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.

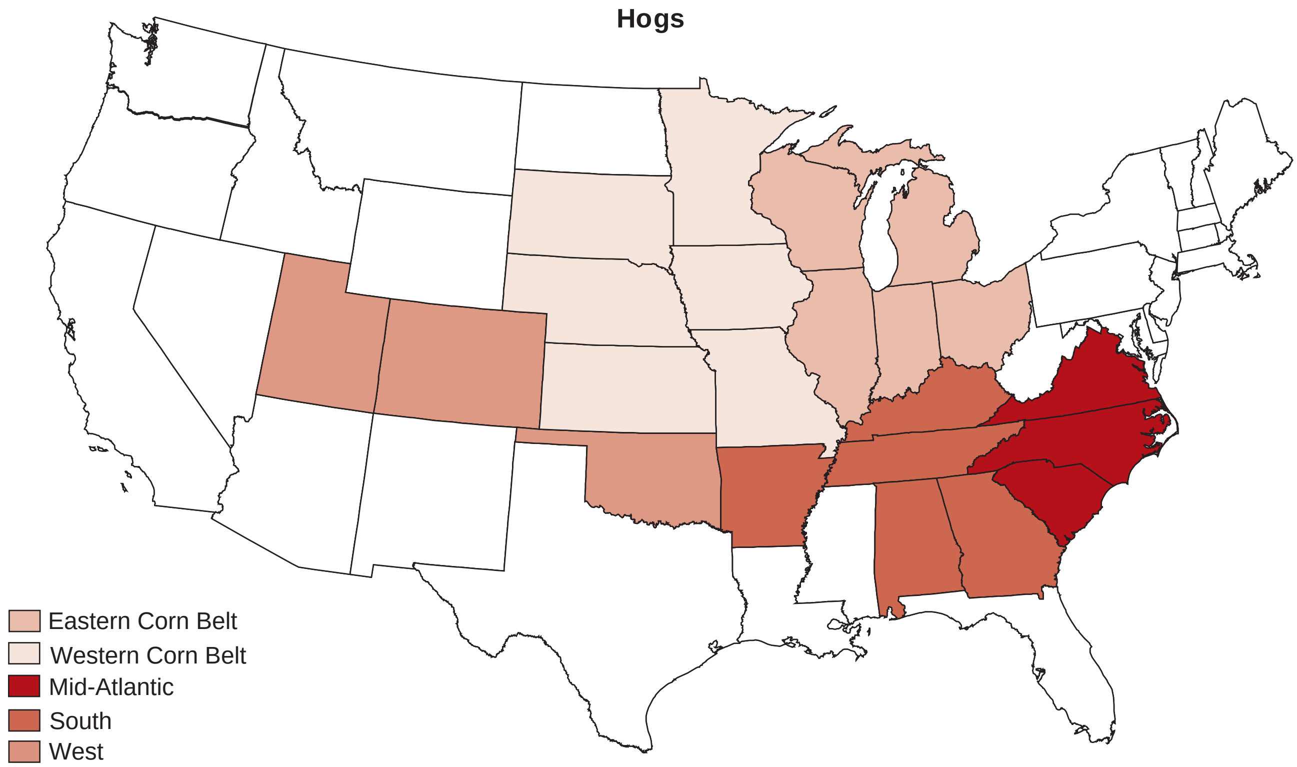
We grouped the survey data into five multistate regions: Eastern Corn Belt (IL, IN, MI, OH, WI); Western Corn Belt (IA, KS, MN, MO, NE, SD); Mid-Atlantic (NC, SC, VA); South (AL, AR, GA, KY, TN); and West (CO, OK, UT) (fig. 3-1). We looked at three size classes based on EPA's definition of animal units (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).

