent WTAM are about half those at 90-percent WTAM, since wetter manure has to travel longer distances.

The capital costs for the PerdueAgriRecycle™ and Harmony Farms Shenandoah Valley (HSV) facilities were $13.5 million and $10 million. Using these two industrial operations as a guide, the amortized capital costs were estimated to be $1.20-$2.10 per ton of raw litter used, depending upon the type of operation, capital cost, and percent of operating capacity utilized.[14] In comparison, the reduction in net land application costs due to a diversion of manure to industrial uses is estimated at $0.50-$5.75 per ton with the N-standard and $8-$33 per ton with a P-standard, depending on the WTAM level.

Our analysis thus indicates that the use of industrial options in the CBW can reduce aggregate manure disposition costs by offering an alternative to hauling manure over greater distances. Animal producers would benefit by not having to incur application costs, and may pay reduced hauling costs. Unless enough industrial capacity was built to use more than the excess amount of manure, crop producers would still need to use the same amount of manure nutrients. Land application cost savings varied considerably with the assumptions made regarding the nutrient standard and willingness to accept manure, but in general they are large enough to warrant further investigation of industrial options. We estimated the potential savings in net land application costs to be nearly $2 million with an N-standard and $3 million with a P-standard (tables 4-2, 4-3).

While this study does not address whether the industrial operations will be profitable and become viable over the long term (data on variable costs for industrial uses were not available), the analysis indicates that the annualized cost of building industrial facilities is often less than the cost of applying manure to land, particularly when meeting a P-standard. While projected industrial use of manure represents less than 1 percent of total CBW manure, potential savings could greatly benefit areas with concentrated animal production and inadequate land for manure application.

Supply-Reducing Technology

Supply-reducing technology is designed to reduce the amount of nutrients excreted in manure, primarily through modification of the diet fed to livestock and poultry.[15] The potential for changing animal diets to reduce nutrient outputs and helping to alleviate potential pollution from nitrogen and phosphorus is widely recognized (CAST, 2002) (see box, "Reducing Manure Nutrients Through Feed Management," p. 19). Possibilities for improving dietary efficiency and reducing nutrient excretion include substituting phytase and synthetic amino acids for other dietary components.

Using the regional model, we estimate the impact of adding phytase to broiler and swine rations on the costs of applying manure to land under a P-standard. Based on the literature, we assumed the addition of phytase to all swine and poultry diets in the CBW would reduce the phosphorus content of their manure by 30 percent.

The addition of phytase to poultry and swine diets with a 90-percent WTAM, where all manure can be applied to land, reduces the regional costs of manure management, transport, and application by almost $7 million per year (5 percent of no-phytase costs), with almost 70 percent of the savings in reduced transport costs. Net land application costs would decline by about 4 percent (table 4-3).

At a 60-percent WTAM, adding phytase enables the region to achieve a P-standard, given the land available and the model's transportation limits. Since the

[14] These estimates assume a capital cost of $10-$14 million, a life of 20 years, and an interest rate of 10 percent.

[15] Other supply-reducing alternatives include adjustment in mix of animals or changes in genetic stock.

Industrial Processes for Using Manure

Concerns over increased supplies and concentration of livestock and poultry manure have resulted in numerous proposed manure management solutions beyond land application. However, many of these proposed solutions are still theoretical or experimental. The feasibility of industrial processing varies between livestock species due to differences in manure composition and handling characteristics. Within the Chesapeake Bay watershed, the development of industrial options has been encouraged by the concentration of poultry production and the resulting manure that is relatively dry and amenable to industrial processes.

Several small-scale composting and other processes have been used in the Chesapeake Bay watershed for some time, but only recently have two large-scale industrial solutions for poultry litter have only recently become operational realities. Additional information on alternative uses of poultry litter and other manure is available elsewhere (Lichtenberg et al., 2002; Christensen, 1999).

Perdue AgriRecycle™

Several processes have been developed to make the nutrients and organic matter in manure more uniform, manageable, and marketable. One of these uses a pelletizing technology and process developed by AgriRecycle[1] to transform raw poultry litter into value-added organic fertilizer. This process was implemented through a joint venture with Perdue Farms as a way to manage surplus poultry litter in the Delmarva area. Perdue AgriRecycle™ began operations in 2001 in Suffolk County Delaware, the largest broiler-producing county in the U.S. The plant's capacity is 94,000 tons of litter annually, with permits to expand to 150,000 tons as markets for final product develop. The final product is a pasteurized organic fertilizer granule or pellet, with a nutrient blend (phosphorus, nitrogen, potassium ratio) of 3-4-3, especially designed for precision agriculture applications. It is a certified organic fertilizer, approved by the Organic Materials Review Institute for organic crop production.

Harmony Farms Shenandoah Valley

Harmony Farms Shenandoah Valley (HSV), in Harrisonburg, VA, uses a fertilizer manufacturing technology to convert litter, primarily turkey litter, into energy and an enriched granular product that can be readily transported and applied to land. The process uses a gasification technology that produces thermal energy, coupled with a mixing and blending process using a liquid urea binder. The HSV plant capacity is about 60,000 tons of litter annually. About 10-15 percent of the incoming poultry litter is used to generate energy to run the plant. The remainder is processed and blended with commercial nutrients to produce enriched organic fertilizers for the golf course, landscape, and home garden markets with the nutrient blends varying from 5-5-3 to 14-3-6.

Large-Scale Use of Manure as Biomass Fuel

Manure can used as a biomass fuel to generate electricity. However, the high moisture content of the manure is a limiting factor. The English company Fibrowatt Limited has proposed to build a large-scale power plant in the Delmarva area similar to what they built in England. The plant would burn biomass (poultry litter and wood products) to produce electric power and a granular fertilizer product from the ash. The proposal has not been accepted for the Delmarva area, primarily because of the high capital and production costs. Energy from litter is estimated to cost 3-4 times the energy from conventional power plants.[2] Even so, Fibrowatt is designing and building a smaller plant in Minnesota to generate power from turkey litter.

[1] No endorsement of any of these processes or commercial entities by USDA is implied.
[2] Broiler litter has about half the caloric value of coal.

model shifts from a "no-phytase" alternative with 154,000 tons of excess manure to a "with-phytase" case with all manure applied to land, the cost savings are difficult to interpret. While the total costs of manure management, transport, and application decline by about 3 percent of the no-phytase costs, net land application costs declined about 11 percent, or $10 million. The application of manure that could not be spread under the P-standard case increased the chemical fertilizer savings with phytase. The manure management, transport, and application cost savings would have been greater if not for the additional 154,000 tons of manure that can be land applied with phytase. Clearly, the use of supply reduction technolo-

Table 4-2—Total and net land application costs to meet an N-standard in the Chesapeake Bay Watershed, by willingness-to-accept-manure and level of industrial use

Cost category	N-standard	Current industrial (CI)	Expanded industrial (EI)	Changes from N-standard (CI)	Changes from N-standard (EI)	Changes per ton (CI)	Changes per ton (EI)
WTAM = 90 percent			*$ million*			*$*	
Transport costs	79.65	78.16	77.14	1.49	2.51	7.49	6.68
Application/incorporation costs	33.61	33.01	32.54	0.60	1.07	3.02	2.85
Management costs	10.5	10.48	10.47	0.02	0.03	0.10	0.08
Total land application costs	123.76	121.65	120.15	2.11	3.61	10.60	9.60
Less: Chemical fertilizer savings	-67.55	-65.55	-64.24	-2.00	-3.31	-10.05	-8.80
Net land application cost	*56.21*	*56.10*	*55.91*	*0.11*	*0.30*	*0.55*	*0.80*
WTAM = 60 percent							
Transport costs	83.08	81.33	80.04	1.75	3.04	8.79	8.09
Application/incorporation costs	33.59	33.07	32.75	0.52	0.84	2.61	2.23
Management costs	10.45	10.44	10.44	0.01	0.01	0.05	0.03
Total land application costs	127.12	124.84	123.23	2.28	3.89	11.46	10.35
Less: Chemical fertilizer savings	-64.45	-62.70	-61.6	-1.75	-2.85	-8.79	-7.58
Net land application cost	*62.67*	*62.14*	*61.63*	*0.53*	*1.04*	*2.66*	*2.77*
WTAM = 30 percent							
Transport costs	88.19	86.18	84.76	2.01	3.43	10.10	9.12
Application/incorporation costs	35.01	33.96	33.61	1.05	1.40	5.28	3.72
Management costs	10.43	10.42	10.42	0.01	0.01	0.05	0.03
Total land application costs	133.63	130.56	128.79	3.07	4.84	15.43	12.87
Less: Chemical fertilizer savings	-62.55	-60.62	-59.74	-1.93	-2.81	-9.70	-7.47
Net land application cost	*71.08*	*69.94*	*69.05*	*1.14*	*2.03*	*5.73*	*5.40*

Table 4-3—Total and net land application costs to meet a P-standard in the Chesapeake Bay Watershed, by willingness-to-accept-manure, level of industrial use, and addition of phytase to feed

Cost category	N-standard	Current industrial (CI)	Expanded industrial (EI)	Phytase	Changes from N-standard (CI)	Changes from N-standard (EI)	Phytase	Changes per ton (CI)	Changes per ton (EI)
WTAM = 90 percent				*$ Million*				$	
Transport costs	91.51	88.37	86.60	87.36	3.14	4.91	4.15	15.78	13.06
Application/incorporation costs	41.39	40.01	39.10	39.04	1.38	2.29	2.35	6.93	6.09
Management costs	11.41	11.34	11.27	11.17	0.07	0.14	0.24	0.35	0.37
Total land application costs	144.31	139.72	136.97	137.57	4.59	7.34	6.74	23.07	19.52
Less: Chemical fertilizer savings	-68.38	-66.08	-63.97	-67.30	-2.3	-4.41	-1.08	-11.56	-11.73
Net land application cost	*75.93*	*73.64*	*73.00*	*70.27*	*2.29*	*2.93*	*5.66*	*11.51*	*7.79*
Excess manure (1000 tons)	0	0	0	0					
WTAM = 60 percent									
Transport costs	102.04	103.72	99.24	97.07	-1.68	2.80	4.97	-8.44	7.45
Application/incorporation costs	39.52	40.53	39.85	39.48	-1.01	-0.33	0.04	-5.08	-0.88
Management costs	11.24	11.24	11.19	11.10	0	0.05	0.14	0.00	0.13
Total land application costs	152.80	155.49	150.28	147.65	-2.69	2.52	5.15	-13.52	6.70
Less: Chemical fertilizer savings	-61.77	-63.09	-61.62	-66.63	1.32	-0.15	4.86	6.63	-0.40
Net land application cost	*91.03*	*92.40*	*88.66*	*81.02*	*-1.37*	*2.37*	*10.01*	*-6.88*	*6.30*
Excess manure (1,000 tons)	154	0	0	0	-154	-154	-154		

gy has greater potential for cost savings at lower WTAM levels.

Phytase also significantly reduces the amount of excess manure at lower WTAM levels. At 30-percent WTAM, the use of phytase reduced the manure in excess of land application capacity by about 45 percent, enabling an additional 500,000 tons of manure to be spread.

Summary

Management of livestock manure is crucial to the Chesapeake Bay watershed (CBW), given its concentration of animal production and the State/Federal commitment to protect the bay's resources. New policies on the handling of animal manure are likely to have a significant impact on the livestock and poultry sectors. This is particularly true in the CBW, where counties rank among the highest in the Nation in concentrations of surplus manure nutrients.

The willingness of crop producers to accept manure on eligible acres is an important consideration. In fact, our results indicate that this could be the most important consideration in determining whether land application as a stand-alone strategy is feasible in the CBW. We find that, at willingness-to-accept-manure (WTAM) levels of 60 percent or lower, there is an insufficient land base to apply all the manure under a P-standard, given the modeled transportation radius and no change in land use, crop mix, or animal location. Similarly, all manure cannot be land applied under an N-standard at WTAM levels of 20 percent or lower. Current data suggest that between 10 and 20 percent of cropland receives manure.

Holding animal production constant, the estimated total cost for land application of manure was $123 million to $155 million per year over the set of solutions in which all manure may be land applied. This is a high proportion of annual total net returns to animal production in the CBW ($313 million). The model cannot estimate land application costs when long-distance hauling would involve transporting the manure beyond the modeled transportation radius of roughly 150 km. Over 60 percent of manure disposition costs were for transport, and less than 30 percent for application/incorporation. By location, **onfarm** hauling and distribution of manure accounted for up to 75 percent of the total costs, but the costs tended to be constant in dollar amount over the range of WTAM levels where all manure could be land applied. Most of the cost increases from reduced WTAM levels were associated with **off-farm** movement of manure. Out-of-county transportation, application, and incorporation costs were estimated to range between $9 million and $55 million, depending on which nutrient standard was in effect and the willingness of crop producers to accept manure.

The net costs of manure management in the CBW depend not only on the total land application cost but also on the potential savings in commercial fertilizer by more efficiently using manure nutrients, as well as on the costs of addressing the manure that could not be land applied due to model transportation limits. The potential savings in commercial fertilizer purchases and application costs were estimated at $60-$68 million, which offset 40-55 percent of the total costs of applying manure to land. The extent to which the potential nutrient savings are translated into farm returns will influence not only the net manure disposal costs but also a producer's willingness to accept manure. Moreover, some portion of those savings will be felt as reduced revenues to fertilizer suppliers.

Finally, significant quantities of manure under the P-standard were not land applied in our modeling framework at many WTAM levels. The disposition of this manure remains a challenge, perhaps an expensive challenge, for manure management in the CBW.

The annual cost savings from shifting manure from land application to industrial uses compare favorably to the annualized capital costs of recently constructed industrial litter processing facilities. A P-standard issued cost savings of $2-$7 million by shifting manure to an industrial plant rather than hauling it to a distant site for land application, depending on the region's willingness to accept manure for land application. These cost savings are concentrated primarily in areas with high animal numbers and limited land for manure application. Similarly, the addition of phytase to the diet of swine and poultry reduced land application costs by $6-$10 million. Phytase also enables the application of much more manure to the region's land base, particularly important for meeting a P-standard when WTAM is not high. These preliminary values provide a starting point for an indepth investigation of industrial options and their potential for the CBW's agricultural economy.

The need to transport manure over longer distances has structural implications for the agricultural sector. Moving manure to a location that is miles away from the manure source presumes that a marketing structure is in place and that a consistent, standardized product is shipped to the destination. It is likely that a more formal marketing system will develop over time to satisfy this need, spurred on by the new policy.

Appendix 4-A

Modeling Manure Management in the Chesapeake Bay Watershed

The model is designed to minimize total regional costs of applied manure, including manure transport, land application, and selected nutrient management plan costs in the Chesapeake Bay watershed, given 1997 animal production levels. The model was developed to (1) provide a mechanism that tracks manure and related nutrient flows within the watershed, from manure source to site application and use, (2) estimate the regional costs of applying manure to land, and (3) provide a framework for evaluating proposed land-application regulations and alternative nutrient management policies. The regional model specification captures the competition for land on which to spread manure by endogenizing access to spreadable land and associated hauling costs. Explicit modeling of competition for land in areas with significant animal concentrations is a central feature of the regional model that is not reflected in existing farm-level models.

Regional Model Structure

The county serves as the primary modeling unit for the regional model. The county-level specification provides consistency with Census of Agriculture data and other county-level data, while permitting differentiation in animal production, nutrient uptake, waste technologies, institutions, and regulatory conditions across county and State boundaries within the watershed.

Manure is produced in a "source" county (ct) and land applied (or otherwise disposed of) in a "destination" county (ct2). "Model" counties include 160 non-municipality counties with farmland in the Chesapeake Bay watershed. "Sink" counties refer to destination counties outside the modeled area that could serve as potential destinations for manure exported from the watershed. Model counties may be both source and destination counties; sink counties are destination counties only. The potential level of out-of-basin exports depends on net assimilative capacity of the sink counties after accounting for county manure applications. There are 104 sink counties included in the full watershed model, comprising non-municipality counties within 60 kilometers (37 miles) of cropland in a model county. Model solution values for "edge" counties, or those that straddle the watershed boundary, are apportioned by share of farmland within the watershed to more accurately account for manure disposition at the basin level.

The optimization model is designed to minimize the regional cost of applied manure, subject to total manure produced, land availability for manure applications, and other disposal options. The model allocates manure flows across the watershed and neighboring sink counties to minimize the objective function expression:

$$(1)\quad \sum_{ct}\sum_{ct2}[\mathrm{HAC}_{ct,\,ct2} + \mathrm{NM1}_{ct} + \mathrm{NM2}_{ct2} + \mathrm{ELA}_{ct} - \mathrm{FS}_{ct2}]$$

Costs include manure hauling and application costs (HAC), land incorporation costs (INC), and nutrient management plan charges for source (NM1) and destination (NM2) counties. A penalty cost for manure levels exceeding land application (ELA) capacity is included to ensure that all manure is land applied subject to available land (this cost is removed from reported costs). Aggregate costs are further adjusted to reflect cost savings from reduced purchase and application costs for chemical fertilizers (FS).

In-county and out-of-county transfers of manure are the primary activities in the model. Potential county-to-county transfers were developed based on an assumed maximum radial distance of 60 kilometers (37 miles), or 150 kilometers (93 miles) for the largest manure-surplus counties (10 percent of total), measured from the outer edge of the source county's cropland base. There are 4,060 county-level transfer possibilities in the full watershed model, including in-county and out-of-county transfer combinations. Manure transfers are further disaggregated by sub-county grid location, manure system type, and distance interval, resulting in over 300,000 transfer alternatives.

The primary decision variables in the model represent the quantity of manure transferred (M_TRN), acres used for manure spreading (AC_SPR), and manure hauling distance (DST). Model equations include (1) balance equations that track stocks and flows of manure and manure nutrients, (2) constraints on land availability, distribution of confined animal farms (manure sources), and manure nutrient use, and (3) cost accounting equations. In general, wet manure quantities form the basis of model hauling and application costs, while manure nutrient content and uptake rates determine the volume and direction of manure flows.

Primary manure transfer equations are as follows:

$$(2)\quad M\_TRAN_{ct,\,ct2} = ((M\_AP_{ct,\,ct2,\,N*} * SH\_N_{ct2}) + (M\_AP_{ct,\,ct2,\,P*} * (1 - SH\_N_{ct2}))) * AC\_SPR_{ct,\,ct2}$$

$$(3)\quad \sum_{ct} AC\_SPR_{ct,\,ct2} \leq A_{ct2} * WTA_{ct2}$$

$$(4)\quad M\_TRN_{ct,\,ct2} = \sum_{gr} \sum_{sy} \sum_{ds} M\_TRN_{ct,\,gr,\,ct2,\,sy,\,ds}$$

$$(5)\quad \sum_{ds} M\_TRN_{ct,\,gr,\,ct2,\,sy,\,ds} \leq M\_PRD_{ct,\,ct2} * SH\_M_{ct,\,gr,\,ct2,\,sy}$$

where N^* represents N-standard and P^* represents P-standard, *gr* is county grid location, *sy* is manure system (lagoon, slurry, dry; see box, "Manure Handling Systems," p. 47), and *ds* is hauling distance interval in miles. Onfarm hauling distance is set based on estimated average county distance. Off-farm hauling distance is derived endogenously, falling within one of three intervals (0.5-2, 2-10, >10) used to calculate hauling costs.

In Equation (2), dry manure tons by county transfer (M_TRAN) is defined as the product of per acre manure application rate (M_AP) by county transfer—weighted by the acreage share under an N-standard (SH_N) and acreage share under a P-standard (1- SH_N)—and receiving acres (AC_SPR) in the destination county. Manure application rate is estimated for each individual in-county and out-of-county transfer, based on: (1) average nutrient content of manure from the source county; (2) average nutrient removal rates for N and P in the destination county, weighted across cropland and pastureland for each of three farm types (non-animal farms, non-confined animal farms, and confined animal farms); (3) nitrogen volatilization factors, with and without incorporation; and 4) the nutrient standard in effect.[16] Data specification by county and farm type allows the model to capture potential variation in assimilative capacity due to differences in cropping pattern, land in pasture, and crop yield.

Equation (3) restricts applied manure from all potential source counties to total spreadable acreage (A) in the destination county. Assumptions on land operator willingness to accept manure (see box, "Willingness to Accept Manure," p. 21) are reflected in automated adjustments in both the quantity of spreadable acreage and slope of "area-to-distance" functions, or hauling distance required to access a given spreadable area. Values for levels of willingness to accept manure on non-animal farms and nonconfined animal farms range from 10 percent to 100 percent; all acreage on confined animal farms is assumed available for manure spreading. Equation (4) sets aggregate county-level manure transfers (M_TRAN) equal to the sum of manure transfers by source-county grid location (*gr*), system type (*sy*), and distance interval (*ds*). Equation (5) bounds manure transfers by the share (SH_M) of total county-level manure production (M_PRD) across system type (*sy*) and grid (*gr*), based on allocation procedures followed in the GIS.

Equations (6) through (8) are used to balance manure production, use, surplus, and quantity of manure exceeding land application capacity at the county level.

$$(6)\quad M\_SRP_{ct} = M\_PROD_{ct} - M\_ONFRM_{ct}$$

$$(7)\quad M\_USE_{ct2} = M\_ONFRM_{ct2} + \sum_{ct2} M\_TRAN_{ct,\,ct2}$$

$$(8)\quad M\_ELA_{ct} = M\_SRP_{ct} - \sum_{sy} M\_IND_{ct,\,sy} - \sum_{ct2} M\_TRAN_{ct,\,ct2}$$

Equation (6) sets surplus manure (M_SRP) as manure production (M_PROD) less that used onfarm (M_ONFRM) in the source county. Equation (7) fixes manure use (M_USE) as onfarm manure use plus that quantity obtained from off-farm sources (M_TRAN) in the destination county. Equation (8) sets the manure that exceeds land application capacity (M_ELA) due to insufficient assimilative capacity within the transport radius equal to the manure surplus in the source county, less the sum of industrial uses (M_IND) and the sum of manure transfers out of county. Manure used for industrial purposes is defined exogenously by county and waste-system type (i.e., dry poultry

[16] Manure application rates may be modified to reflect adjustments in nutrient content (i.e., due to changes in feed supplements or animal mix) and nutrient uptake rates (i.e., due to changes in cropping patterns or yields), as well as county-level acreage shares by nutrient standard, for cropland and pastureland.

litter) and converted to dry-ton equivalents for use in the model. Quantities of ELA manure are minimized in the model through the use of a penalty cost parameter that assigns a high cost to manure that is not land applied.

Hauling distances are computed based on Equations (9) – (11).

$$(9)\quad DS_{ct,\,gr,\,ct2} = \{(\alpha_{ct,\,gr,\,ct2} * \delta^{1}_{ct,\,ct2}) + (\beta_{ct,\,ct2} * (AC\_ONF_{ct} + \sum_{ct} AC\_SPR_{ct,\,ct2}))] * \delta^{2}_{ct2}$$

$$(10)\quad DS_{ct,\,gr,\,ct2} * M\_TRN_{ct,\,gr,\,ct2} = \sum_{sy}\sum_{ds}(DST_{ct,\,gr,\,ct2,\,sy,\,ds} * M\_TRN_{ct,\,gr,\,ct2,\,sy,\,ds})$$

$$(11)\quad D\_MN_{ds} \le DST_{ct,\,gr,\,ct2,\,sy,\,ds} \le D\_MX_{ds}$$

In Equation (9), average hauling distance (DS) from source county (*ct*) and grid location (*gr*) is calculated as a function of onfarm and off-farm spreadable acres in the destination county (*ct2*), based on α and β coefficients from the GIS-derived linear regression estimates. The intercept term, representing linear hauling distance from the source farm for out-of-county transfers, is adjusted (δ^1) for selected county-to-county transfers due to natural barriers (e.g., large bodies of water). In addition, a circuity parameter (δ^2) is used to convert linear distance to road miles (USDC, 1978). In Equation (10), average hauling distance represents a weighted average of hauling distances (DST) by manure-system type (*sy*) and distance interval (*ds*). Minimum (D_MN) and maximum (D_MX) distance is specified by distance interval in Equation (11).

Stocks and flows of manure nutrients (*np*)—nitrogen (*n*) and phosphorus (*p*)—are tied to manure quantities as follows:

$$(12)\quad M\_SRP_{ct} = NP\_EXC_{ct,\,np} \,/\, NP\_M_{ct,\,np}$$

$$(13)\quad NP\_ONF_{ct2,\,np} = M\_ONFRM_{ct2} * NP\_M_{ct,\,np} \;\; \textit{where } ct = ct2$$

$$(14)\quad NP\_TRN_{ct,\,ct2,\,np} = M\_TRAN_{ct,\,ct2} * NP\_M_{ct,\,np}$$

Total excess nutrients (NP_EXC) are obtained from farm-level Census data on manure production and onfarm assimilative capacity aggregated to the county level. Equation (12) calculates surplus manure (M_SRP) based on excess N or excess P, depending on the nutrient standard in effect (N^* or P^*) and county-average nutrient content per dry ton of manure (NP_M). In Equation (13), onfarm manure nutrients (NP_ONF) reflect the quantity (M_ONFRM) and composition of manure produced and used on confined animal feeding operations. In Equation (14), manure nutrients transferred (NP_TRN) reflects manure land-applied off the farm.

$$(15)\quad HAC_{ct,\,ct2} = \sum_{gr}\sum_{sy}\sum_{ds}[C1_{sy,\,ds} + (C2_{sy,\,ds} * DST_{ct,\,gr,\,ct2,\,sy,\,ds})]$$
$$* M\_TRN_{ct,\,gr,\,ct2,\,sy,\,ds} \,/\, (1 - (MS_{sy} + BED_{sy})]$$

$$(16)\quad INC_{ct2} = (C3 * SH\_I_{ct2} * (AC\_ONF_{ct2} + \sum_{ct} AC\_SPR_{ct,\,ct2}) * SH\_C_{ct2})$$

In Equation (15), manure hauling and application costs (HAC) are computed for onfarm and off-farm transfers based on loading, unloading, and application costs per ton hauled (C1), hauling cost per ton-mile (C2), distance hauled (DST), and quantity of manure hauled in dry tons (M_TRN), adjusted for moisture content (MS) and bedding (BED). Hauling and application costs vary across animal-waste systems due to differences in manure moisture content and equipment used, by species and system type. The model simulates a stepwise cost function for manure hauling/application cost, with cost coefficients defined by manure system type and distance interval hauled. Incorporation costs (INC) (incorporating manure into the soil) are computed in Equation (16) based on per acre cost (C3), share of acres incorporating (SH_I), total onfarm and off-farm acres using manure, and share of acres in cropland (as manure is not generally incorporated on pastureland).

$$(17)\quad NM1_{ct} = (M\_TST + C\_NMP) * AFO_{ct}$$

$$(18)\quad NM2_{ct2} = S\_TST * (AC\_ONF_{ct2} + \sum_{ct} AC\_SPR_{ct,\,ct2})$$

Selected nutrient management plan costs related to land application are identified for manure source farms and receiving farms. Equation (17) computes source-county costs (NM1) for manure testing and plan development costs, based on a representative cost (M_TST and C_NMP) applied to the number of confined animal-feeding operations (AFO) in the source county. Equation (18) computes destination county costs (NM2) for soil testing, based on representative costs (S_TST) per acre of land receiving manure.[17] Structural costs associated with manure processing and storage are not considered in this study, although capital costs to improve manure storage and handling may be required to accomplish the extent of land application addressed in the study.

$$\begin{aligned}(19)\quad FSV_{ct2,\,N*} = {} & (PR_n * (NP\_ONF_{ct2,\,n} + \sum_{ct} NP\_TRN_{ct,\,ct2,\,n})) \\ & + (PR_p * (NP\_ONF_{ct2,\,p} + \sum_{ct} NP\_TRN_{ct,\,ct2,\,p}) * P\_PCT_{ct2} \\ & + (C\_AP * (AC\_ONF_{ct2} + \sum_{ct} AC\_SPR_{ct,\,ct2}))\end{aligned}$$

$$\begin{aligned}(20)\quad FSV_{ct2,\,P*} = {} & (PR_n * (NP\_ONF_{ct2,\,n} + \sum_{ct} NP\_TRN_{ct,\,ct2,\,n})) \\ & + (PR_p * (NP\_ONF_{ct2,\,p} + \sum_{ct} NP\_TRN_{ct,\,ct2,\,p}))\end{aligned}$$

$$(21)\quad FS_{ct2} = (FSV_{ct2,\,N*} * SG\_N_{ct}) + (FSV_{ct2,\,P*} * (1 - SH\_N_{ct}))$$

Fertilizer cost savings (FSV) are calculated differently, depending on the nutrient standard in effect. In Equation (19), savings calculated under an N-standard reflect (1) reduced chemical fertilizer purchases, computed based on the price (PR) of nutrients N and P and the quantity of manure nutrient offset—adjusted to capture that portion of P (P_PCT) that is beneficially used by the crop over the growing season, and (2) savings from reduced field application costs, as applied manure satisfies the full crop-nutrient requirement. In Equation (20), savings calculated under the P-standard reflect the value of the manure nutrient offset only; field application costs for chemical fertilizer are required as manure-N is insufficient to meet full crop needs.[18] Equation (21) computes an acreage-weighted fertilizer cost savings (FS), based on the share of acres permitted to land-apply manure at the less-stringent N-standard.

Model Data

The Chesapeake Bay Watershed model relies on two primary data sources: the 1997 Census of Agriculture and the National Land Cover Dataset from the U.S. Geological Survey (USGS). Farm-level Census data are used to generate county-level measures of animal operations and animal units, total manure production, surplus recoverable manure, manure-nutrient content, and potential assimilative capacity of the land for applied manure nutrients. The National Land Cover Dataset was used to define the spatial pattern of land available for manure spreading and to simulate the spatial distribution of animal operations. Cost data and other information reflecting conditions in the CBW/Mid-Atlantic region were obtained from various sources, including the USDA's Natural Resources Conservation Service (NRCS) Cost and Capabilities Assessment (USDA, NRCS, 2003), ARMS data (USDA, ERS, 2002a), published literature, and subject matter specialists within the government and various universities.

[17] Nutrient management plan costs involving record keeping and visual inspection were not specifically related to manure land application, and were not addressed here. Costs for training and certification for manure application, and calibration of manure spreader, were assumed to be incorporated within reported application costs per ton of manure hauled.

[18] For purposes of this analysis, it is assumed that chemical nutrients are applied at strict agronomic rates, that manure nutrients directly offset nutrients obtained from chemical fertilizers, that per-acre field application costs are fixed regardless of the level of applied chemical fertilizer, and that producers are not permitted to "bank" phosphorus (over-apply for use over multiple years) to minimize annual field application costs under the P-standard. A multi-year P-standard, permitted by NRCS under certain soil conditions, may be modeled by adjusting for savings in the application cost of chemical fertilizer during the treatment year of a multi-year manure rotation.

Agricultural Census Data

Using data collected for the 1997 Census of Agriculture (USDA, 1999), we estimate manure-nutrient surpluses by applying farm-level measures of manure-nutrient production relative to the farm's potential to use nutrients for crop production. For modeling purposes, results from the farm-level calculations are aggregated to the county level.[19] Manure-nutrient production, potential manure nutrient use by farms with animals, surplus recoverable manure nutrients, and potential assimilative capacity of farms by farm type are computed following procedures in Gollehon et al. (2001) and Kellogg et al. (2000). Manure-nutrient production—nitrogen and phosphorus—is estimated using Census-reported end-of-year inventory and annual sales data, based on coefficients of manure production by animal type. Additional information on manure system shares by animal type is obtained from ARMS data (USDA, ERS, and 2000b). Nutrient content of manure reflects a composite nutrient content by county, based on county-level distributions of animal species from the Census of Agriculture. Potential manure-nutrient use is estimated across farm types based on reported yields and acreage for 24 major field crops and pasture. Excess recoverable manure nutrients are calculated as those that exceed the onfarm assimilative capacity of confined feeding operations, based on the amount of land controlled by the farms with the animals.

The farmland base available for surplus manure spreading is defined in the model to include all cropland and pastureland on non-animal farms and some portion of acreage on nonconfined animal operations (adjusting for nonrecoverable N available) and confined animal operations (from those farms with surplus acreage capacity). The model incorporates adjustments in total farmland base to reflect alternative assumptions on the willingness of landowners to accept manure, expressed as a share of total acreage (10 to 100 percent). Other land-adjustment factors not explicitly addressed in the model—including crop-type considerations, stream buffer provisions, and use of municipal sludge—may also affect availability of land for manure spreading. Crop and pastureland acreage in sink counties is assumed available for manure from the watershed, after adjusting for application of locally produced manure within the sink county.

Manure-hauling weights are based on dry tons of manure, adjusted for moisture and bedding content by manure system and species type (USDA, NRCS, 1999c; Barker et al., 2001) (see box, "Manure Handling Systems," p. 47). Manure application rates are calculated based on manure-nutrient composition (source county) and aggregate nutrient uptake (destination county) from Census calculations (USDA, NRCS, 1999c). Separate onfarm application rates are derived for confined animal farms, reflecting differences in cropping patterns and yields.[20] Since reliable data on the share of land likely to adhere to a phosphorus standard are not available, model scenarios are specified as if all acres would apply manure according to an N-standard or to an annual P-standard, thus covering the full range of possible results (see box, "Nutrient Standards," p. 38).

Spatial Land and Distance Data

To assess the spatial pattern of spreadable land for manure application, we use the USGS National Land Cover Dataset. This dataset is based on 1992 Landsat thematic mapper imagery at 30-meter resolution, classified into 21 land-use categories. By combining cropland and pastureland categories, we capture the spatial distribution of the spreadable land base for counties within the study region.

To estimate hauling-distance requirements for off-farm manure spreading, a GIS creates "area-to-distance" functions for each county and county-to-county transfer in the CBW.[21] These functions are a central component of the optimization model, linking the area used for manure spreading in the destination county with the average transport distance required to reach all of the land.

The number, location, and size of confined animal operations will influence the degree of competition for available acreage on which to spread manure. With greater concentrations of animal production, the nearby spreadable acreage is more fully used, resulting in increasing transport distances and greater potential for out-of-county manure exports. The number and average size of confined feeding operations is available by county from the

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[19] Our analysis meets all respondent confidentiality requirements of the published Census of Agriculture values.

[20] Model application rates assume a base nitrogen adjustment due to normal field loss of 30 percent. This base N loss factor is further adjusted downward by 5 percent for systems with soil incorporation and 30 percent for systems without incorporation (Fleming et. al., 1998, and Kellogg et al., 2000).

[21] Onfarm hauling distances by county are fixed in the model based on data obtained through the NRCS Cost and Capabilities Assessment (USDA, NRCS, 2003).

Census, although the specific location of these operations within the county is unknown. Using the GIS, animal operations are randomly assigned by county grid location within cropland and pastureland areas of the county.[22]

Area-to-distance functions are estimated for all in-county and out-of-county transfer possibilities in the model, based on the spatial relationship between manure source and the location and density of spreadable area. In-county transfers reflect the average hauling distance from confined feeding operations within a given county to spreadable land in that county, both onfarm and off-farm. With small amounts of surplus manure, spreadable land is relatively accessible and hauling distances are generally short. As surplus manure increases, so, too, does the land needed for spreading manure, increasing the transport distance to access needed acreage.[23] Depicted graphically, the relationship between the spreadable acreage requirement and average distance hauled is upward sloping and fairly linear along much of the observed range (fig. 4-A-1).

Out-of-county functions reflect hauling distances for confined feeding operations in the source county to spreadable acreage in the destination counties. A two-stage process is used to generate area-to-distance functions for out-of-county transfers. First, distance is measured from each confined animal farm in a source county to the edge of spreadable acreage in a destination county; this distance represents the intercept term of the area-to-distance function. Second, the slope of the distance function is generated by calculating hauling distance required for a given area of spreadable acreage in the destination county, measured from the direction of the source county.

The slope of the area-to-distance functions reflects the spatial pattern of farmland relative to the number and location of confined feeding operations from a given source county. Competition for spreadable land is, in part, a function of the spatial distribution of cropland and pastureland. Where farmland is scattered, a higher slope coefficient reflects relatively long average hauls within the destination county to access a given spreadable area. Where farmland distribution is more dense, a lower slope coefficient reflects comparatively shorter hauls to access a given acreage. The degree of competition will depend on both spatial distribution of the spreadable land base and the quantity and proximity of competing manure sources across counties.

Integration of GIS data within the optimization framework represents a key component of the model. Regression coefficients for the area-to-distance functions are incorporated as model parameters for within- and out-of-county transfers. A unique set of slope coefficients is produced for each within-county function and for each county-to-county transfer, representing distance hauling requirements within the destination county. In addition, out-of-county functions involve separate intercept terms by source farm-grid location for every possible destination-county option, representing linear distance from the farm to the edge of the landbase within the destination county. County-to-county transfer possibilities include all counties within an assumed 60-kilometer (km) radius of a given source county; the radius for source farms in the 16 counties with highest concentrations of surplus manure was expanded to 150 km (93 miles).[24] To reduce the number of manure source and destination combinations, animal operations were aggregated (binned) into 12-km grids across the watershed area. Although the binning procedure reduces the precision of intercept terms for intercounty functions, this was necessary to keep the model optimization reasonably within the bounds posed by our computer hardware. In addition, the distance functions estimated from the GIS are linearized for modeling purposes by truncating the upper and lower tails of the distribution (10 percent of acreage respectively) and fitting a linear function to the nearly linear 80 percent of the midrange observations (fig. 4-A-1).