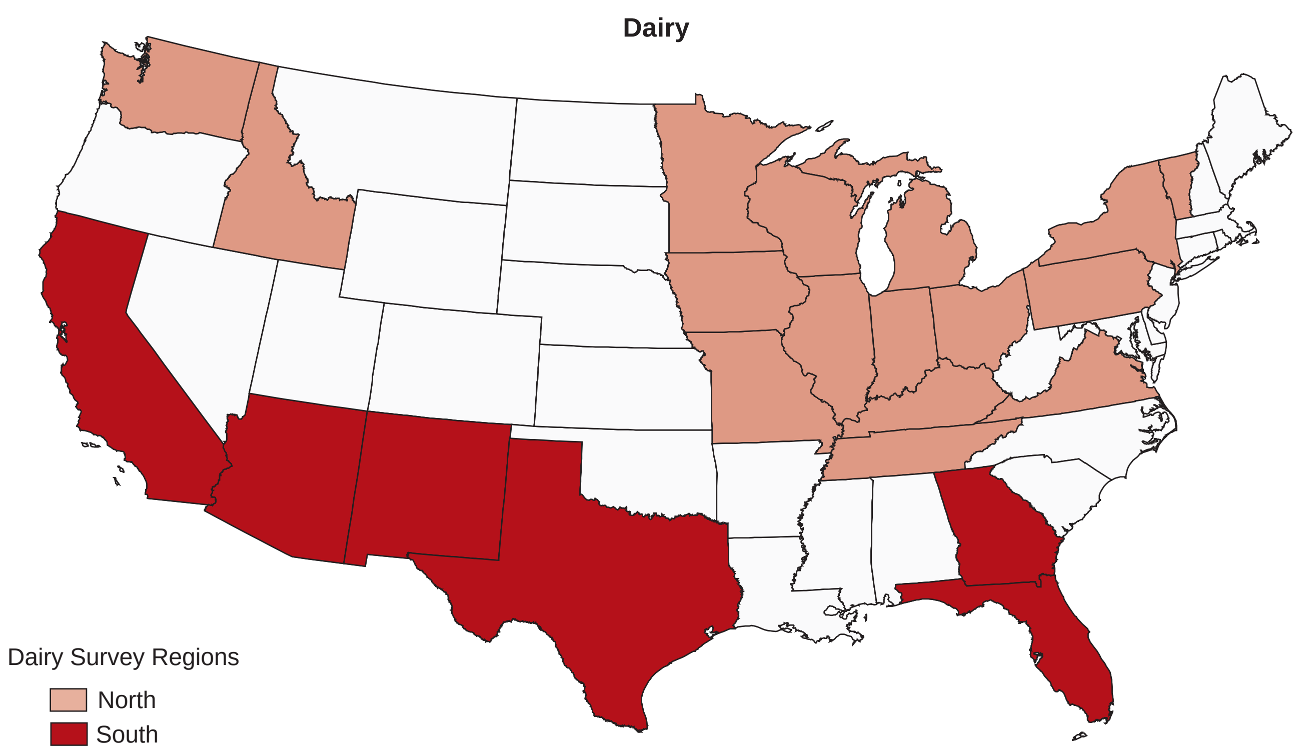
How Many Farms Are Potentially Meeting a Nutrient Standard?