Production Cost Data

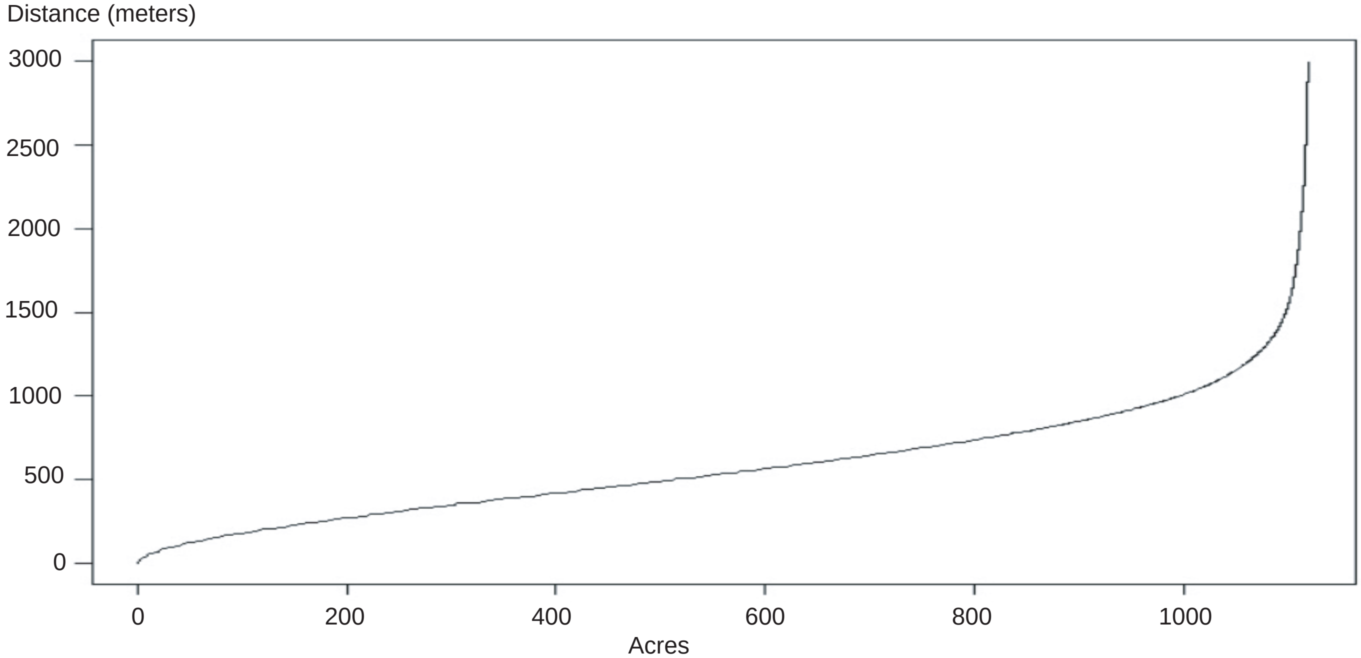
The NRCS Cost and Capabilities Assessment was the primary source of cost data for nutrient management plan components (USDA, NRCS, 2003). Cost components for manure management addressed in this study include nutrient management planning ($1.67 per acre receiving manure), manure testing ($200 per farm), and soil testing ($0.40 per acre receiving manure).

[22] Although animal operations may be separated from arable land as animal production is not as sensitive to soil conditions, the majority of operations tend to be located in proximity to cropland and pasture land. While the random farm location assumption is regarded as reasonable at the watershed scale, it likely yields somewhat conservative estimates of actual hauling distances due to observed clustering of animal operations, in some cases increasing competition for adjacent land resources.

[23] The actual area of available spreadable acreage used for manure application in a given county is determined endogenously in the optimization model.

[24] Individual hauling distances in the model may exceed the maximum radial distance assumed for county transfer selection (150 km) due to (1) additional hauling requirements within the destination county, and (2) parameters that translate linear distance to road miles. The maximum radial distance assumption of 150 kms could be relaxed but at a cost of model dimensionality.

Figure 4-A-1
Representative area-to-distance function



Manure hauling and application charges were based on published literature (Pease et al., 2001; Fleming et al., 1998), supplemented with data from the NRCS Cost and Capabilities Assessment. Transportation charges reflect a base rate per wet ton (loading/unloading and application) and hauling cost per ton-mile, by hauling mode and distance interval (table 4-A-1).[25] Application costs are incorporated within hauling charges for lagoon and slurry systems; an additional charge of $4.00 was included for dry manure application. Manure incorporation costs assume a cost of $6.00 per acre (Iowa State Farm Survey, 2001), with 40 percent of acres incorporating regionally based on information from the ARMS hog and dairy surveys.

Chemical fertilizer costs are based on reported 1997 prices by USDA's National Agricultural Statistics Service (NASS), based on representative fertilizer products for the Northeastern U.S. (USDA, NASS, 2001). Nitrogen price reflects the U.S. average price ($160 per ton) for a nitrogen solution of 30 percent N, or a price per active ingredient of $0.27 per lb.-N. (The 30-percent nitrogen solution is selected as a representative form of N because it was the lowest priced form of N with adequate use for NASS to record region prices for both the Northeastern and Southeastern U.S. regions.) Phosphorus price reflects the price per ton of triple superphosphate (45 percent P), averaged across the Northeastern and Southeastern regions ($267 per ton), or an active ingredient price of $0.30 per lb.-P. Cost-savings for reduced field application costs (under an N-standard) of $5 per acre were from Fleming, 1998. While the model provides for the pricing of manure, revenue received for manure is currently set to zero. Prices paid for manure will not affect total regional cost, but would have distributional implications across areas of the watershed.

[25] While not addressed in this analysis, adjustments may be incorporated to reflect lower hauling charges with backhauls, public cost-sharing for manure hauling, allocation of costs across manure providers and recipients, and manure pricing.

Table 4-A-1—Manure hauling costs by system type

System type	Distance interval	Hauling mode	Base charge[1]	Distance charge	Distance charge, with backhaul[2]
	Miles		*$/ton*	*$/mile*	*$/mile*
Lagoon	onfarm	Pump/spray field	1.25	.25	
	0.5-2.0	Truck mounted liquid sprayer	2.00	.30	
	2.0-10.0	Truck mounted liquid sprayer	2.00	.30	
Slurry	onfarm	Tractor/spreader (honey wagon)	2.00	.30	
	0.5-2.0	Truck mounted liquid sprayer	2.00	.30	
	2.0-10.0	Tanker truck	2.00	.30	
	>10.0	Tanker truck	2.00	.30	
Dry	onfarm	Spreader truck	6.00	.50	
	0 .5-2.0	Spreader truck	6.00	.50	
	2.0-10.0	Truck	10.00	.11	
	>10.0	Truck	10.00	.11	.07

[1]Includes cost of hauling and unloading. Application costs are reflected for lagoon and slurry manure; an additional application charge of $4.00 per ton-not reflected in the table-is included in the model for dry manure. Manure incorporation costs are estimated at $6.00 per acre, with acreage shares set to 40 percent in the base model.

[2]A cost adjustment for backhauling may be applied to long-distance hauls for dry manure, although the base model assumes 0% backhauling.

Sources: NRCS, 2003; Fleming et al., 1998; Pease et. al., 2001; Borton et al., 1995.

Chapter 5—National Analysis: Industry Effects of Manure Management

Changes in manure management will likely have broader effects than those captured in farm-level and regional analyses. In this chapter, we examine changes in the livestock and poultry sectors throughout the United States that would result from the adoption of nutrient standards by animal feeding operations. Adherence to a nutrient application standard by all AFOs, or even just the largest, is likely to affect the prices received by producers and prices paid by consumers. How would prices for crops and livestock/poultry products be affected by nutrient standards? How would the spatial distribution of agricultural sectors change under nutrient standards? And how much would nutrient standards reduce the amount of manure nutrients produced across the Nation?

The farm-level and regional analyses demonstrated that nutrient standards are likely to increase the cost of production for those operations required to adhere to them. The magnitude of these cost increases depends on a number of factors, including the amount of manure that would require transporting off the farm, the availability of cropland for the application of manure nutrients, and the willingness of cropland operators to substitute manure nutrients for commercial fertilizer. Increased production costs in the animal sector could be transferred through supply and demand interactions to livestock and poultry producers, cropland operators, and consumers (see Appendix 5-A, "Market Interaction Primer," for a graphical presentation of these interactions).

We use the U.S. Regional Agricultural Sector Model (USMP) to investigate several possible scenarios for the adoption of nutrient standards by livestock and poultry producers in the United States (see appendix 2 in Claassen et al., 2001). The USMP is a spatial and market equilibrium model designed for general-purpose economic and policy analysis of the U.S. agricultural sector. The economic units analyzed within USMP include products, inputs, geographic areas, and supply/demand markets.

We modify the basic model to evaluate how equilibrium conditions will change in response to nutrient application standards. First, we calculate the generation of livestock and poultry manure nutrients by region and species. The base costs and mileage costs to transport this manure to available cropland are endogenously determined using the Fleming et al. (1998) formulation in conjunction with regional and species-specific cost coefficients from the literature (Borton et al., 1995; Pease et al., 2001). The costs to develop a nutrient management plan, for periodic testing of manure nutrient composition, and for periodic testing of soil nutrient content are also included using USDA estimates (USDA, NRCS, 2003). Furthermore, using current market values for commercial nitrogen and phosphorus, we calculate the savings from substituting manure nutrients for commercial fertilizers. The costs of using manure nutrients are assumed to be covered by the livestock sectors. The savings to cropping enterprises are then incorporated into the regional cropping acreage activities.

The nutrient constraints are chosen to represent likely policy scenarios. Essentially, the adoption of manure-nutrient application standards forces manure production and crop production within a geographic area to be in balance. That is, the aggregate generation of affected manure nutrients in a region is constrained to be no greater than the agronomic nutrient demands of accepting cropland, with no allowance for noncrop use. Manure generation is calculated according to Kellogg et al. (2000) and crop nutrient demands are calculated using the Environmental Policy Integrated Climate Model (EPIC; Mitchell et al., 1998). A region is out of balance if it has more (or less) manure nutrients than can be assimilated by available cropland.

Several changes can occur within the model to allow a region to return to balance. If demand for nutrients is in excess of manure nutrients, commercial fertilizer makes up the difference. If manure nutrients exceed demand, the composition of cropping or livestock/poultry production could change to alter the amount of manure nutrients demanded or supplied. For example, broilers produce manure with higher phosphorus-to-nitrogen ratio than do dairy cows. A region that is generating excess phosphorus relative to the plant needs on manure-receiving cropland could reduce broiler production and increase dairy production. Similarly, different crops utilize nutrients at different rates. For example, hay utilizes more phosphorus than corn, so a region that is generating excess phosphorus could substitute hay acres for corn. The model finds the combination of crop and animal changes across the regions that minimize the net cost to society.

We use this model to evaluate the implementation of nutrient standards by animal feeding operations defined by EPA as CAFOs on the basis of size (CAFO scenario) and by all animal feeding operations (AFO scenario). EPA regulations directly affect only CAFOs. We evaluate the implications of all AFOs meeting a nutrient standard because that is the long-term goal of USDA. While the adoption of nutrient management practices for non-CAFOs would be voluntary, the AFO scenarios indicate of how much the poultry and livestock sectors might gain or lose by such a change.

We evaluate the impacts on the animal sector across a range of assumptions about the willingness of cropland operators to substitute manure nutrients for commercial fertilizer, paralleling the willingness-to-accept-manure (WTAM) assumptions used in the previous analyses (see box, "Willingness to Accept Manure," p. 21). However, because the national analysis cannot replicate farm-level decisions, we represent WTAM differently here. We define WTAM as the percentage of a region's agronomic demand for nitrogen and phosphorus (based upon crop requirements in that region) that is met by manure nutrients. In other words, as the willingness of cropland operators to accept manure nutrients increases, so does the percentage of each region's nutrient demand that is met by substituting manure nutrients for commercial fertilizers. Therefore, throughout this chapter we will refer to "willingness-to-substitute" rates, or simply substitution rates.

Currently, cropland operators supplement commercial fertilizer with manure as part of their crop fertilization regime on 17 percent of corn acreage and 2-9 percent of soybean acreage (most commonly grown crops) (USDA, ERS 2000a, p. 36). It is unclear to what extent these rates would change as nutrient standards become more integral in livestock and poultry production. We consider four scenarios based on the rate at which manure nutrients are substituted for commercial fertilizer on cultivated crops in each region: 20 percent, 30 percent, 40 percent, and 80 percent. These are compared with the baseline case of no standards/no substitution. The results from these scenarios are compared with the USDA 2010 baseline, when it is assumed that the agricultural sector will have fully adjusted to the adoption of nutrient standards.

Unlike the preceding chapters, we evaluate only a single nutrient standard in this chapter. Because each region in the model is large, there is sufficient land to assimilate manure nitrogen at all of the substitution rates, leaving production decisions for the most part unchanged. However, in many cases, the constraint that manure phosphorus generation be no greater than agronomic phosphorus demand was binding. Therefore, while we impose a nitrogen and phosphorus application standard, the changes resulting from our policy scenarios are for the most part driven by the phosphorus constraint.

Manure Nutrient Restrictions at the National Level

The eight scenarios that we examine (CAFO20, CAFO30, CAFO40, CAFO80, AFO20, AFO30, AFO40, and AFO80) correspond to which livestock and poultry operations adopt manure application constraints (e.g., just CAFOs or all AFOs) and the degree to which cropland operators substitute manure nutrients for commercial fertilizers (20, 30, 40, or 80 percent). As noted earlier, new water quality regulations require that the largest livestock and poultry facilities meet manure nutrient application standards, and the current rates of manure nutrient substitution average between 10 and 20 percent. Therefore, we might expect the CAFO20 scenario to most accurately illustrate the potential changes to the agricultural sector as a response to meeting these nutrient standards without any increases in manure use by cropland operators.

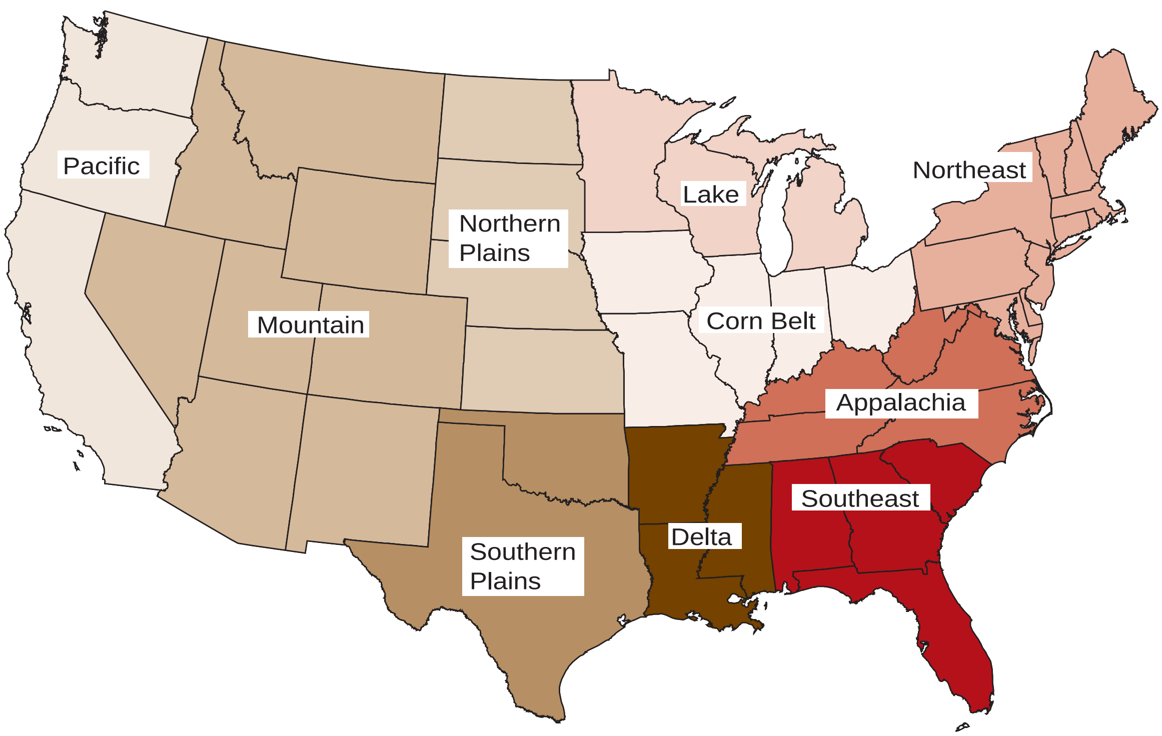
The findings from policy simulations are expressed in terms of changes in animal units produced, crop acreage planted, and costs, savings and net returns across sectors. The national results illustrate the aggregate impacts of these scenarios. For example, CAFOs are only 4.5 percent of the total AFOs in the U.S. (table 5-1). However, the quantity of manure generated by these facilities exceeds 200 million tons, more than 46 percent of the U.S. total and 65 percent of excess nutrients, indicating the substantial differences in the quantities of manure regulated under our CAFO and AFO policies. Disaggregating these results illustrates how the regional cropping, livestock, and poultry sectors may react to manure nutrient standards. Following from our earlier example, the Corn Belt has the greatest number of CAFOs, but those operations generate less than 40 percent of Corn Belt manure. On the other hand, CAFOs generate more than 60 percent of the manure in the Northern Plains, Appalachia, Mountain, and Pacific regions. Clearly, these regions will be affected differently under the various policy scenarios considered. Regional impacts are evaluated across the USDA Farm Production Regions (fig. 5-1).

Table 5-1—Operations with confined livestock/poultry and manure distribution

Region	Operations: AFOs	Operations: CAFOs	Operations: Share of CAFOs	Manure generated: CAFO	Manure generated: AFOs	Manure generated: Share of CAFOs
	Number		*Percent*	*Million tons*		*Percent*
Northeast	31,350	499	1.59	39	6	15.42
Lake	52,498	861	1.64	59	15	25.10
Corn Belt	71,252	2,264	3.18	73	29	39.55
Northern Plains	26,087	1,245	4.77	65	42	64.01
Appalachia	22,776	1,698	7.46	66	41	62.69
Southeast	12,635	1,386	10.97	23	10	43.31
Delta	12,252	917	7.48	19	7	39.04
Southern Plains	10,500	735	7.00	46	18	38.22
Mountain	7,780	656	8.43	33	23	69.31
Pacific	7,654	1,137	14.85	40	24	60.55
Total	254,784	11,398	4.47	462	214	46.36

Source: 1997 U.S. Census of Agriculture (USDA-NASS, 1997).

Figure 5-1
USDA Farm Production Regions



Agricultural Prices and Supplies

Results suggest that animal production in general would decrease with nutrient standards when substitution rates remain at or near current levels (table 5-2). (Those operations in the farm-level analysis with the greatest production cost increases are the most likely to leave the industry.) However, under the CAFO20 and CAFO30 scenarios, these production changes are generally less than 2 percent. Two notable exceptions are production of broilers and turkeys, which fall by more than 7 percent when substitution rates remain at or near current levels. Under both scenarios, there is a slight increase in the production of veal. Under the AFO scenarios, production falls more, especially at the lowest substitution rate. When substitution rates exceed 40 percent, there are essentially no changes in production under the CAFO scenarios and only marginal changes under the AFO scenarios.

With less supply, the prices received by most livestock and poultry producers and those paid by consumers for animal products (milk, eggs, cheese) would increase (table 5-3) when manure-fertilizer substitution remains at or near current levels. Under the CAFO20 and CAFO30 scenarios, most price increases are minimal (less than 2 percent), except for poultry. Price changes would be greatest when all AFOs must meet nutrient standards and the least amount of manure nutrients is substituted for commercial fertilizer. Price changes are negligible when nutrient substitution exceeds 40 percent.

Impacts may spill over into the crop sectors, driven by the demand for land to assimilate manure nutrients and the demand for feed in the more stringent scenarios (tables 5-4 and 5-5). The changes in crop production vary by crop under the various scenarios. However, under the CAFO20 scenario (again, the most "immediate"), acreage planted to corn, barley, and oats falls and production of sorghum, wheat, rice, soybeans, cotton, silage, and hay increases. Most of these changes are small and the net change in total acreage is less than 1 percent. At the lower substitution rates, prices generally fall (with the exception of silage) under both the CAFO and AFO scenarios. At the higher substitution rates, prices generally increase by less than 0.5 percent.

National Net Returns

The analyses in the previous chapters assumed prices remain constant, so the costs of meeting a nutrient standard are borne fully by animal operations. In this analysis, price increases can mitigate some of the implementation costs to operations that remain in pro-

Table 5-2—Change in product supply under manure nutrient standard

Commodity	Baseline quantities	AFO 20%	AFO 30%	AFO 40%	AFO 80%	CAFO 20%	CAFO 30%	CAFO 40%	CAFO 80%
	Million	*Percent change*							
Fed beef (Cwt)	149.66	-12.12	-4.39	-1.68	-0.01	-0.51	-0.15	0.00	-0.01
Broilers (Carcass lbs.)	34,942.99	-27.56	-18.55	-9.09	-0.01	-7.57	-1.92	0.00	-0.01
Turkey (Carcass lbs.)	5,950.01	-23.04	-13.97	-8.19	0.00	-7.22	-1.80	0.00	0.00
Manufactured milk (Cwt)	884.62	-3.38	-1.09	-0.48	0.00	-0.54	-0.16	0.00	0.00
Veal (Cwt)	1.34	-2.19	-0.30	-0.01	0.00	0.22	0.07	0.00	0.00
Pork (Cwt)	189.82	-6.61	-2.34	-0.80	0.00	-1.52	0.01	0.00	0.00
Eggs (Dozen)	7,585.81	-1.63	-0.66	-0.32	0.00	-0.35	-0.10	0.00	0.00
Butter (Lbs.)	1,360.34	-5.45	-1.76	-0.78	0.00	-0.87	-0.26	0.00	0.00
American cheese (Lbs.)	2,776.93	-3.35	-1.08	-0.48	0.00	-0.54	-0.16	0.00	0.00
Ice cream (lbs.)	1,193.10	-1.38	-0.45	-0.20	0.00	-0.22	-0.07	0.00	0.00

Table 5-3—Change in product prices

Commodity	Baseline price	AFO 20%	AFO 30%	AFO 40%	AFO 80%	CAFO 20%	CAFO 30%	CAFO 40%	CAFO 80%
	Dollars	*Percent change*							
Baseline									
Fed beef (Cwt)	335.42	3.00	1.09	0.42	0.00	0.13	0.04	0.00	0.00
Broilers (Carcass lbs.)	0.36	24.64	7.38	3.62	0.00	3.02	0.76	0.00	0.00
Turkey (Carcass lbs.)	0.39	37.35	14.34	0.06	0.00	5.00	1.25	0.00	0.00
Manufactured milk (Cwt)	11.98	11.12	3.59	1.59	0.00	1.78	0.54	0.00	0.00
Veal (Cwt)	562.61	1.65	0.22	0.01	0.00	-0.16	-0.05	0.00	0.00
Pork (Cwt)	263.00	3.09	1.09	0.37	0.00	0.71	0.00	0.00	0.00
Eggs (Dozen)	0.69	29.10	11.69	5.72	0.01	6.33	1.78	0.00	0.01
Butter (Lbs.)	1.07	19.30	6.23	2.76	0.00	3.09	0.93	0.00	0.00
American cheese (Lbs.)	1.34	9.17	2.96	1.31	0.00	1.47	0.44	0.00	0.00
Ice cream (lbs.)	1.38	11.44	3.69	1.64	0.00	1.83	0.55	0.00	0.00

Table 5-4—Change in crop production

Commodity	Baseline quantities	AFO				CAFO			
		20%	30%	40%	80%	20%	30%	40%	80%
	Million	*Percent change*							
Corn (Bu)	11,235.38	-2.10	-1.26	-0.60	-0.02	-0.49	-0.11	-0.01	-0.02
Sorghum (Bu)	668.50	10.07	3.01	1.60	-0.07	0.22	0.05	-0.03	-0.07
Barley (Bu)	365.10	3.60	-1.04	-0.06	-0.04	-0.20	0.21	-0.02	-0.04
Oats (Bu)	149.89	-7.25	-5.23	-1.89	-0.03	-1.96	-0.27	-0.01	-0.03
Wheat (Bu)	2,545.09	4.18	1.65	0.81	-0.03	0.35	0.04	-0.02	-0.03
Rice (Cwt)	194.20	16.44	10.16	3.17	-0.11	3.42	1.43	-0.05	-0.11
Soybeans (Bu)	3,245.04	3.52	1.71	0.75	-0.04	0.82	0.09	-0.01	-0.04
Cotton (Bale)	17.50	2.11	1.04	0.48	-0.01	0.25	0.07	-0.01	-0.01
Silage (Ton)	95.60	3.89	1.42	0.72	-0.01	0.66	0.14	0.00	-0.01
Hay (Ton)	155.60	7.48	2.40	1.30	-0.03	1.36	0.48	-0.01	-0.03
Total crop acres	337.42	3.66	1.42	0.67	-0.04	0.51	0.10	-0.02	-0.04

Table 5-5—Change in crop prices

Commodity	Baseline price	AFO				CAFO			
		20%	30%	40%	80%	20%	30%	40%	80%
	Dollars	*Percent change*							
Corn (Bu)	2.60	-6.03	-2.70	-1.29	0.03	-1.09	-0.21	0.01	0.03
Sorghum (Bu)	2.35	-4.34	-1.61	-0.73	0.01	-0.39	-0.06	0.01	0.01
Barley (Bu)	2.40	-2.22	-0.48	-0.27	0.01	-0.22	-0.08	0.00	0.01
Oats (Bu)	1.45	-13.12	-7.25	-3.34	0.03	-3.34	-0.43	0.02	0.03
Wheat (Bu)	3.70	-1.56	-0.62	-0.30	0.01	-0.13	-0.02	0.01	0.01
Rice (Cwt)	7.71	-1.65	-1.02	-0.32	0.01	-0.34	-0.14	0.01	0.01
Soybeans (Bu)	6.30	-3.54	-1.88	-0.88	0.02	-0.85	-0.14	0.02	0.02
Cotton (Bale)	312.00	-1.58	-0.78	-0.36	0.01	-0.19	-0.05	0.00	0.01
Silage (Ton)	21.73	-1.38	-0.12	-0.03	0.00	0.02	0.02	0.00	0.00
Hay (Ton)	60.66	-4.36	-1.47	-0.71	0.01	-0.67	-0.22	0.00	0.01

duction. However, these results do not account for other costs that would accompany the passage of new CAFO regulations, such as additional storage, handling, and relocation costs. The aggregate effects on net returns of meeting manure nutrient standards vary across agricultural sectors.

The net effect on the livestock and poultry sectors when only CAFOs meet nutrient standards range from a gain of $89 million (0.3 percent) at the lowest nutrient substitution rate to a loss of over $1 billion (3.2 percent) at the highest substitution rate. Under the more stringent AFO scenarios, net returns to the livestock and poultry sector would increase nearly $5 billion (14.4 percent) under the lowest substitution rate, and decrease nearly $2.5 billion (7.3 percent) under the highest substitution rate. The increase in net returns at low substitution rates is due to the expansion effect of prices responding to supply changes. This holds true for both the AFO and CAFO scenarios.

These results might be surprising to some because the cost of nutrient standards would be greatest at lower substitution rates (as shown in the farm-level analysis). However, increases in prices for animal products, due to the exit from the industry of high-cost producers and thus lower supply, are able to compensate for cost increases. As shown in the Market Interaction Primer (Appendix 5-A), net returns can actually increase if prices for livestock and poultry products in both the domestic and export markets are assumed to be very responsive to changes in production. Those producers able to remain in production are the ones that benefit. If prices are less responsive than assumed in the model, net returns in the livestock and poultry sector would decline.

A composite of potential net returns to livestock and poultry sectors and manure production highlights the differences between the AFO and CAFO scenarios and the influence that willingness to substitute manure nutrients has on the economic performance of the U.S. livestock and poultry sectors (fig. 5-2). As the willingness of cropland operators to substitute manure nutrients for commercial fertilizer decreases, manure production decreases and net returns to livestock and poultry producers increase. The reduction in manure reflects a reduction in the number of animals as marginal production costs increase and high-cost producers leave the industry. The impacts to the animal sector are generally smaller when only CAFOs are required to meet a nutrient standard.

The net effect on returns to the U.S. agricultural sector (crops and animals) under the CAFO scenarios is predicted to range from a loss of $201 million (0.3 percent from baseline estimates of net returns) when substitution rates remain at or near current levels to a loss of $644 million at high substitution rates (1.0 percent) (table 5-6). When all AFOs must meet nutrient standards, effects range from a loss of $1.6 billion (2.4 percent loss relative to the baseline) at high substitution rates to a gain of $2.1 billion (3.2 percent) at low manure-fertilizer substitution rates. In this latter case, the percentage increase in prices under the most stringent scenario (AFO20) is greater than the percentage decrease in supply, resulting in greater net producer returns. The reductions in animal numbers reduce the demand for feed, thereby reducing income for crop producers. Generally, when returns to the livestock and poultry sectors increase, returns to crop sectors fall. The aggregate effect on net returns to the entire agricultural sector from imposition of nutrient standards would be negative, except at low manure substitution rates.

At high manure substitution rates, there are few changes in livestock and poultry production and prices, because there is sufficient cropland for spreading manure nutrients at agronomic rates (tables 5-2, 5-3). However, livestock and poultry producers still incur additional costs in transporting manure, developing a nutrient plan, and performing the necessary nutrient tests. Similarly, there are few changes in the production levels and prices for crops at high substitution rates (tables 5-4, 5-5). Returns to cropland operators would increase due to savings from substituting manure nutrients for commercial fertilizer. These savings at high nutrient substitution rates do not fully compensate for the increasing costs to the livestock and poultry sectors, resulting in net losses to the agricultural sector as a whole (table 5-6).

Projected quantity and price changes for crop, livestock, and poultry sectors would be the greatest with

Figure 5-2
National level net returns and manure generation

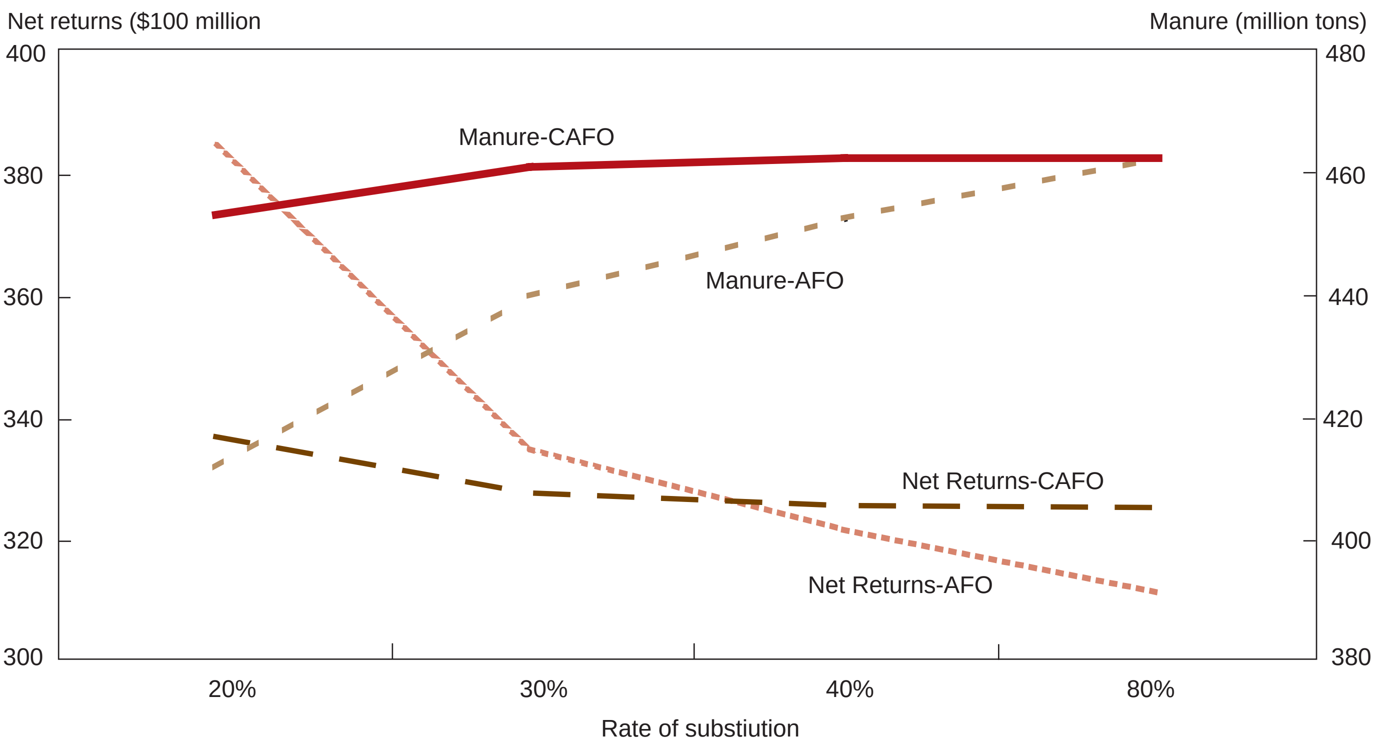


Table 5-6—Change in net returns

Sector	AFO 20%	AFO 30%	AFO 40%	AFO 80%	CAFO 20%	CAFO 30%	CAFO 40%	CAFO 80%
				$ Million				
Corn	-1,702.2	-697.4	-231.2	194.0	-272.1	17.4	86.5	90.3
Soybeans	-2,332.7	-935.0	-206.3	399.7	-350.5	90.9	180.7	184.2
All crops	-2,749.2	-814.7	68.7	901.7	-289.9	262.3	426.8	432.2
Dairy	1,250.7	-172.7	-571.4	-889.7	97.7	-125.3	-216.9	-220.2
Swine	1,385.8	401.6	-9.6	-274.1	290.2	-102.0	-117.7	-132.4
Beef	123.1	-284.8	-603.6	-821.1	-378.6	-486.6	-495.3	-506.4
Poultry	2,118.6	-62.3	-255.5	-491.1	79.5	-127.0	-214.9	-216.7
All animals	4,878.3	-118.2	-1,440.1	-2,476.0	88.9	-841.0	-1,044.7	-1,075.7
Total	2,129.1	-932.9	-1,371.4	-1,574.3	-201.0	-578.8	-617.9	-643.5

manure substitution rates at or near current levels. Livestock and poultry production would decline in general to meet manure nutrient standards, and animal product prices would increase. Incentives would arise for land to come into crop production to meet an increased demand for cropland on which to spread manure. Coupled with decreasing demand for livestock and poultry feed, this effect would result in decreasing prices and increasing quantities for the crop sector. In the most restrictive scenario, where all confined animal operations adopt manure nutrient application standards (AFO scenario) and where relatively few acres are available for manure spreading, the expansion effect in the livestock and poultry sectors would more than offset losses in the cropping sectors, resulting in a net increase in returns to agriculture ($2.1 billion).

While these potential effects of nutrient standards are described in aggregate, individual sectors would experience a range of changes depending on the extent to which livestock and poultry producers adopt nutrient standards and the extent to which cropland operators are willing to substitute manure nutrients. For example, the poultry sector under the most restrictive scenario (AFO20) shows a nearly $2.1 billion increase in net returns. However, at high substitution rates (e.g., 80 percent), the land constraints on manure use would not be binding, even when all AFOs meet the standard. With sufficient land in each region for spreading manure, there would be no decrease in poultry production or increase in prices for poultry products. Consequently, net returns in the poultry sector would fall, due to the higher fixed and variable costs associated with the adoption of nutrient standards.

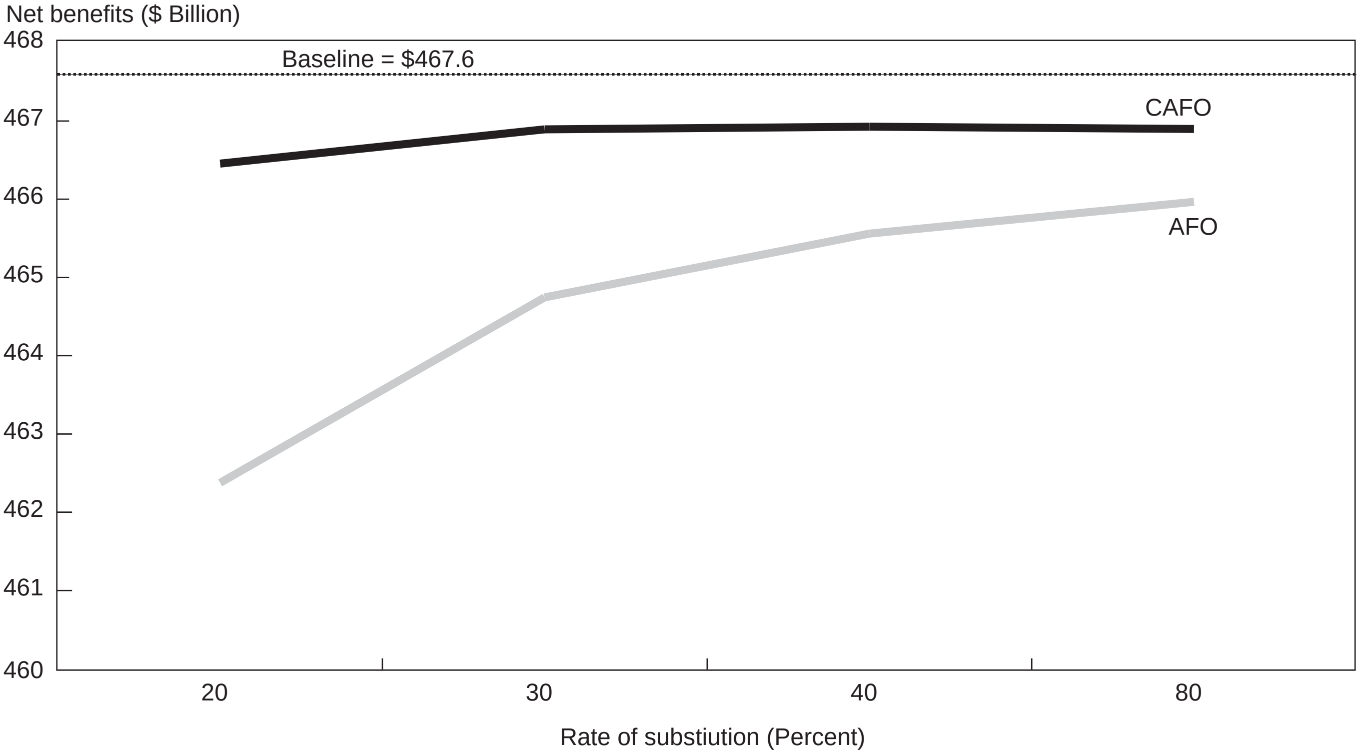
Consider the likely scenario of CAFO20. Net returns increase in the poultry, swine, and dairy sectors, and decrease in the corn, soybean, and beef sectors. The aggregate effect is positive for the livestock and poultry sectors and negative for the crop sector. This illustrates the importance of disentangling aggregate effects to reveal the potential impacts on individual sectors.

National Welfare

Changes in net returns in the agriculture sector (livestock/poultry and crops) are only part of the impacts on the economy. Consumers are affected as prices of commodities change. An aggregate measure of how consumers and producers fare under the alternative policy scenarios expands our analysis even wider (fig. 5-3). As substitution rates decline from 80 percent to 20 percent, manure management costs increase and the net benefits to U.S. agricultural consumers and producers decline (at most, approximately $1.1 billion under CAFO scenarios and $5.2 billion under AFO scenarios). This result suggests that consumers and cropland operators bear the losses when the substitution rate is low, given that the declines in net benefits exceed the increases in net returns to livestock and poultry producers (shown in table 5-6). The opposite can be seen at higher substitution rates. Specifically, under CAFO80, net benefits to U.S. agricultural consumers and producers decline $650 million, yet net returns for cropland operators increase $432 million. Consumers and livestock/poultry producers bear the losses.