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

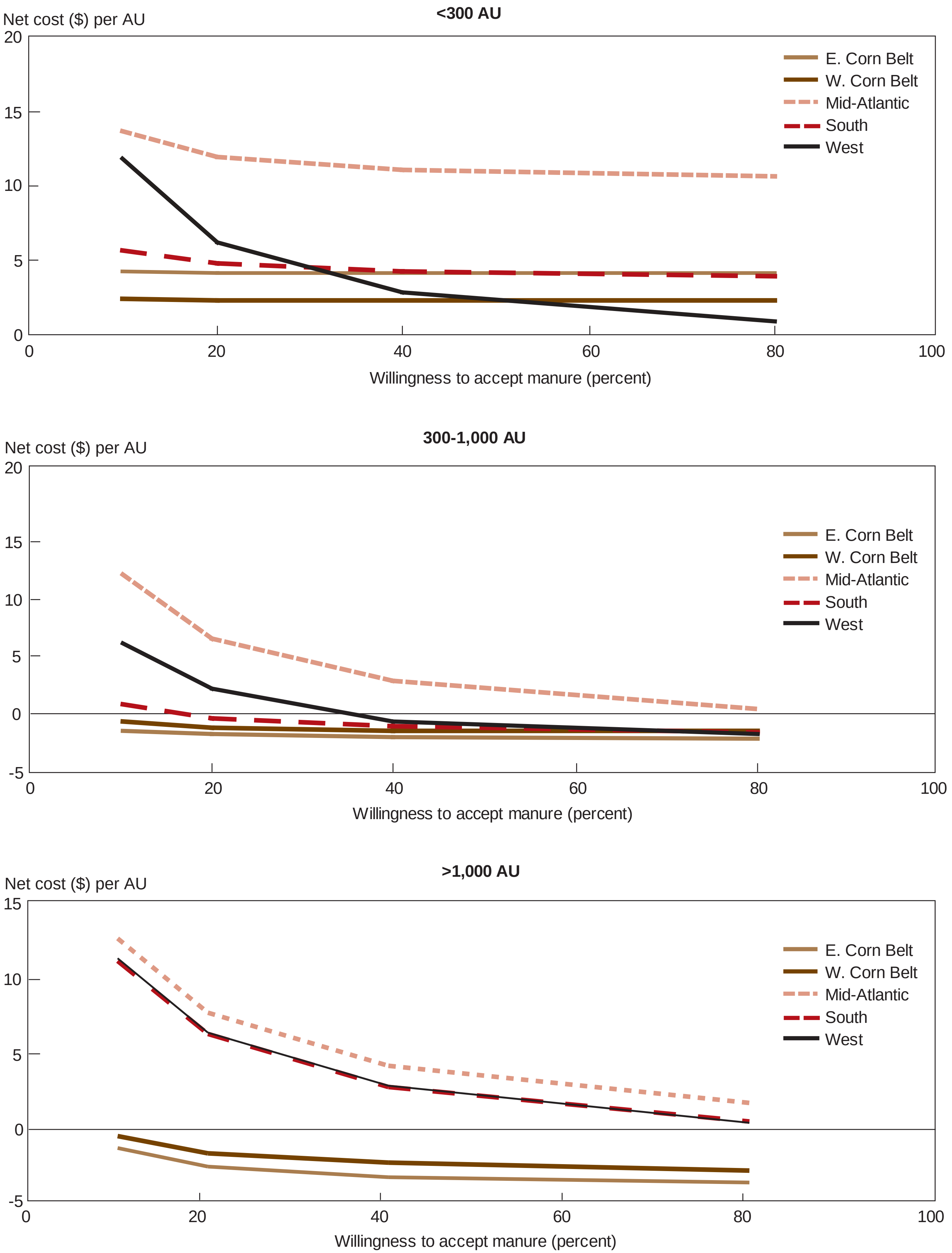


Figure 3-3

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