These losses could be viewed as the cost for improving U.S. water quality by reducing the amount of manure and redistributing it to regions that can best utilize its potential for crop fertilization. We have not tried to assess the value of environmental benefits from improved water quality, nor have we included

Figure 5-3
Net benefits to consumers and agricultural producers, by substitution rate and CAFO/AFO standard



alternative options for disposing of manure. Industrial technologies may be able to use manure nutrients as inputs in a value-added product. For example, in our most restrictive scenario, the cost of restricting an additional pound of phosphorus from being land applied approaches $30 per pound in the Pacific and Southeast regions, but is less than $5 per pound in the Mountain, Northern Plains, and Corn Belt regions. As such, industrial options that cost less than $30 per pound to reduce phosphorus supply would enhance overall welfare in the Pacific and Southeast regions, but might not be as advantageous in regions with relatively abundant land for manure applications.

Regional View

Because national results may mask regional impacts, we compare performances across the 10 USDA Farm Production Regions. Discerning patterns from these results is sometimes difficult because they are the result of many simultaneous economic forces. It is useful to recall what meeting nutrient standards implies for regional production decisions; i.e., how might a region balance manure nutrient production and agronomic nutrient demands.

Regional Animal Production

The most noticeable changes in animal production levels would occur when substitution rates remain at or near current levels (i.e., when manure nutrients replace only 20 percent of commercial fertilizer). At 20-percent substitution, widespread spatial shifts in production are readily observed. Noticeable changes in the livestock, poultry, and crop sectors are observed at 40 percent. At a substitution rate of 80 percent, only minor changes occur because most areas would have sufficient cropland for spreading manure.

When only CAFOs must meet nutrient standards, changes are generally small (fig. 5-4a). However, animal numbers drop more than 20 percent in the Appalachia, Pacific, and Southeast regions under the CAFO20 scenario. Other regions increase production. Under the AFO scenarios, where all operations adopt nutrient standards, production declines occur in all the regions except for the Corn Belt, Mountain, Lake, and Northern Plains (fig. 5-4b). Reductions are greatest when the substitution of manure for commercial fertilizer is lowest.

Crop Acreage

Overall, crop acreage changes little (0.5 percent or less) when only CAFOs adhere to a nutrient standard (fig. 5-5a). When all AFOs meet a nutrient standard, changes in crop acreage are slightly greater (0 to 3.7 percent) (fig. 5-5b). Acreage increases could occur in those regions where the demand for land to spread manure is high. These increases allow at least some of

Figure 5-4a
Animal production when only CAFOs meet nutrient standards

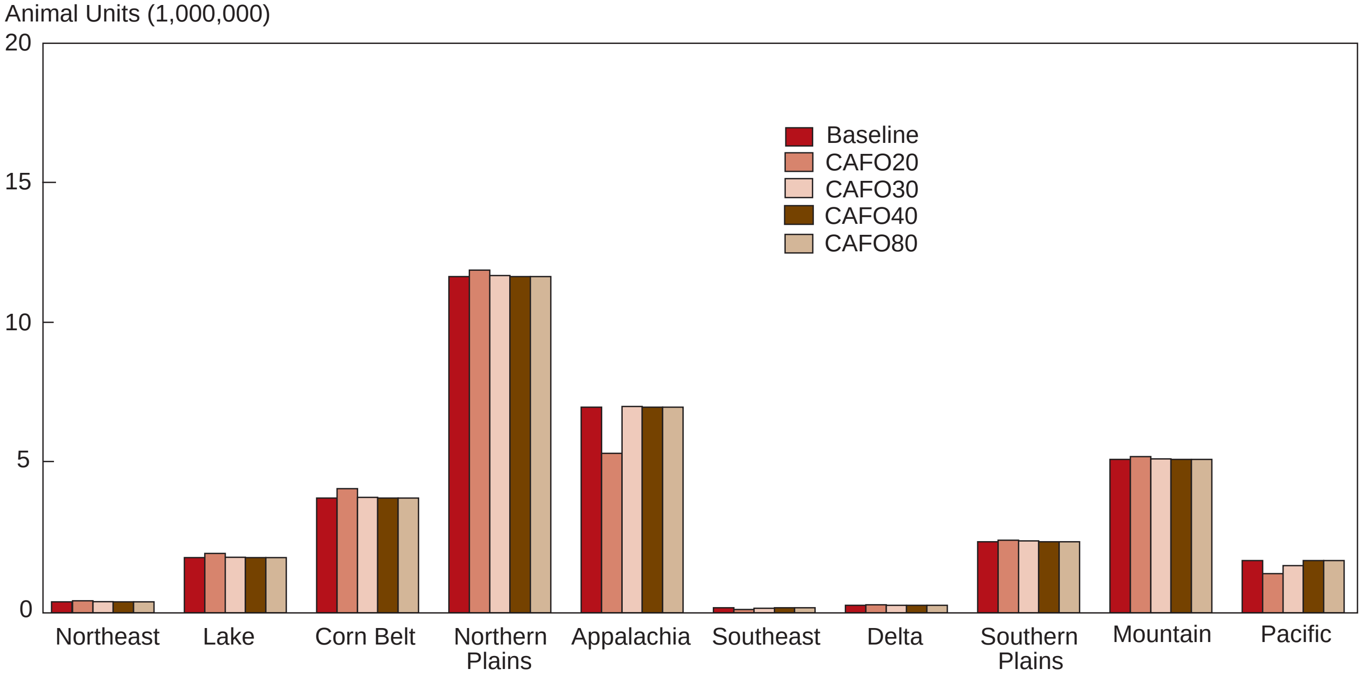
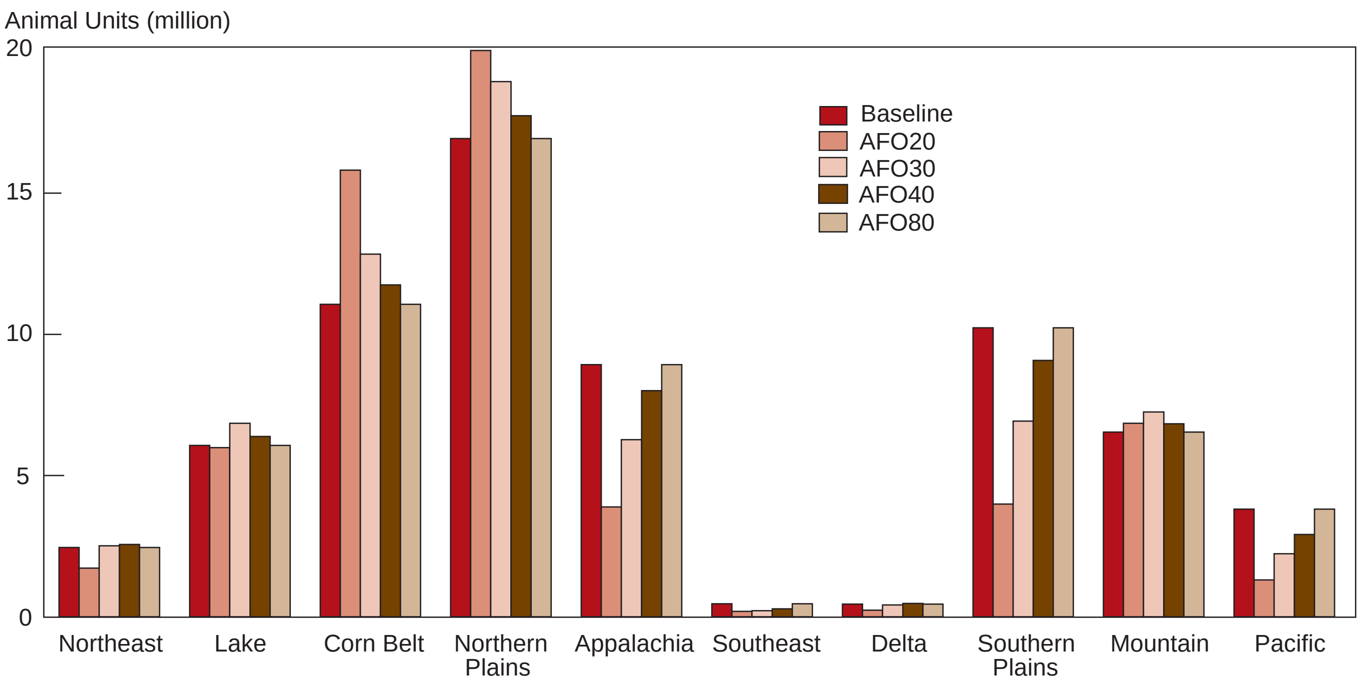


Figure 5-4b
Animal production when all AFOs meet nutrient standards



the livestock and poultry production at the margin to remain viable, particularly in the Appalachia, Southeast, and Pacific regions. The Corn Belt is the only region to show noticeable declines in crop acreage.

Transportation Costs

Transportation costs for hauling manure are a large contributor to the costs of meeting a manure-nutrient application standard. Hauling costs differ between regions because each region has different amounts of land available for spreading manure, different mixes of

Figure 5-5a
Crop acreage when only CAFOs meet nutrient standards

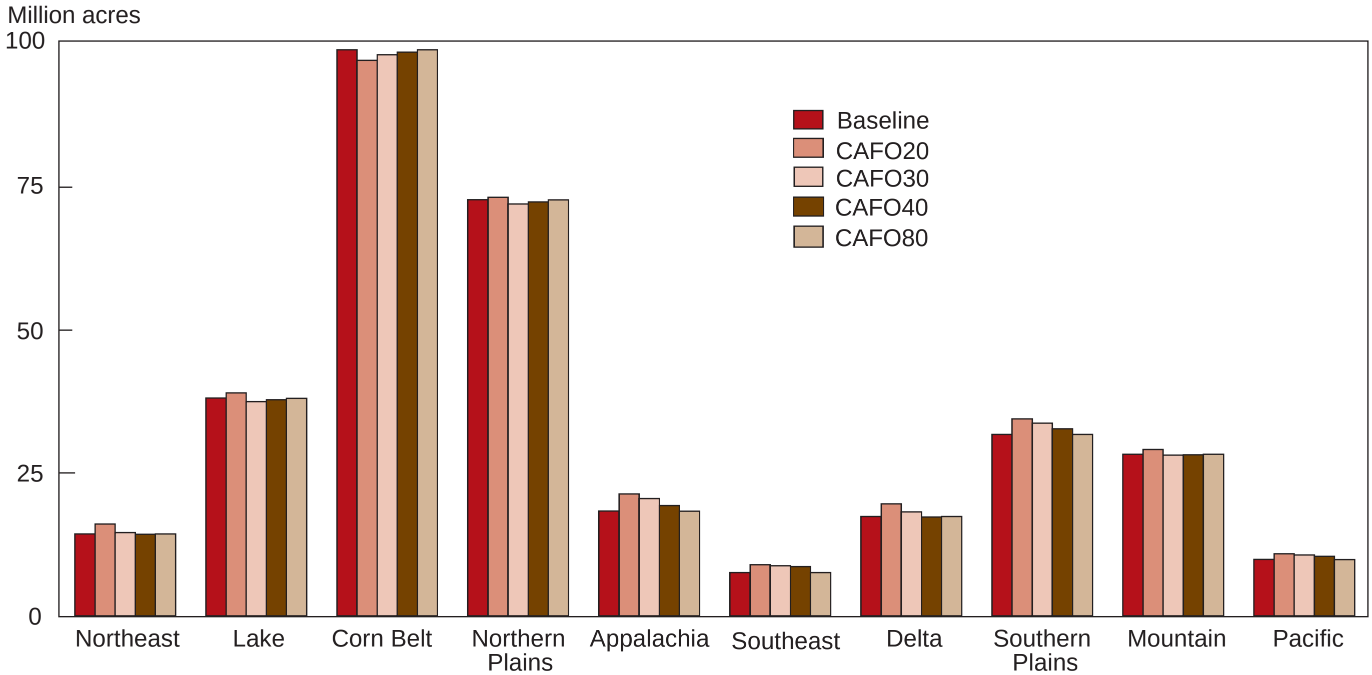
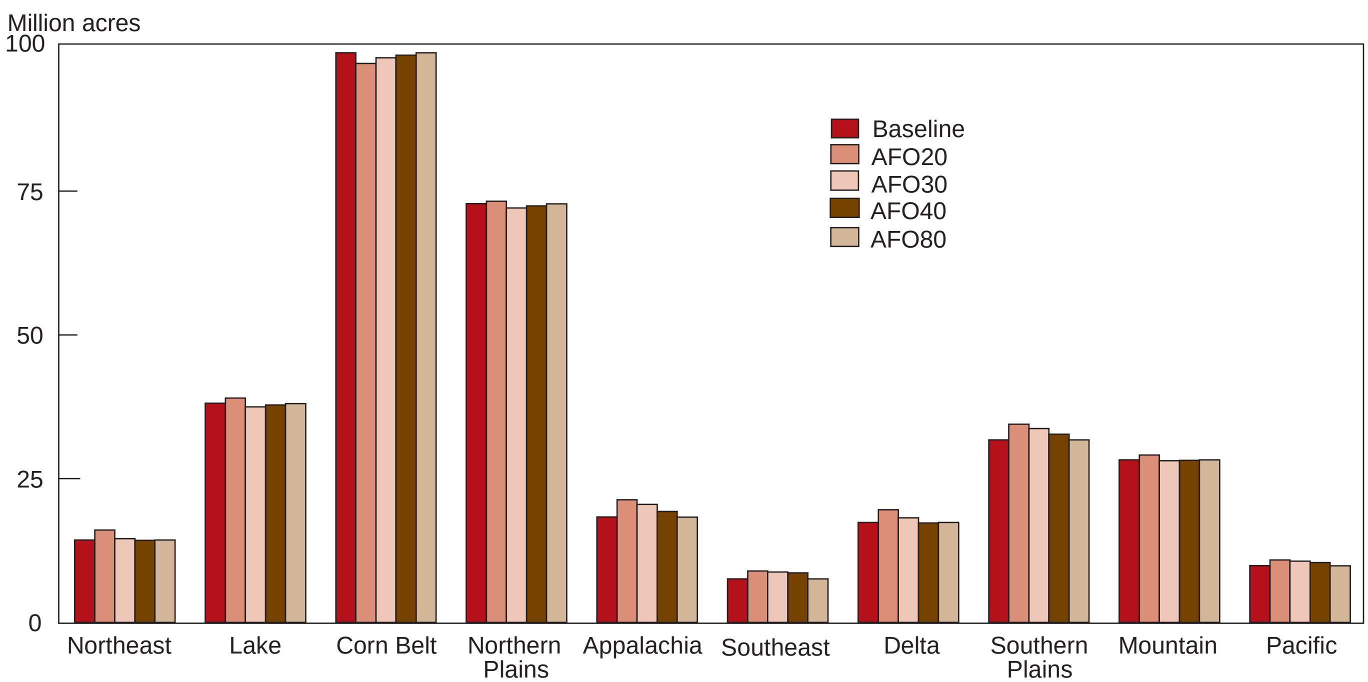


Figure 5-5b
Crop acreage when only AFOs meet nutrient standards



predominant crops, and different quantities of manure that need to be spread. Changes in transportation costs generally move in concert with changes in the number of animals.

Transportation costs remain fairly constant across the CAFO scenarios (fig. 5-6a). Under the CAFO20 scenario, estimated transportation costs range from $33.4 million per year in the Northeast to $237 million in the Northern Plains, where the most animals are produced. Transportation costs can also be viewed in terms of dollars per ton of manure transported. Under the CAFO20 scenario, these costs range from $2.46 per ton in Appalachia to $6.05 in the Pacific region.

Greater changes in transportation costs (relative to the baseline) are seen when all AFOs adhere to the nutrient standard (fig. 5-6b) Transportation costs are high-

Figure 5-6a
Manure transportation costs when only CAFOs meet nutrient standards

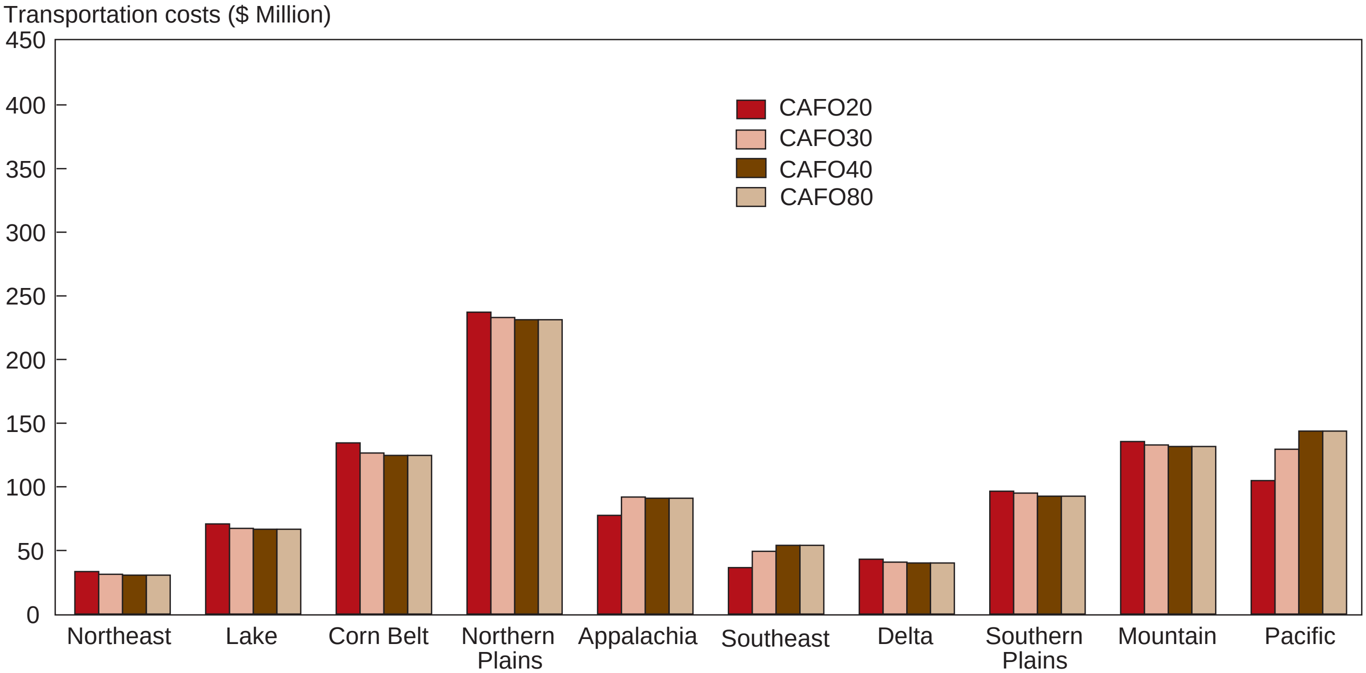
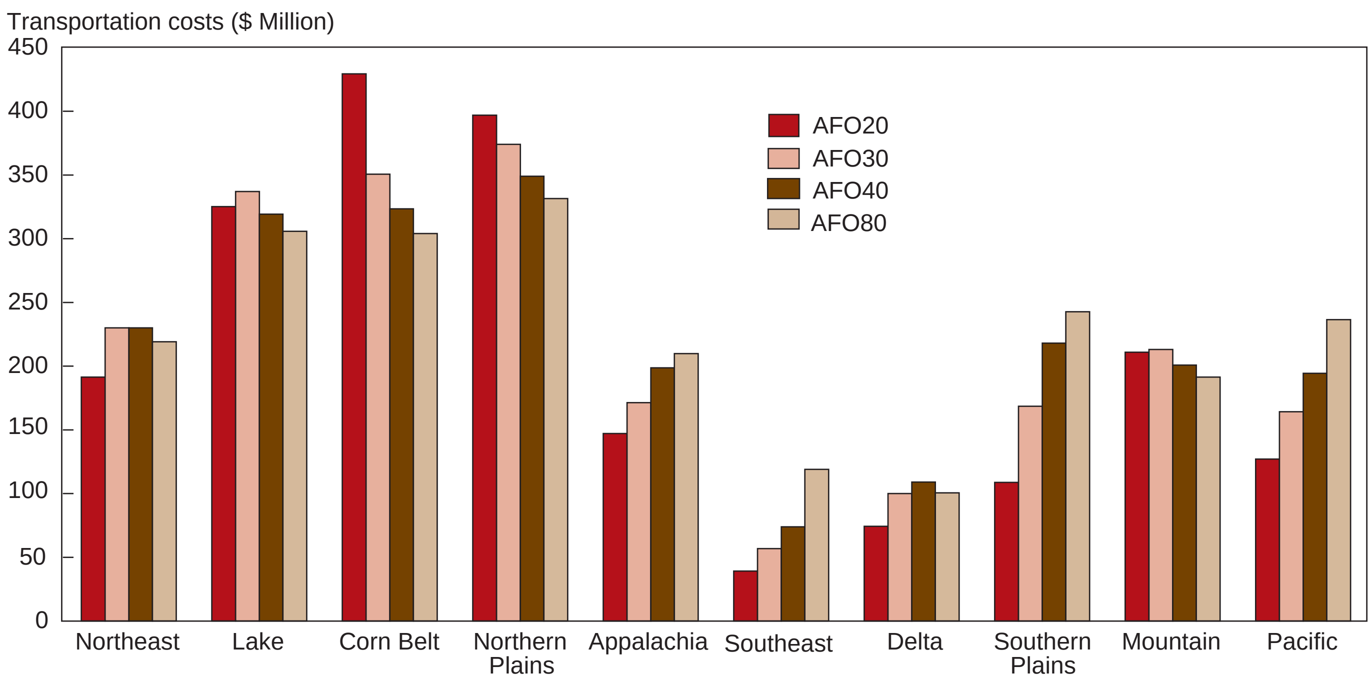


Figure 5-6b
Manure transportation costs when all AFOs meet nutrient standards



est in the Lake, Corn Belt, and Northern Plains regions and typically fall as substitution rates increase. However, in the Southern Plains, Pacific, Appalachia, and Southeast regions, transportation costs are greatest when substitution of manure nutrients is high, and decline noticeably when the willingness of cropland operators to use manure nutrients declines. This result mirrors changes in animal production shown in figure 5-4b.

Fertilizer Savings

Throughout our analysis, we assume that substituting manure nutrients for commercial fertilizer would generate savings for cropland operators (Lazarus and Koehler, 2002). Savings would closely follow the regional quantities of manure generated and the assumed willingness of cropland operators to use manure (table 5-1). Nationally, savings for cropland operators would increase as more livestock and poultry operations meet standards and as more manure nutrients are substituted by cropland operators. When all AFOs meet standards and 80 percent of cropland operators substitute manure nutrients, savings would total $887 million (assuming no change in the price of commercial fertilizer). When only CAFOs meet standards and only 20 percent of cropland operators substitute manure, nutrient savings would fall to $393 million as animal production decreases in order to balance manure nutrients with available cropland.

Regionally, the story is more complex. When only CAFOs meet standards, the region showing the greatest savings at higher substitution rates (30 percent, 40 percent, and 80 percent) would be Appalachia ($70 million) (fig. 5-7a). Even though CAFOs in Appalachia would not generate as much manure as those in the Northern Plains, the manure content would be more valuable (a higher phosphorus-to-nitrogen ratio), reflecting the larger concentration of poultry producers. However, at low substitution rates (e.g., 20 percent), the nutrient standards would become more binding in Appalachia and animal production would decrease. Consequently, at the 20-percent substitution rate, the potential savings from manure nutrients would be greatest in the Northern Plains ($70 million).

When all AFOs meet standards and the substitution rate is low (e.g., 20 percent), the greatest savings to cropland operators would occur in the Corn Belt, totaling more than $201 million (fig. 5-7b). This region has an abundance of animals and cropland and, as expected, savings would be substantial. However, as substitution rates increase, savings in the Corn Belt would decrease to $133 million. These changes are correlated to the changes in the numbers of animals produced under the different scenarios.

Net Returns

Changes in net returns to livestock and poultry production vary between regions for many reasons, including availability of cropland and mix of animal types. Under both AFO and CAFO scenarios, net returns would increase in most regions under assumed current nutrient substitution rates (about 20 percent). When only CAFOs meet nutrient standards, net returns in the Corn Belt would increase the most ($502 million or 14 percent). Plentiful land for spreading manure keeps the costs of meeting a standard down in this region, so it benefits most from the price increases (for animal products) that occur. Overall production in the livestock and poultry sector also increases. In contrast, net returns would decrease in the Southeast and Pacific regions (about 24-percent reduction in net returns each), where land suitable for spreading manure is relatively scarce (fig. 5-8a). If all AFOs must meet nutrient standards, the impacts on net returns are magnified. Net returns in all but three regions would increase, with the largest again in the Corn Belt ($3.8 billion or 105 percent). Net returns decrease in the Southeast, Southern Plains, and Pacific (fig. 5-8b).

As nutrient substitution rates increase, the expansion effect is reduced so price increases do not compensate as much for higher manure management costs. Net returns decrease in all regions under both AFO and CAFO scenarios when the substitution rate is 80 percent. Percentage reductions are greatest in the Northern Plains in both the CAFO (7.4 percent) and AFO (11 percent) scenarios.

Implications for Individual Sectors

We report results for the three principal livestock sectors (beef, dairy, and swine), the poultry sector, and the corn and soybean sectors. In general, when constraints from nutrient standards are not binding or marginally binding (i.e., greater than an 80-percent substitution rate), there would be small decreases in returns to all the regional livestock and poultry sectors because of the cost of meeting nutrient standards. There would be little to no corresponding price effect because, for the most part, no decreases in production would occur. However, changes in the various agricultural sectors would be larger when nutrient constraints become more binding (more livestock/poultry operations having to meet nutrient standards and fewer cropland operators substituting manure nutrients for commercial fertilizers).

Beef Sector

Changes to net returns in the beef sector vary widely between regions and manure substitution rates (table 5-7). Under the CAFO20 scenario, net returns to the beef sector fall in most regions (-5.1 percent nationally), approaching $290 million (-54.5 percent) in the Pacific region. Increases in net returns occur in the Northeast, Southeast, Southern Plains, and Mountain regions. As manure nutrient substitution increases, losses are reduced in the Pacific, but greatly increase in the Northern Plains to $218 million (-9.5 percent).

The greatest changes in net returns would occur if all AFOs met a nutrient standard and only 20 percent of commercial fertilizer were replaced by manure nutrients. Six regions would suffer declines in net returns, although national returns would increase by $123 million (1.7 percent). Some regions benefit greatly. The

Figure 5-7a
Savings from manure use when only CAFOs meet nutrient standards

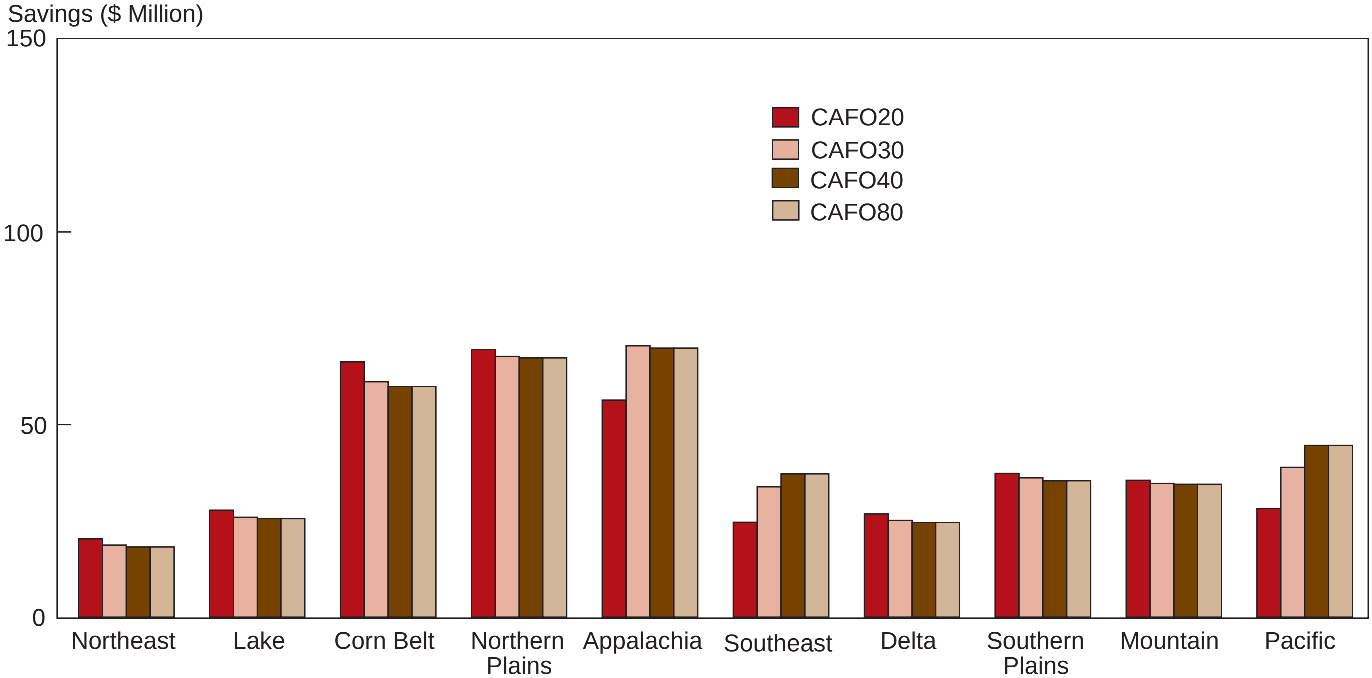
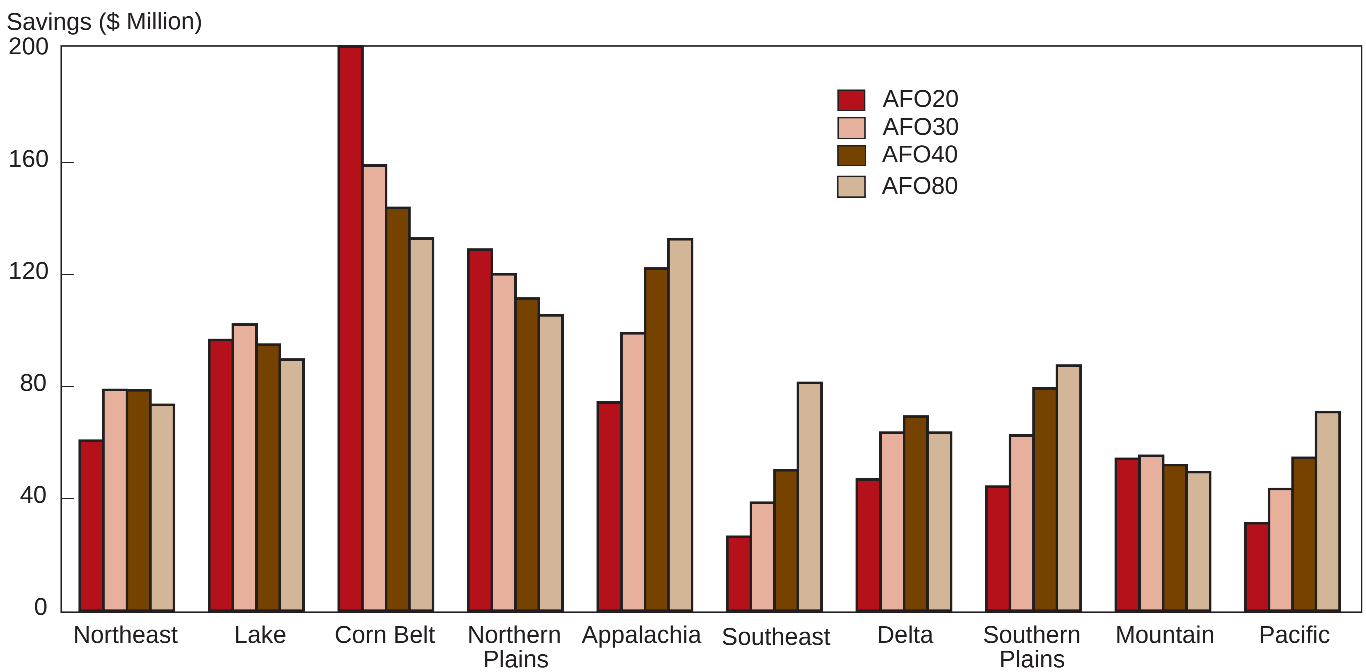


Figure 5-7b
Savings from manure use when all AFOs meet nutrient standards



Northern Plains would enjoy an increase of $986 million (42.8 percent). In contrast, the Southern Plains would suffer a $988 million loss (more than 45.0 percent). As substitution rates increase, the magnitude of the impacts is greatly reduced. When the manure nutrient substitution rate is 80 percent, all but one region suffer losses in net returns, with the greatest loss in the Northern Plains ($291 million).

Dairy Sector

Returns to dairy production would follow a different pattern than seen in the beef sector (table 5-8). When only CAFOs adhere to a nutrient standard, net returns actually increase for most regions (0.7 percent) with substitution near or at current levels. However losses occur in the Southeast and Pacific regions ($3.5 million

Figure 5-8a
Net returns to livestock/poultry production when only CAFOs meet nutrient standards

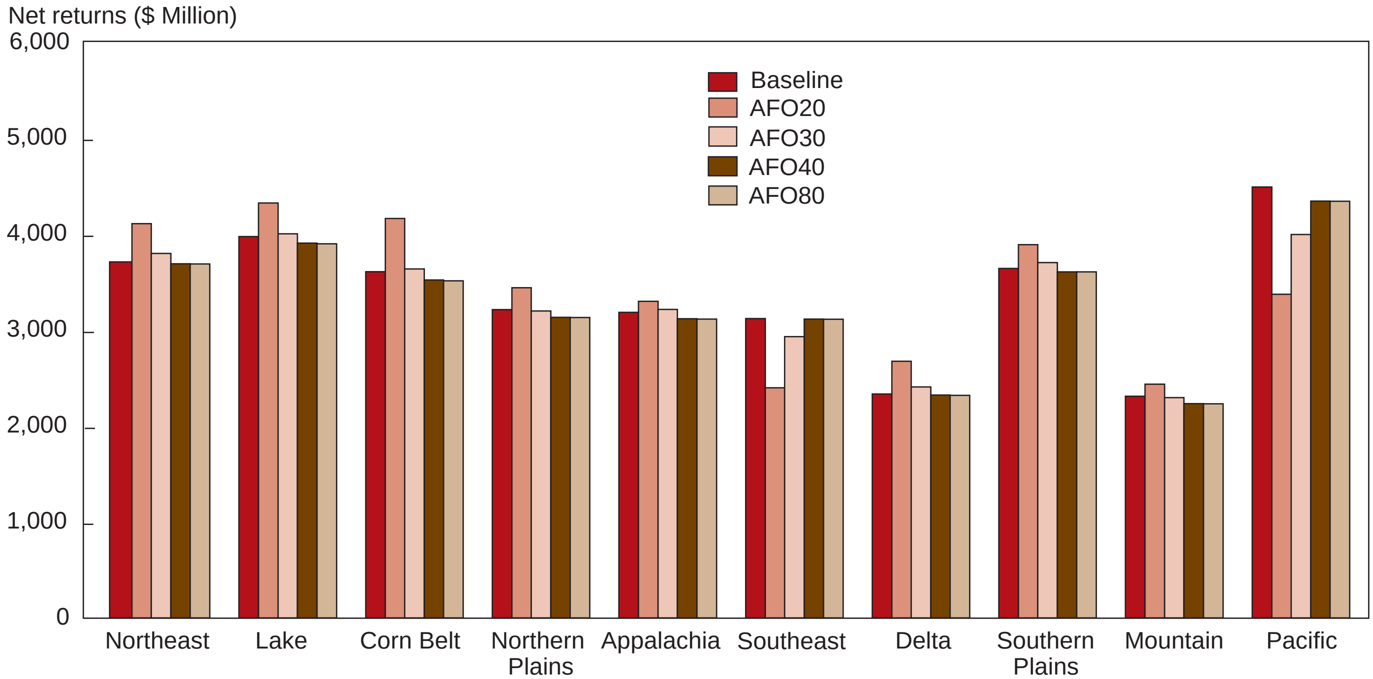
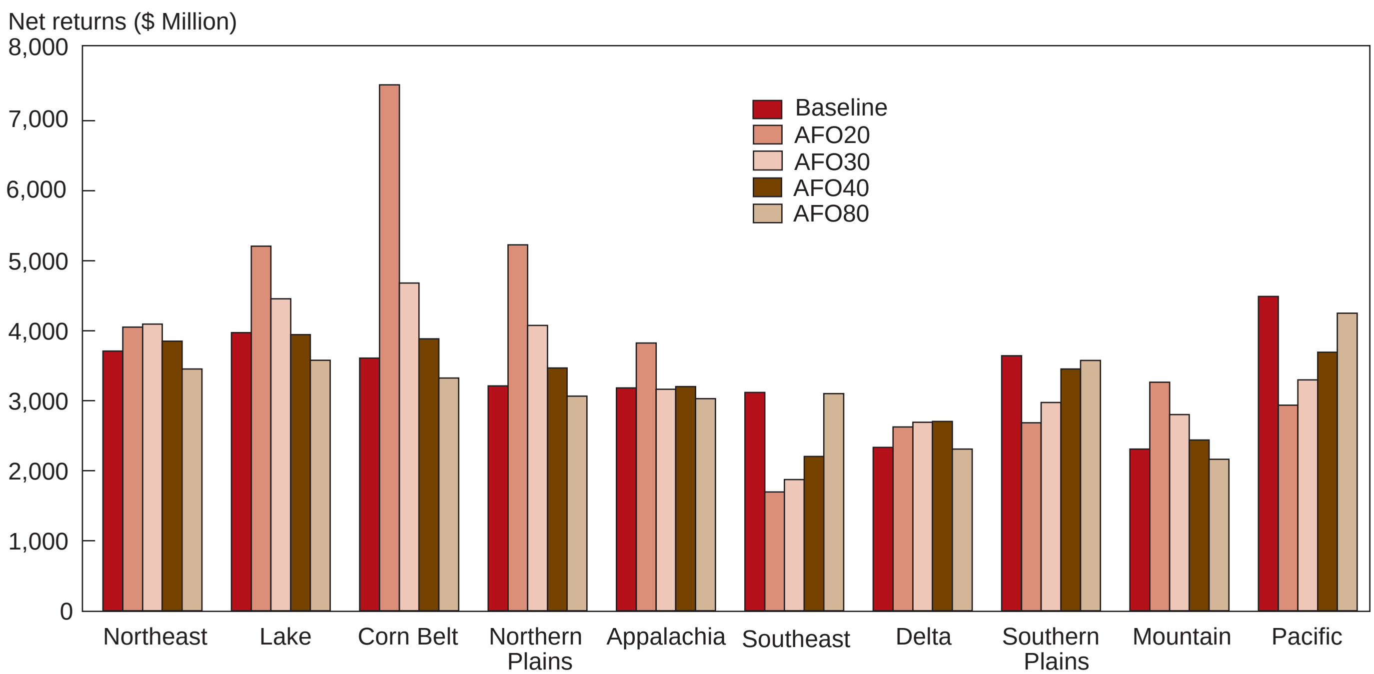


Figure 5-8b
Net returns to livestock/poultry production when all AFOs meet nutrient standards



and $474 million). At higher manure nutrient substitution rates, all regions suffer losses in net returns, with the largest loss in the Pacific ($102 million).