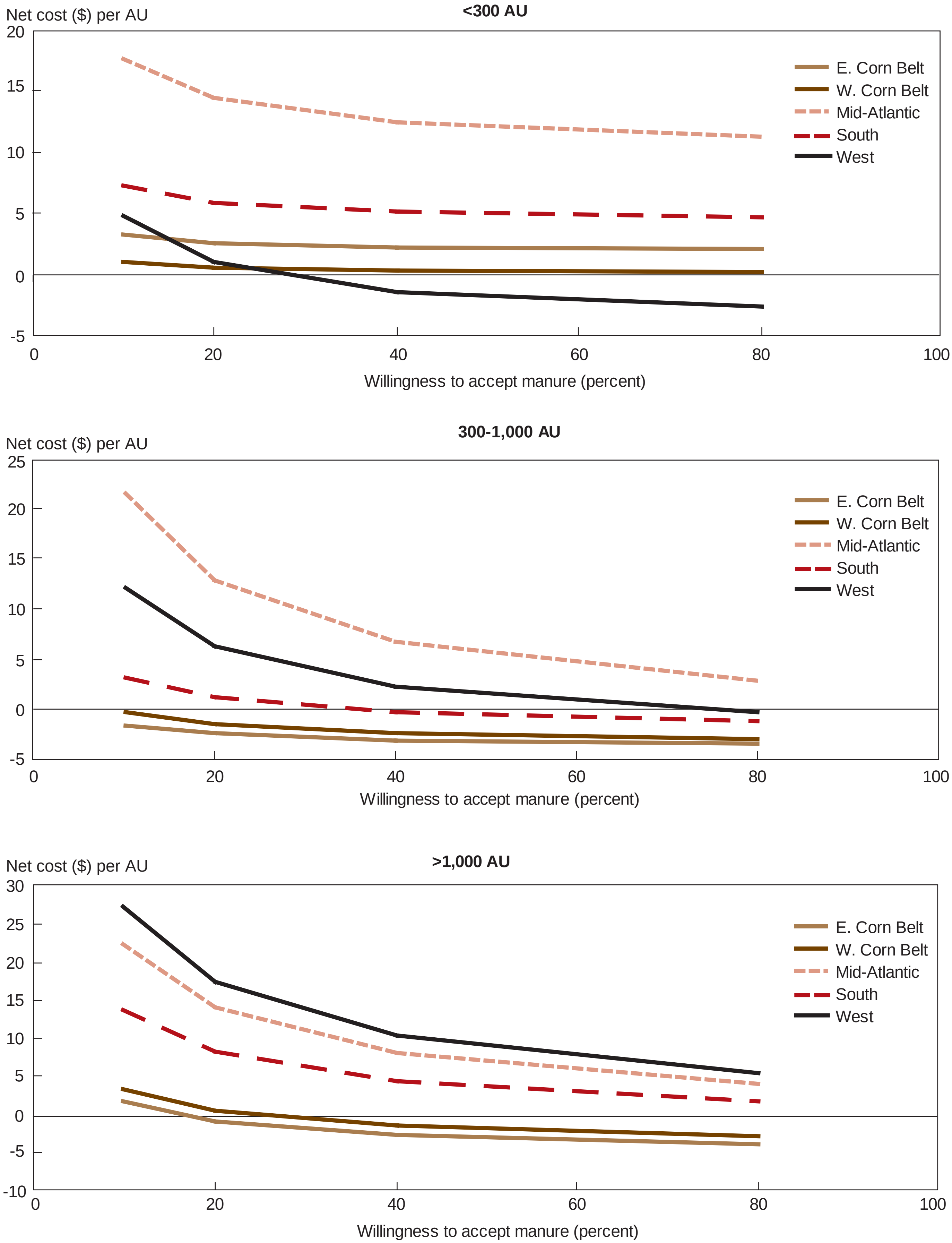
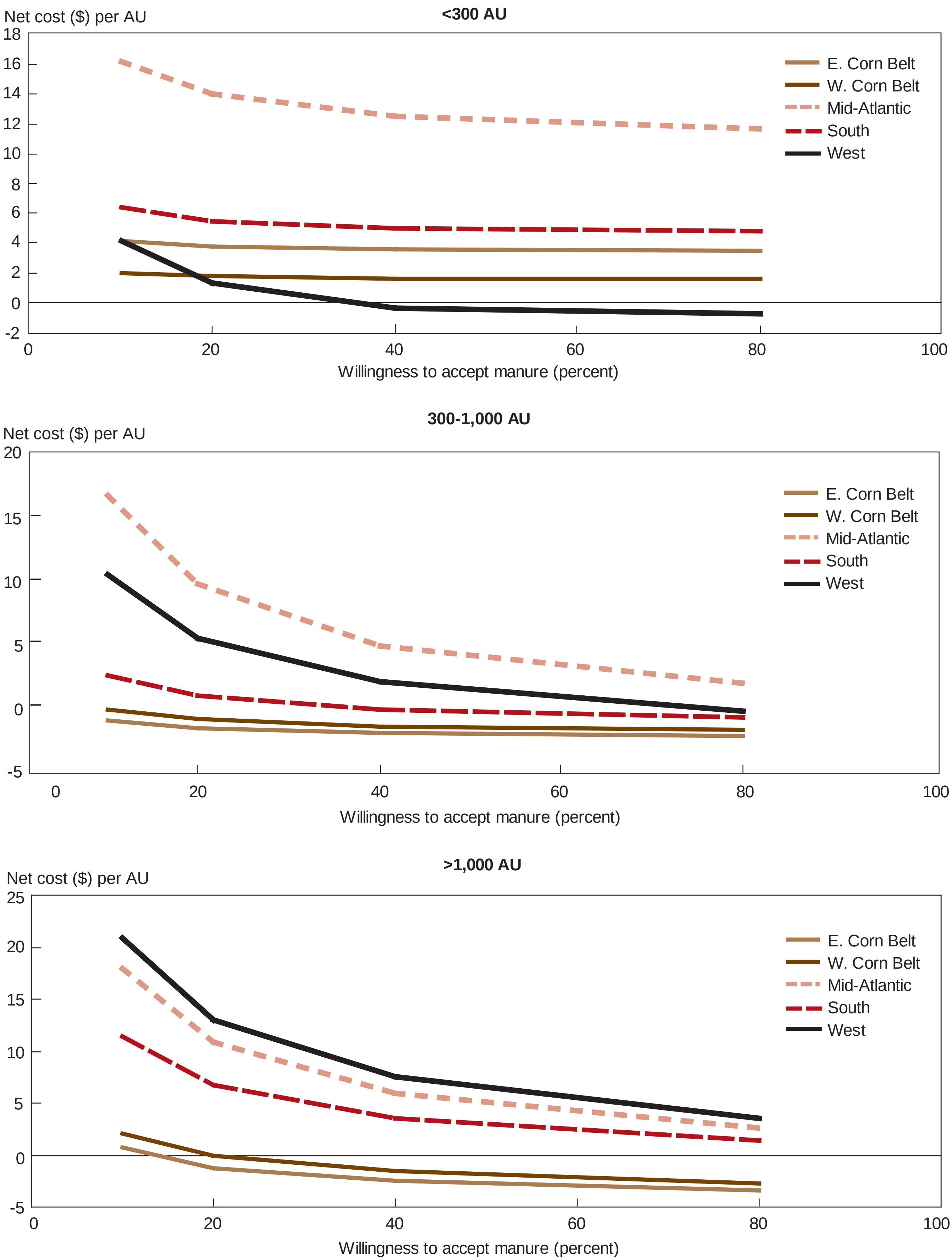


Figure 3-4

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.