Net returns would increase in most regions if all operations met nutrient standards and substitution rates remain at or near current levels. Net returns for the dairy sector as a whole would increase over $1.2 billion (9.4 percent). The largest increases would occur in the Lake States ($655 million) and Corn Belt ($495 million). The Pacific, however, would see large losses, approaching $625 million (-19.3 percent). As the substitution of manure nutrients for commercial fertilizer increases, the dairy sector as a whole suffers increasingly larger net losses. When manure nutrients substitute for 80 percent of commercial fertilizer, all

Table 5-7—Change in net returns to the beef sector

Region	AFO				CAFO			
	20%	30%	40%	80%	20%	30%	40%	80%
	$ Million							
Northeast	-59.8	-5.0	-0.8	-4.6	1.9	-3.0	-4.5	-4.8
Lake States	-64.3	-8.4	-28.3	-41.2	-3.4	-16.4	-20.3	-22.2
Corn Belt	254.4	11.5	-62.8	-112.0	-22.1	-46.9	-54.8	-57.8
Northern Plains	986.3	361.0	-29.5	-290.6	-82.5	-173.6	-216.3	-218.5
Appalachia	-31.6	-24.0	-17.0	-14.2	-23.8	-12.0	-13.8	-13.9
Southeast	33.5	12.2	5.1	0.0	7.3	1.6	0.0	0.0
Delta States	-43.5	-13.4	-6.4	-10.2	-2.7	-7.2	-8.6	-9.7
Southern Plains	-987.7	-617.5	-312.3	-199.0	24.6	-24.3	-67.9	-68.8
Mountain	526.6	316.8	77.0	-105.2	12.6	-52.0	-89.0	-89.9
Pacific	-490.7	-318.0	-228.8	-43.9	-290.4	-152.9	-20.2	-20.7
U.S.	123.1	-284.8	-603.6	-821.1	-378.6	-486.6	-495.3	-506.4

Table 5-8—Change in net returns to the dairy sector

Region	AFO				CAFO			
	20%	30%	40%	80%	20%	30%	40%	80%
	$ Million							
Northeast	123.1	77.3	-23.6	-181.7	167.4	43.1	-7.9	-8.3
Lake States	654.6	197.2	-53.5	-250.4	188.1	33.8	-29.7	-30.6
Corn Belt	495.5	90.8	-11.0	-90.7	71.5	9.3	-16.2	-16.5
Northern Plains	145.2	31.8	-2.8	-29.8	21.7	0.4	-8.3	-8.3
Appalachia	135.4	-15.5	-31.4	-57.0	44.8	10.0	-6.9	-6.9
Southeast	-12.9	-41.5	-38.4	-9.2	-3.5	-1.6	-2.0	-2.4
Delta States	30.8	12.6	7.3	-5.4	12.5	3.2	-0.5	-0.7
Southern Plains	28.8	-22.7	-7.2	-10.7	37.3	9.3	-2.8	-2.8
Mountain	275.3	64.2	-21.0	-87.2	32.1	-19.9	-41.0	-41.1
Pacific	-625.1	-566.9	-389.8	-167.5	-474.2	-212.9	-101.7	-102.5
U.S.	1,250.7	-172.7	-571.4	-889.7	97.7	-125.3	-216.9	-220.2

regions suffer losses, with the largest in the Lake States ($250 million, or -7.8 percent).

Poultry Sector

The poultry sector in most regions shows increases in net returns (AFO and CAFO) with a 20-percent nutrient substitution assumption (table 5-9). If only CAFOs meet a nutrient standard, net returns for the sector would increase by $79.5 million (0.7 percent) when substitution rates remain at or near current levels, with all but two regions seeing increases. The Southeast would suffer the greatest losses ($749 million or -28.1 percent). As more manure nutrients are substituted for commercial fertilizer, sector losses start to mount, until all regions suffer losses in net returns.

When all AFOs must meet nutrient standards, the poultry sector realizes a large gain in net returns when nutrient substitution is most limited ($2.1 billion or nearly 20 percent). The Corn Belt in particular would benefit, enjoying an increase of $1.9 billion. In contrast, the Southeast would suffer a loss of over $1.4 billion. As the substitution assumption is relaxed, the number of regions with losses increases. When 80 percent of commercial fertilizer is replaced by manure nutrients, net returns decline in all regions, with the largest still occurring in the Southeast ($116 million). Total sector losses reach $491 million (5 percent).

Swine Sector

Net returns to swine production increase relative to the baseline. Under the CAFO20 scenario, most regions benefit (13.5-percent increase nationally), with the largest increase in the Corn Belt ($192 million or 26.6 percent) (table 5-10). As the substitution rate increases to 80 percent, all regions suffer relatively small losses.

Table 5-9—Change in net returns to the poultry sector

Region	AFO				CAFO			
	20%	30%	40%	80%	20%	30%	40%	80%
	$ Million							
Northeast	355.5	318.7	176.7	-44.5	198.4	37.5	-16.9	-17.1
Lake States	574.6	247.2	91.0	-18.2	98.4	17.9	-8.6	-8.7
Corn Belt	1,916.8	592.2	232.6	-51.2	260.7	44.2	-29.9	-30.0
Northern Plains	232.9	86.4	34.1	-6.6	41.9	9.5	-1.7	-1.7
Appalachia	595.0	33.9	39.0	-91.0	133.5	42.9	-27.8	-28.0
Southeast	-1,456.1	-1,245.2	-933.7	-115.7	-749.4	-229.9	-52.9	-53.4
Delta States	255.3	269.5	271.5	-92.0	290.0	46.5	-32.1	-32.7
Southern Plains	-36.8	-125.7	-24.8	-38.2	117.2	17.9	-20.8	-20.9
Mountain	74.5	33.1	14.1	-1.9	17.6	4.4	-0.2	-0.2
Pacific	-393.2	-272.4	-156.0	-31.7	-328.7	-118.0	-23.9	-23.9
U.S.	2,118.6	-62.3	-255.5	-491.1	79.5	-127.0	-214.9	-216.7

Table 5-10—Change in net returns to the swine sector

Region	AFO				CAFO			
	20%	30%	40%	80%	20%	30%	40%	80%
	$ Million							
Northeast	-59.7	5.2	-0.4	-11.8	15.1	-3.3	-4.1	-5.4
Lake States	114.0	89.7	6.2	-40.0	60.6	-12.0	-14.8	-18.0
Corn Belt	1,108.6	280.0	28.3	-109.5	192.3	-26.3	-33.5	-38.2
Northern Plains	400.8	146.7	34.6	-25.5	90.7	-5.7	-8.5	-8.8
Appalachia	-113.3	-76.5	-45.8	-68.1	-69.4	-39.2	-46.9	-50.0
Southeast	-22.3	-22.7	-17.1	-4.6	-10.1	-4.8	-1.4	-1.9
Delta States	-17.7	-0.2	-0.2	-6.1	6.3	-1.8	-2.3	-3.5
Southern Plains	-36.1	-24.4	-9.2	-3.7	6.6	-2.6	-2.9	-3.1
Mountain	23.1	15.7	3.1	-3.7	8.2	-2.6	-2.9	-2.9
Pacific	-11.7	-11.7	-9.2	-1.2	-10.0	-3.9	-0.6	-0.6
U.S.	1,385.8	401.6	-9.6	-274.1	290.2	-102.0	-117.7	-132.4

The largest occurs in the Appalachia region ($50 million, or 7.4 percent).

Under the AFO scenario at the lowest substitution rate, hog returns would decline in 6 of the 10 regions, but national net returns would increase $1.4 billion (more than 64 percent). This is in large part due to the $1.1-billion increase in the Corn Belt. At the highest nutrient substitution rate, net returns decline in all regions, with the largest loss in the Corn Belt ($110 million).

Corn and Soybean Sectors

Balancing manure nutrient production with nutrient uptake in each region can result in shifts in the acreage of various crops and in crop prices (tables 5-11 and 5-12). (We assume that livestock and poultry producers do not pay cropland operators to receive manure.) If CAFOs are the only operations adhering to a nutrient standard, net returns to corn producers decrease in most regions (and -1.7 percent nationally) at 20-percent substitution. Increased willingness to substitute manure nutrients for commercial fertilizer quickly reverses the impacts so that all regions enjoy increases in net returns. If all animal operations met nutrient standards, net returns to corn producers would decline everywhere except in the Pacific region (and -10.6 percent nationally) under low substitution rates. Net returns would decline by over $1 billion (nearly 11 percent) in the Corn Belt, driven by the large volume of corn grown there and the projected declines in crop prices given production increases throughout the United States. At the highest rates of substitution, net returns increase in all regions, with the Corn Belt seeing the largest increase ($60 million or 0.6 percent). Price changes in this scenario are negligible, so the results reflect savings in fertilizer expenditures.

Table 5-11—Change in net returns to the corn sector

Region	AFO 20%	AFO 30%	AFO 40%	AFO 80%	CAFO 20%	CAFO 30%	CAFO 40%	CAFO 80%
				$ Million				
Northeast	-29.5	-12.1	1.0	17.4	-9.9	1.4	4.3	4.4
Lake States	-182.3	-74.2	-20.3	30.8	-34.8	0.0	9.0	9.5
Corn Belt	-1,054.4	-453.2	-188.9	59.8	-183.7	-16.1	27.3	29.3
Northern Plains	-306.7	-158.5	-67.0	22.2	-63.0	-2.5	13.9	14.9
Appalachia	-74.3	-11.8	12.6	32.6	1.4	12.9	17.2	17.3
Southeast	-12.2	12.2	22.7	21.8	15.6	13.4	10.0	10.1
Delta States	-12.6	-2.1	-0.8	2.3	-1.8	0.4	0.9	0.9
Southern Plains	-11.4	2.3	3.0	2.9	-4.2	-0.1	1.2	1.3
Mountain	-26.5	-12.6	-5.2	1.8	-4.7	0.0	1.2	1.3
Pacific	7.7	12.7	11.6	2.3	13.1	8.0	1.4	1.5
U.S.	-1,702.2	-697.4	-231.2	194.0	-272.1	17.4	86.5	90.3

Table 5-12—Change in net returns to the soybean sector

Region	AFO 20%	AFO 30%	AFO 40%	AFO 80%	CAFO 20%	CAFO 30%	CAFO 40%	CAFO 80%
				$ Million				
Northeast	-1.4	1.4	3.5	5.7	-0.9	1.0	1.5	1.4
Lake States	-58.9	-18.1	2.3	21.0	-12.3	2.9	6.3	6.4
Corn Belt	-403.1	-196.4	-65.9	52.6	-90.4	3.7	25.0	24.7
Northern Plains	-59.6	-31.6	-8.0	12.8	-12.2	4.5	8.3	8.3
Appalachia	-43.1	-3.9	24.0	39.8	2.5	19.2	21.1	21.1
Southeast	5.6	20.9	31.5	35.7	19.1	20.6	16.4	16.4
Delta States	-75.8	-22.2	25.5	34.8	3.0	13.2	13.7	13.8
Southern Plains	-1.8	-0.5	0.4	1.0	-0.2	0.3	0.4	0.4
Mountain	na	na	na	na	na	na	na	na
Pacific	na	na	na	na	na	na	na	na
U.S.	-2,332.7	-935.0	-206.3	399.7	-350.5	90.9	180.7	184.2

na = Not applicable (crop not grown).

A similar story emerges for soybeans. When only CAFOs meet nutrient standards, most regions would see reduction in net returns (-4.5 percent relative to the baseline) at 20-percent substitution. When 30 percent and more of commercial fertilizer is replaced by manure nutrients, net returns increase in all regions (2.4 percent for the sector with 80-percent substitution). The greatest losses (nearly 30 percent nationally) would occur if all operations met nutrient standards and if manure nutrients replaced only 20 percent of commercial fertilizer. Net returns would decrease in almost all regions, with the largest loss occurring in the Corn Belt ($403 million). In contrast, net returns to soybeans would increase in all regions (5.2 percent nationally) if 80 percent of commercial fertilizer were replaced with manure.

Summary

The new CAFO regulations could have many possible outcomes. As in the previous two chapters, we have focused on only one aspect of this proposed rule: the adoption of nutrient standards by confined animal feeding operations. However, while chapter 3 focused on farm-level implications and chapter 4 considered regional costs for the Chesapeake Bay watershed, this analysis considers the U.S. agriculture sector holistically. To do this, we model eight possible scenarios based on adoption and substitution rates for implementing nutrient standards for various sectors of U.S. agriculture, with the most likely scenarios being substitution rates of 20 percent (CAFO20) and 30 percent (CAFO30). The eight scenarios also vary in scope. Four scenarios consider implications of CAFO-only requirements, while the other four are more extreme, requiring all AFOs to meet nutrient application standards. The results from these scenarios are compared with the USDA 2010 baseline, a year when it is assumed that the agricultural sector will have adjusted to the adoption of nutrient standards.

The imposition of nutrient standards on animal feeding operations is estimated to result in net economic gains of $89 million (or a 0.3-percent increase in net returns) for the livestock and poultry sectors under CAFO20, though individual producers may gain or lose. The price increases that result in an overall increase in net returns are the result of a reduction in the number of animals being produced. Benefits are realized only by those operations that remain in production. However, the livestock and poultry sector suffers economic losses of $841 million (2.5-percent decrease) under CAFO30. This swing is attributed to the livestock supply-dampening and price-enhancing effects observed in the CAFO20 scenario. Economic losses to consumers (higher prices) plus producers are $1.1 billion (-0.23 percent) and $0.66 billion (-0.14 percent decrease) under the CAFO20 and CAFO30 scenarios.

This analysis also showed that requiring all AFOs to meet a nutrient standard would greatly increase the magnitude of national impacts. As of now, only CAFOs are required to meet a nutrient standard. If there is a cost to operations other than CAFOs for meeting a nutrient standard, then they would not voluntarily alter their manure management practices and the estimated price changes would not occur.

There are significant variations in economic impacts between animal types and regions that are hidden by national aggregate results. Within a single scenario, some regions and sectors gain while others lose. For example, while animal feeding operations in aggregate would realize a net gain of $89 million under the CAFO20 scenario, the beef sector would suffer a net loss of $379 million. Furthermore, within the beef sector, the Southern Plains would realize a net gain of $25 million while the Pacific would see a net loss of $290 million. The wide range of results makes it exceedingly difficult to generalize the impacts of the nutrient application restrictions.

This analysis cannot reveal how individual operations would be affected by the standards. What can be said is that the livestock, poultry, and cropping sectors would undergo changes under all scenarios considered. The livestock and poultry sectors would benefit in some cases, possibly at the sacrifice of some individual operations, but net returns to the U.S. agriculture sector, including impacts on the cropping sectors, generally fall. However, these losses must be weighed against improved surface and ground water (from reduced nutrient loadings), the benefits of which are not estimated in this analysis.

Changes to agricultural sectors in response to manure nutrient application standards will not occur in a vacuum. Other technologies for treating manure nutrients might develop over time. In regions where cropland for spreading manure nutrients is scarce, it is likely that other nonagricultural lands (such as on timber plantations) would be used for assimilating manure nutrients. Similarly, other agri-environmental policies may bear on these issues. For example, the 2002 Farm Act provides a large increase in funds intended to help livestock and poultry producers to comply with Federal and State water quality regulations and to encourage the adoption of practices such as nutrient management. These policies could alter the changes in production arising from the adoption of nutrient standards. Specifically, the Environmental Quality Incentives Program (EQIP) is authorized to fund $9 billion of manure management and conservation efforts by crop, livestock, and poultry producers over the next 10 years (USDA, NRCS, 2002). This amount exceeds total agricultural losses under five of the eight scenarios we analyzed. While implementation of EQIP will reduce farmer costs of responding to CAFO regulations—indeed it is designed to do so—we did not explicitly analyze this option. Instead, we raise this as a topic to be addressed in future research.

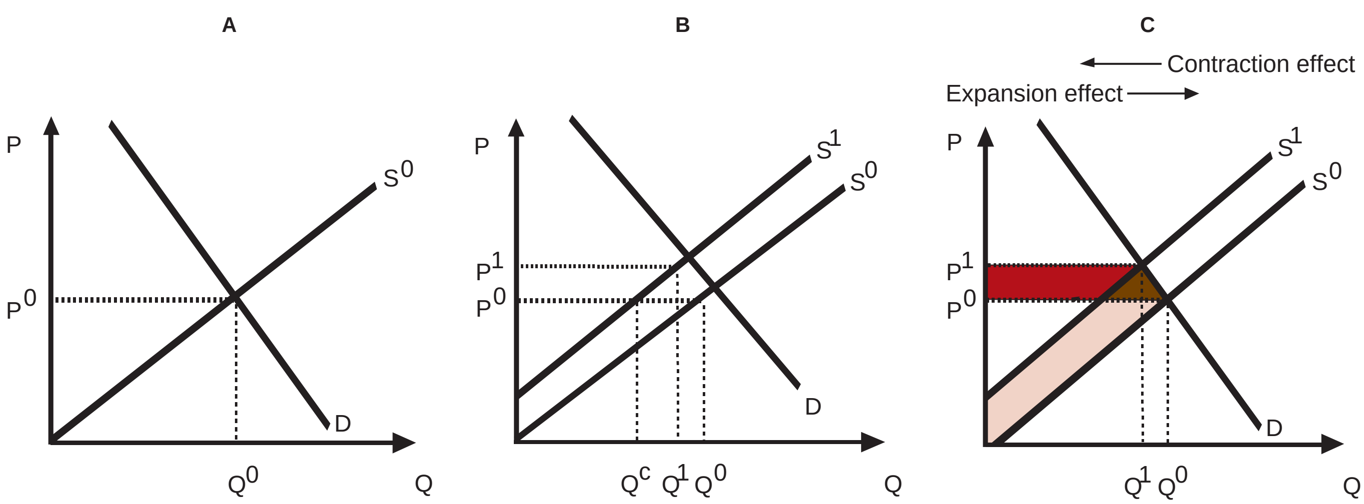
Appendix 5-A
Market Interaction Primer

If animal feeding operations (AFO) adopt land application restrictions for manure nutrients, the marketplace could react in several ways (fig. 5-A-1). In figure 5-A-1-A, the intersection of initial supply (S^0) and demand (D) for livestock and poultry products establishes the market clearing quantity and price for exchange (Q^0, P^0). If AFOs adopt nutrient standards, production would decline as a result of increased costs of production. Decreased production would result in a shift in the supply of livestock and poultry products (a movement from S^0 to S^1 and a corresponding change in quantity supplied to Q^c, as shown in figure 5-A-1-B). A new market-clearing quantity would then be established at a higher price, re-equilibrating supply and demand (i.e., at Q^1, P^1). Note that the slope of the demand curve will determine the extent to which prices increase. For instance, if the demand curve were horizontal (an extreme assumption), the effect would be contraction but not price changes.

Two inferences can be gleaned from this example. First, assuming downward sloping demand curves, consumers would purchase fewer livestock and poultry products at the higher price. Second, producers would reduce the supply of livestock and poultry products but would receive a higher price for their products. Clearly, consumers would be worse off. The potential loss to consumers is shown by the dark red and brown shaded areas in figure 5-A-1-C. The situation for the industry is less certain and would ultimately depend on the interaction between production changes, price changes, and increased production costs. These interactions would, in turn, depend on the responsiveness of prices for livestock and poultry products in both the domestic and export markets following changes in the cost of production. If the increased returns to producers depicted by the dark red shaded area exceeds the lost returns (the tan shaded area) then the industry, as a whole, would benefit even though individual producers with relatively higher costs may exit the industry.

We would expect the responses of AFOs to the standards to vary regionally. As noted, increased costs would initially result in reduced livestock and poultry production. However, under nutrient standards, some regions would face greater increases in the cost of production than others, due to such factors as available land for manure spreading. This was clearly shown in the farm level analysis in chapter 3. Figure 5-A-2 use hypothetical supply and demand curves to depict two heterogeneous regions. The contraction in supply due to nutrient standards is shown for the two regions by a movement from s^0 to s^1. A corresponding expansion effect, or positive supply response due to increased livestock and poultry prices, accompanies this contraction (Silberberg, 1990). The national market-clearing price would increase from P^0 to P^1. We assume that regional markets are price takers and thus the demand curve is depicted by the horizontal line equivalent to the prevailing price. In Region A, where the supply shift would be relatively small, production increases overall due to the supply response to the new higher price.

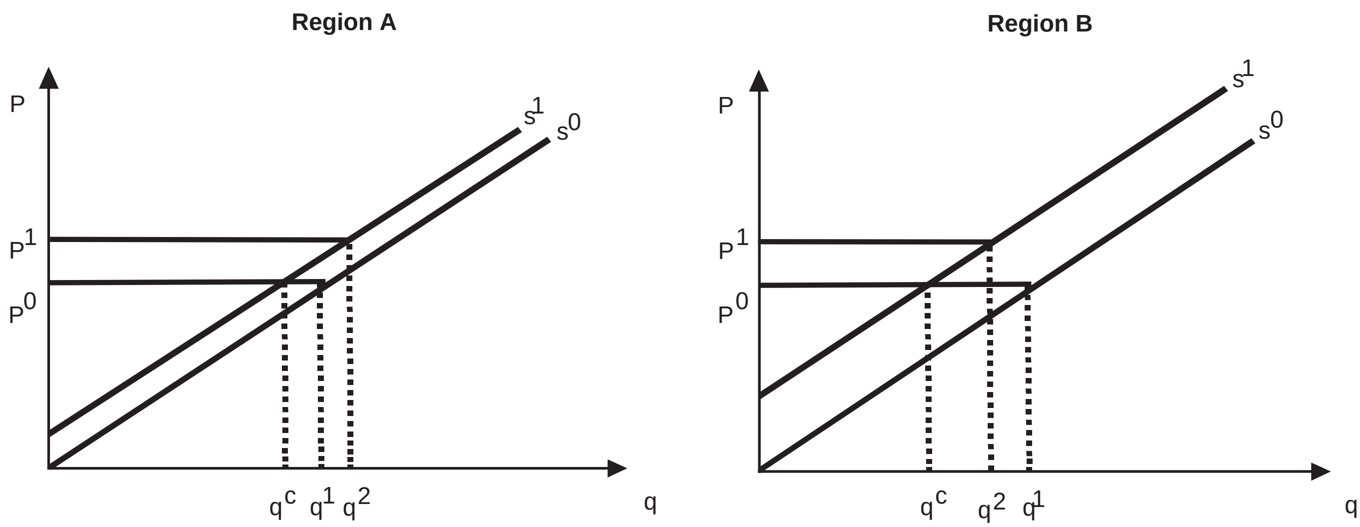
Figure 5-A-1
U.S. supply and demand for livestock and poultry products



Region A experiences increased net returns arising from the implementation of nutrient standards throughout the United States. This region's operators would produce more and receive a higher price for their products even though they face greater costs of production. In Region B, the supply shift is relatively large and the price response does not compensate for the increased production costs. Consequently, production falls in Region B due to the increased cost of production brought about by the change in production practices.

Figure 5-A-2

Heterogeneous production shifts resulting from nutrient standards



Chapter 6—Summary and Implications for Policy and Research

Livestock and poultry manure can provide valuable organic material and nutrients for crop and pasture growth. However, nutrients contained in animal manure can degrade water quality if they are overapplied to land and enter water resources. The nutrients of greatest water quality concern are nitrogen and phosphorus. Animal waste is a source of both. A shift in the livestock and poultry industry over the past several decades toward fewer, larger operations has prompted public concern over the utilization and disposal of animal manure and the potential degradation of water quality.

EPA recently developed new regulations under the Clean Water Act to address this problem. Under these regulations, operations designated Concentrated Animal Feeding Operations (generally the largest animal feeding operations) are required to meet a nutrient application standard when applying animal manure to land. In addition, all other animal feeding operations are being encouraged by USDA to voluntarily meet these standards by adopting nutrient management plans. Education, technical, and financial assistance are available to all operations through USDA conservation programs. These policies for encouraging or requiring animal feeding operations to meet a nutrient application standard when applying animal manure to land will raise the cost of producing livestock and poultry, and may affect prices throughout the agricultural sector.

Under the EPA regulations, some livestock and poultry producers would have to meet either a nitrogen-based or phosphorus-based application standard, depending on local soil conditions. For most animal operations to meet a nutrient standard, they will have to spread manure on more land than they are currently using. Generally, more land is needed to meet a phosphorus standard because manure contains more phosphorus relative to plant needs than nitrogen. The cost of hauling manure and applying it to a larger land base is the primary source of higher production costs. Some additional costs of meeting a nutrient standard include nutrient testing, soil testing, and plan development. We examine the impacts of these costs on the animal sector and the rest of the economy through analyses conducted at the farm, regional, and national levels.

The new CAFO regulations' impacts on manure disposal costs depend greatly on how willing cropland operators are to use manure as a source of nutrients. The higher the willingness to accept manure, the less distance manure will have to be moved, and the smaller the increase in production costs. Currently, 20 percent or less of cropland is receiving manure. We do not know how much this would increase if animal operations actively seek additional land off their own farms to spread manure. We assume here, for presentation sake, that up to 40 percent of cropland would receive manure after nutrient application standards are implemented. (A wider range is considered in the chapter results). Under this scenario, the overall economic impacts to consumers and producers from CAFOs meeting nutrient standards are a loss of $625.2 million (0.13 percent) in national economic welfare. The added costs of meeting a nutrient standard reduce net returns to the livestock and poultry sectors by $1.04 billion (3.1 percent). This loss is partially offset by gains to the crop sector of $427 million. Consumers see a small reduction in welfare from slightly higher prices for animal products. These estimates do not include the value of improved water quality, nor do they consider lost revenue to the commercial fertilizer industry.

These aggregate results mask the fact that the impacts vary widely between sectors and regions. Costs to the animal sector range from a reduction in net returns of 1.6 percent in the dairy sector ($217 million) to a reduction of 6.7 percent in the beef sector ($495 million). Regional costs range from a reduction in net returns of 7.3 percent in the Northern Plains ($235 million) to a reduction in net returns of less than 1 percent in the Northeast ($33.4 million). These differences are due to availability of land for spreading manure, baseline production costs, and regional animal and crop mix.

Regulations on animal waste spill over into the crop sector for two reasons. Manure nutrients become a cheap source of fertilizer that replaces more expensive commercial forms, reducing production costs. Feedgrains (primarily corn and soybeans) are an import source of animal feed, so changes in the number of animals affect the demand for feed. These sometimes conflicting influences result in increases in net returns in all regions for both corn and soybeans. With a 40-percent substitution between manure nutrients and commercial fertilizer, increases in net returns range from $27 million for corn in the Corn Belt (0.3

percent) to $0.4 million for soybeans in the Southern Plains (16 percent). Most regional changes are less than 5 percent.

While EPA's regulations affect only operations designated as CAFOs, USDA is actively promoting efficient nutrient management for all animal feeding operations. Our analyses show that if all AFOs were to meet a nutrient standard, the magnitude of the impacts to costs, production, and prices would be greatly increased. For example, reductions in net returns in the livestock and poultry sector are about 37 percent greater under an all-AFO requirement than a CAFO-only requirement, with a willingness-to-accept-manure of 40 percent ($1.4 billion vs. $1.0 billion). National economic welfare for producers and consumers declines almost $2 billion (0.43 percent).

Again, this is a hypothetical scenario; operations other than CAFOs are not required to meet a nutrient standard. It is a goal of USDA that these operations adopt nutrient management plans voluntarily. The reduction in net returns when all AFOs meet a nutrient standard is an indication that many will incur costs to do so. If those not designated a CAFO face a cost for meeting a nutrient standard, then they probably would not voluntarily alter their manure management practices without financial assistance, and the estimated economic impacts would not occur.

Potential changes to agricultural sectors in response to manure nutrient standards will not occur in a vacuum. New technologies for treating manure nutrients might develop over time, particularly in areas with high concentrations of animals relative to cropland, such as Delmarva, eastern North Carolina, and southeastern Pennsylvania. In regions where cropland for spreading manure nutrients is scarce, it is likely that other, nonagricultural lands (such as timber plantations) would be used for assimilating manure nutrients. Similarly, other agri-environmental policies may bear on these issues. For example, the 2002 Farm Act provides a large increase in funds intended to help livestock and poultry producers comply with Federal and State water quality regulations, to encourage the adoption of nutrient management practices, and to assist them to move manure off their farms to other landowners. Specifically, the budget for the Environmental Quality Incentives Program (EQIP; NRCS, 2002) is authorized to fund $9 billion in conservation efforts by crop, livestock, and poultry producers over the next 10 years. This amount exceeds agricultural losses under many of the scenarios we evaluated.

How individual farms adjust to nutrient application standards 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 cropland operators to accept manure, type of crops grown (providing different nutrient uptake), and type of nutrient standard the farm must meet (nitrogen-based or phosphorus-based). We looked at how these factors affect hog and dairy farms across the country. While many farms (primarily small and medium-sized) control enough land to meet nutrient standards, most are not using all of their cropland, thereby over-applying manure nutrients on the portion that receives manure. Only 18 percent of large hog farms and 23 percent of large dairies are currently applying manure on enough land to meet a nitrogen standard. On average, large hog and dairy farms would have to increase the acreage receiving manure by 114 percent and 99 percent to meet an N-based standard. If a P-based plan is required (which generally requires more land), the increase in acreage would have to be 550 percent for hogs and 529 percent for dairies. Smaller operations also have to increase the amount of land for spreading, but to a lesser degree.

Spreading manure on additional land raises hauling and application costs, which can be partially offset by reduced commercial fertilizer costs. Farms that don't control enough land to meet a nutrient standard (primarily large farms and all farms in some areas) must find land off the farm if applying manure to land is the only option, greatly increasing hauling costs. The impacts on large hog farms for meeting a nitrogen-based standard with a willingness-to-accept-manure of 40 percent would range from a net benefit of $3.20 per animal unit, on average, in the Eastern Corn Belt to a net cost of $4.20 in the South (assuming no changes in prices or number of animals). The availability of cropland both on and off the farm in the Eastern Corn Belt results in the fertilizer benefit from manure outweighing the additional transportation costs. The results in the South reflect a relative scarcity of cropland both on and off the farm.

Impacts to large dairy farms range from a net cost of $8.10 per animal unit in the North to $11.80 in the South. Generally, costs increase the greater the percentage of manure that must be moved off the farm, the smaller the percentage of surrounding land that is in crops that can use manure, and the smaller the nutrient uptake of predominant crops. Consistent with the three analyses, costs are higher with a lower willingness-to-accept-manure.

The relative importance of higher manure management costs to the farm can be indicated by comparing them to production costs. Meeting nitrogen application standards would raise hog production costs on large farms in the South by 1.2 percent with a willingness-to-accept-manure of 40 percent, assuming no other changes are made to the operation. Production costs increase 0.6 percent or less in the other regions. This is an average, and costs to individual farms could be higher (or lower). Manure management costs would be about 75 percent higher if willingness-to-accept-manure does not increase beyond 20 percent.

The results are similar for large dairies. Meeting a nitrogen application standard would raise production costs between 0.6 and 0.7 percent with a willingness-to-accept-manure of 40 percent. Manure management costs double if willingness-to-accept-manure does not increase beyond 20 percent.

If a farm must meet a P-based standard, costs would generally be greater because more land would be required for spreading manure. In the Mid-Atlantic, for example, hog production costs would rise 1.5 percent under a P-standard, compared with an increase of 0.5 percent under an N-based standard. Dairies would see similar increases in production costs if a P-standard is to be met.

Expanding nutrient management requirements to all AFOs would affect numerous small and medium-sized farms. Nearly 90 percent of small hog and dairy farms control adequate cropland to meet the needs of a nitrogen standard, so they would generally not incur the cost of moving manure off the farm. In contrast, less than half of large hog farms and only 25 percent of large dairy farms can make this claim. Nutrient plan development and testing costs tend to be more important to these operations than to larger farms because the costs are spread over fewer animals. The additional manure management costs generally increase production costs 1 percent or less for small and medium hog and dairy farms. Again, costs are higher if willingness-to-accept-manure is lower.

While the costs to small and medium-size AFOs for meeting a nutrient standard are relatively low, the benefits from reducing manure runoff are also low. Raising production costs on the 94 percent of AFOs that are small and medium-sized to reduce the 35 percent of all excess nutrients they produce may not be a cost-effective means of improving water quality. This is a major reason why EPA focused its regulations on large AFOs.

While we did not analyze other sectors at the farm level, it is likely that the results would be similar. Poultry in particular is produced on large operations that have relatively little land for spreading manure. However, poultry manure is drier than other types, so it can be economically transported longer distances.

A factor that can greatly increase the cost an individual farm may face in meeting a nutrient standard is the regional concentration of animals. As noted in chapter 2, in some regions the amount of manure nutrients generated exceeds all that region's crop nutrient needs. In this setting, finding adequate land for spreading may be more costly than elsewhere because of competition for land. The Chesapeake Bay watershed (CBW) is one example; it contains counties with concentrations of surplus manure nutrients that rank among the highest in the Nation.

Using a model of the CBW that accounts for competition for land on which to apply manure, we estimate that net land application costs for meeting an N-based standard increase by $66.6 million per year under a 40-percent willingness-to-accept-manure assumption (21 percent of total net revenues from animal production). The average distance manure would have to hauled is greater than that estimated in the farm-level analysis, where competition for land was not considered. The farm-level analysis for hog farms in the Mid-Atlantic region, which includes most of the CBW, found that the average distance manure would have to be hauled is 1.4 miles, with a maximum for any one farm of 14 miles. In contrast, the average distance manure would have to be hauled in the CBW is 2.3 miles (on farm and off). Some manure would have to be hauled more than 50 miles to other counties.

If a phosphorus-based plan is required in the CBW (with a willingness-to-accept-manure of 40 percent), about 20 percent of manure would be in excess of what the accessible land in the watershed could assimilate. This manure would have to be hauled more than 90 miles, or a nonland-based solution would have to be found. Willingness-to-accept-manure would have to be greater than 60 percent for the watershed's manure to be spread agronomically within 90 miles of manure producing areas within the watershed.

One way of coping with a regional excess of manure is to find alternatives to land application. The cost of building an industrial facility that uses manure to produce a fertilizer product compares favorably to the cost savings from shifting manure from land application to industrial uses. For example, shifting manure to an industrial plant rather than hauling it to a distant site for land application would save $2-$7 million in land application costs per year under a P-standard, depending on the region's willingness-to-accept-manure.

Another way to reduce the amount of land required for spreading manure is to reduce the nutrient content of manure. Advances in feed and nutrition management are starting to offer some options to farmers for doing just this. Phytase is an enzyme currently being used in some swine and poultry feed. Adding phytase to the diet of swine and poultry in the Chesapeake Bay watershed could reduce land application costs by $6-$10 million.

The need to transport manure over longer distances has structural implications for the agricultural sector. Moving manure many miles from its source presumes that a marketing structure is in place and that a consistent, standardized product is shipped to the destination. It is likely that a more formal marketing system will develop over time to satisfy this need. The recently adopted USDA policy and EPA regulations could well spur a growth in these markets. The fertilizer industry could recoup some its losses in fertilizer sales by using manure as a source of raw materials (e.g. the Harmony Farms Shenandoah Valley fertilizer plant), organizing and operating regional manure markets, and providing manure nutrient management services to farmers.

Another structural issue is what happens to the economic advantages of vertical integration seen in the poultry and swine sectors. There are significant economic benefits to this structure, but one of its consequences is regional concentration. Our results indicate that the large production units typical of this structure would generally have the largest costs per animal unit for applying manure to meet a nutrient standard. Thus, the benefits of integration might be reduced because of manure management regulations.

Manure nutrient standards have been shown to affect regions differently, largely because of the availability of cropland for spreading manure. Animal feeding operations in regions with abundant cropland would generally have lower costs than other regions, giving them a competitive advantage. These regional differences can spur shifts in production between regions, as demonstrated in the national-level analysis. Large animal feeding operations looking to expand would likely consider the availability of spreadable land when making a decision.

Implications for Policy and Research

The analysis presented here is only a first step in fully evaluating the implications of environmental policies on animal feeding operations. Several issues deserve further research.

Advances in feed management may soon increase the options available to farmers for reducing nutrients in manure (CAST, 2002). While we study how phytase use reduces phosphorus in manure and affects manure spreading costs under a P-based plan, other feed management options include optimizing the amino acid content of feed, thereby reducing manure nitrogen. Optimizing feed for nitrogen excretion is more difficult to manage than for phosphorus, but it may play a future role in reducing excess nitrogen on animal farms. Further economic analyses could indicate the potential for such advances to reduce overall manure management costs.

The willingness of cropland owners to accept manure was found to be an important variable in all three analyses. Impediments to using manure are well known. However, the willingness to accept manure has not been directly studied. Survey data indicate that less than 20 percent of cropland in major crops currently receives manure. Whether this reflects willingness-to-accept-manure is unknown. It might be that agricultural land currently receiving manure is on operations that have animals. A study of the willingness of cropland operators who don't have livestock to use manure in place of commercial fertilizer would indicate the potential of using land application of manure as the principal manure disposal method, and it could identify areas for education and extension that might reduce cropland operators' reluctance. Financial assistance through programs such as the EQIP could be used to encourage crop operators to use manure as a fertilizer and soil amendment. Animal producers might be able to increase willingness-to-accept-manure by paying crop farmers to take manure. Savings in manure hauling costs by increasing willingness-to-accept-manure could make this worthwhile.

The farm and regional analyses took a short-term view, not considering farm-level changes in animal numbers and manure handling that might be made if a nutrient standard is met. The national analysis also took a short-term view in that it did not take into account structural changes on the farm or induced technological change. Analyses using optimization models that allow for all inputs on the farm to adjust would help indicate the longer run impacts on the industry. The impacts of manure management costs on the nature of production contracts and on the structure of the industry are of significant interest.

The results of the national analysis reflect in part the responsiveness of consumers, domestic producers, and foreign suppliers of livestock and poultry to U.S. price changes. The greater the responsiveness of supply and demand to price changes (also known as elasticities of supply and demand), the smaller the price shocks from increased production costs. Smaller price shocks are beneficial to consumers, but reduce the ability of market prices to compensate animal operators for higher manure management costs. Research on how changes in international trade patterns and consumer preferences affect price elasticities for livestock and poultry products— and the eventual costs to consumers and the agriculture sector from enhanced manure management—would provide additional depth to the analysis.

Our analysis only provides a first look at how alternative uses for manure might alleviate some of the costs of land application. Further assessment of the potential for manure products such as compost, fertilizer, and energy would be helpful. Such markets, if they develop, can be expected to have impacts on the cost of meeting regulations, and thus on location and structure of animal operations.

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