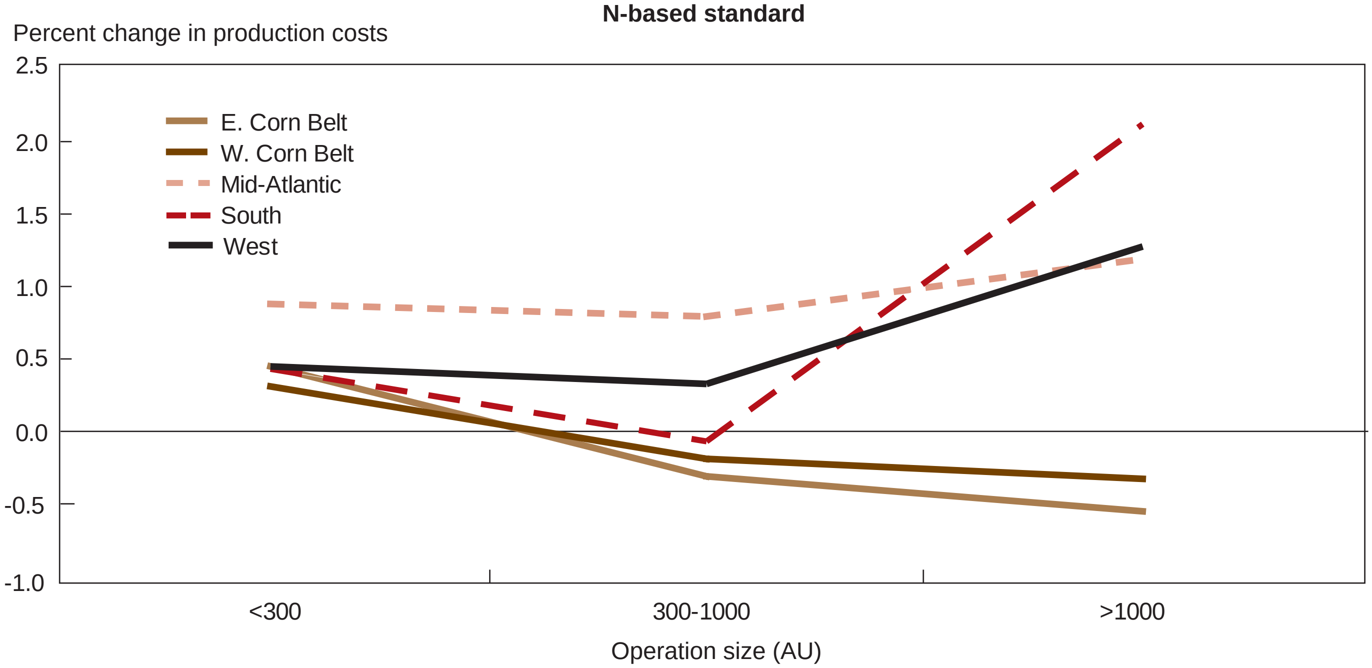
The dairy ARMS data were divided into two regions, North and South (fig. 3-1). We examined three size classes based on EPA's definition of animal unit (one AU is 0.7 mature dairy cow): small (<300), medium (300-1,000 AU), and large (>1,000). Small dairies dominate the North, while dairies in the South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

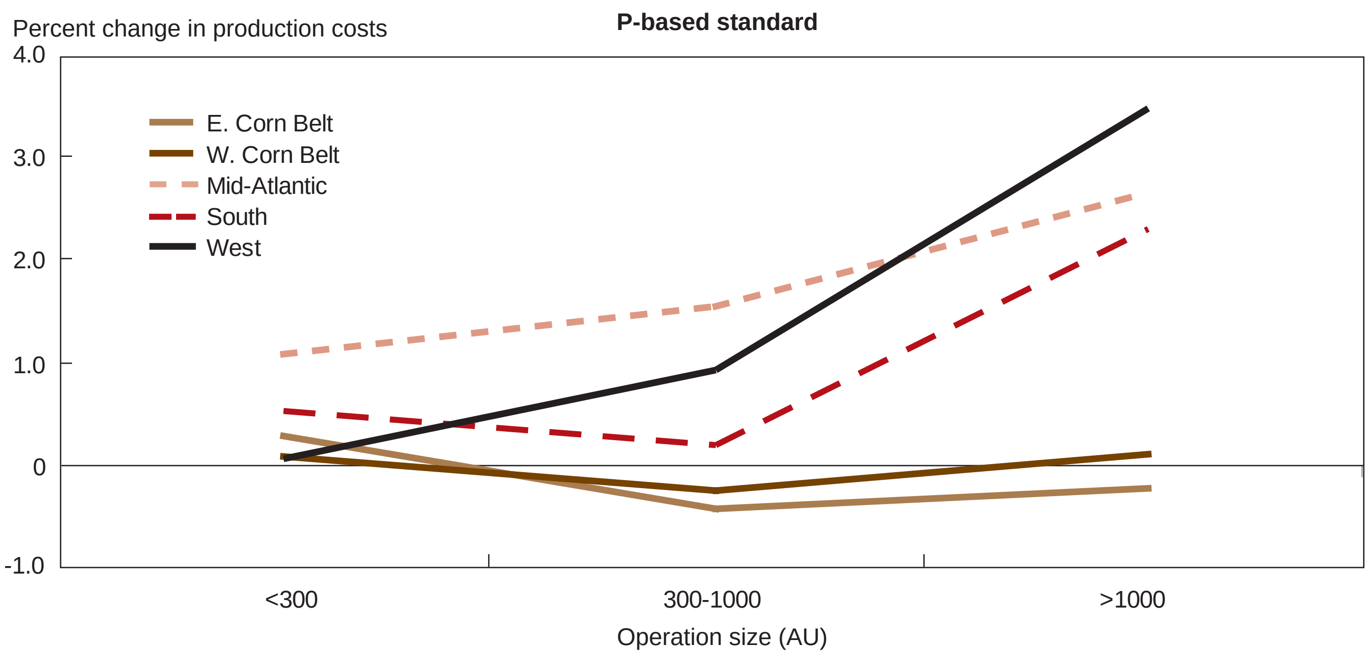
How Many Farms Are Potentially Meeting a Nutrient Standard?

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
		Acres		
South				
<300 AU	52.6	76.5	143.4	262.0
300-1,000 AU	129.4	114.8	343.8	795.3
>1,000 AU	310.4	319.6	661.3	2001.0
North				
<300 AU	100.7	207.0	63.6	147.2
300-1,000 AU	328.3	584.0	338.8	756.8
>1,000 AU	330.9	391.4	564.2	1,979.0
Nation				
<300 AU	99.5	203.8	65.6	150.1
300-1,000 AU	235.9	366.0	341.1	774.6
>1,000 AU	316.9	342.4	630.5	1,994.0

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

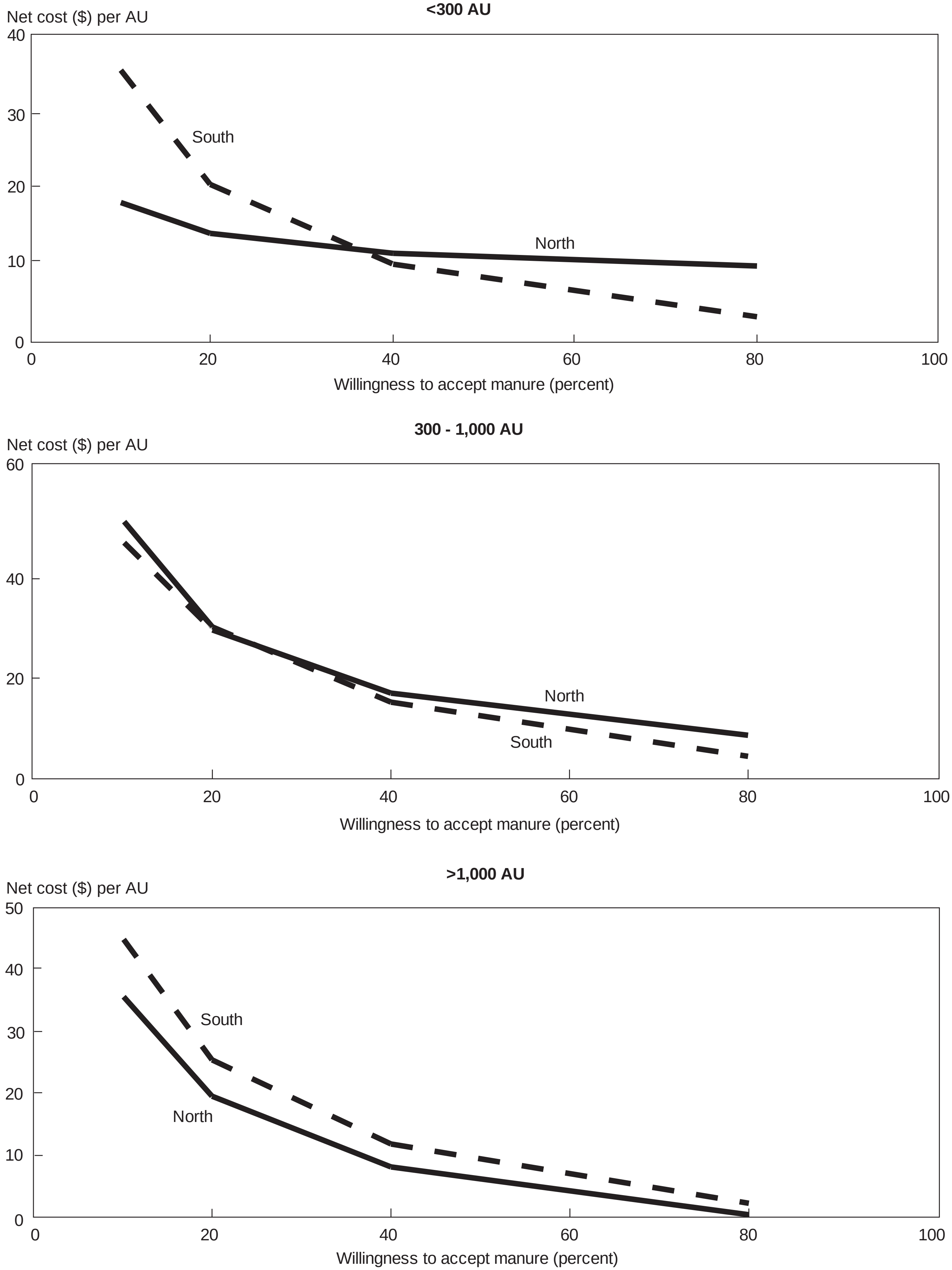
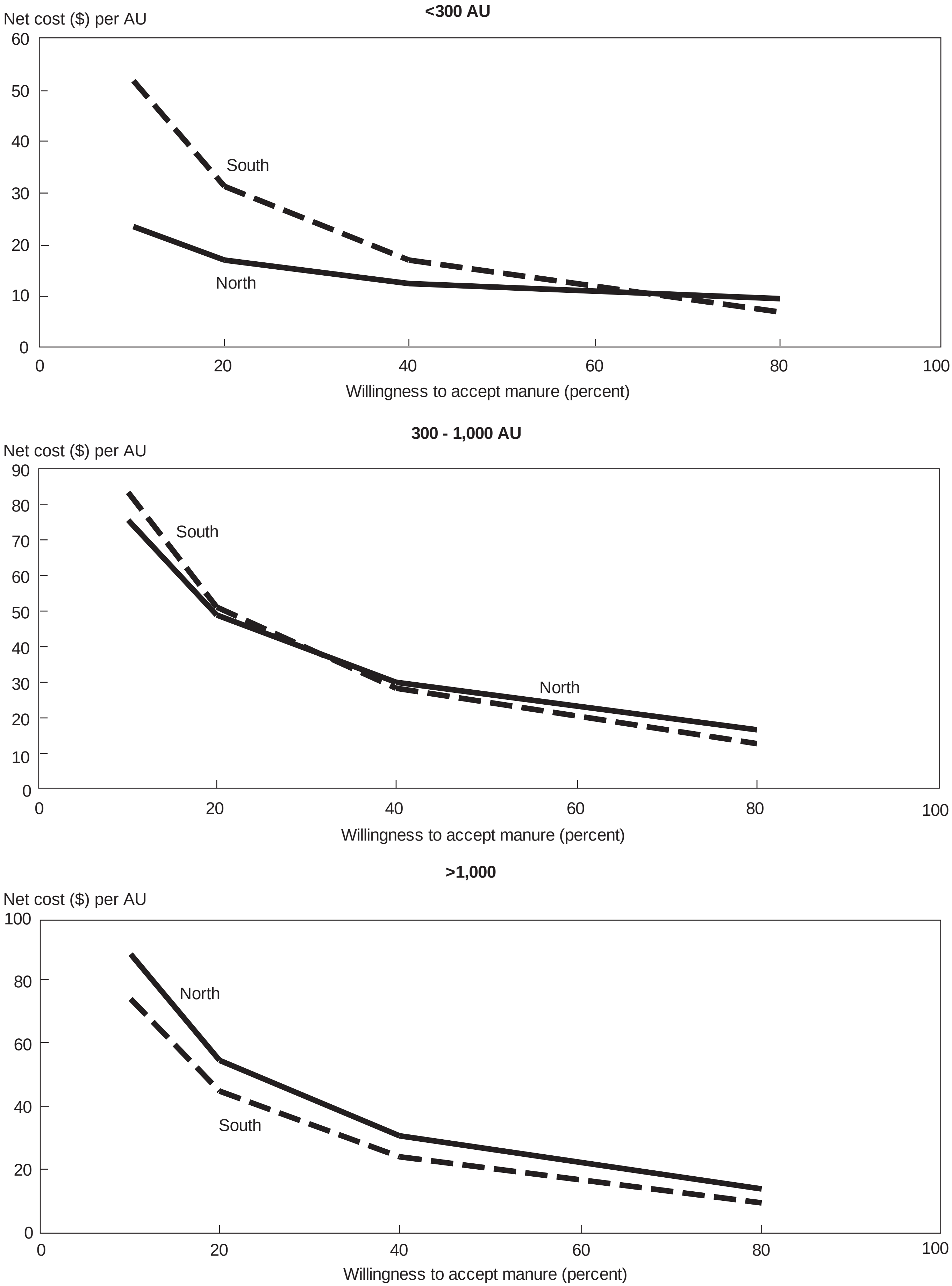


Figure 3-7

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.

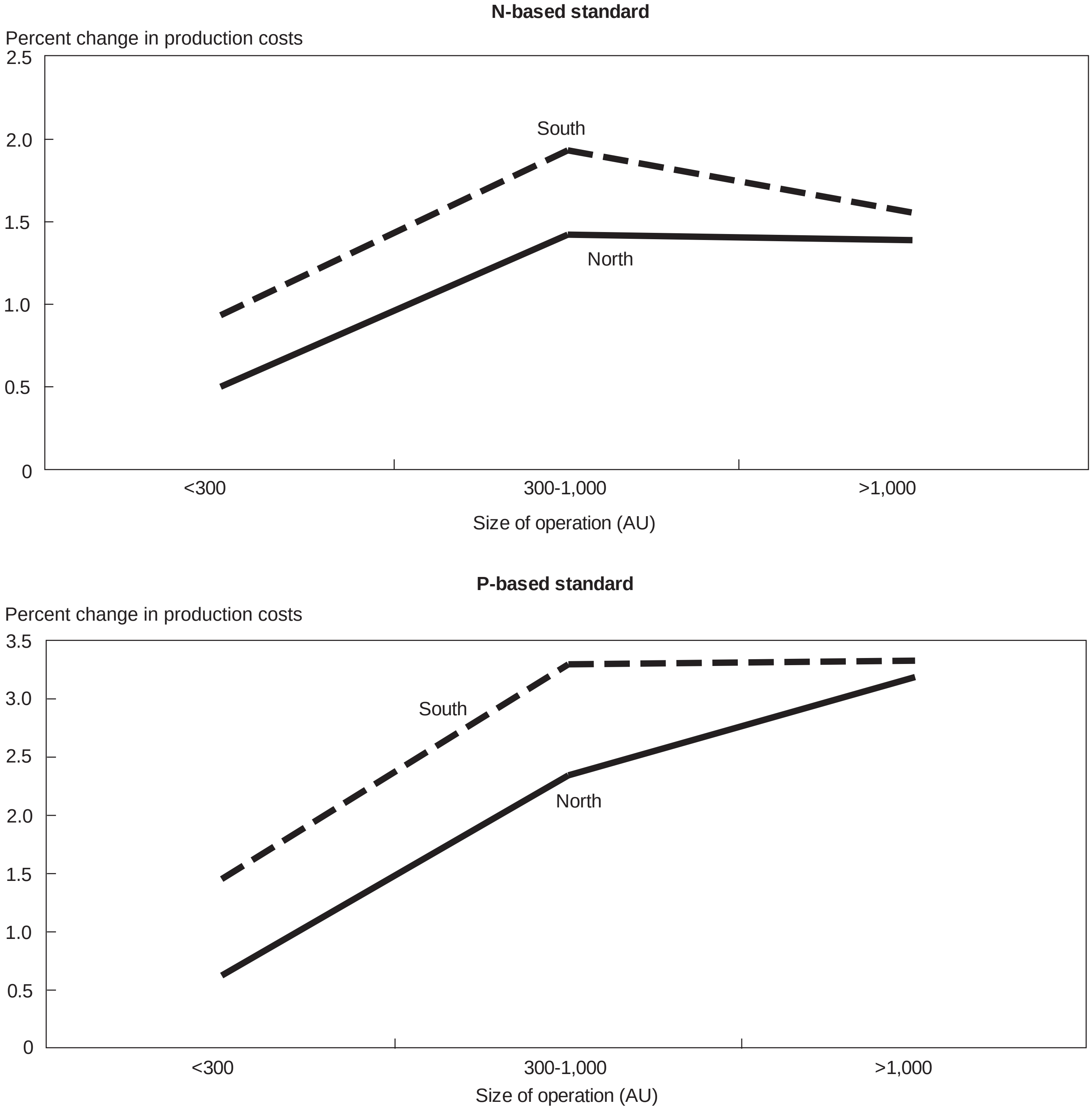
Implementing a nutrient management plan for meeting a standard (plan development and testing) and hauling/applying manure to fields both add to the cost of producing animals. These costs will vary by species, by the size of the operation, and by region. The average costs of meeting a standard (per animal 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



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:

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

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:

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

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

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

$P_{M,i}$ = 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