Chapter 5
Impact of Spatial Factors on the Costs of Manure Management:
A Case Study of the Chesapeake Bay Watershed

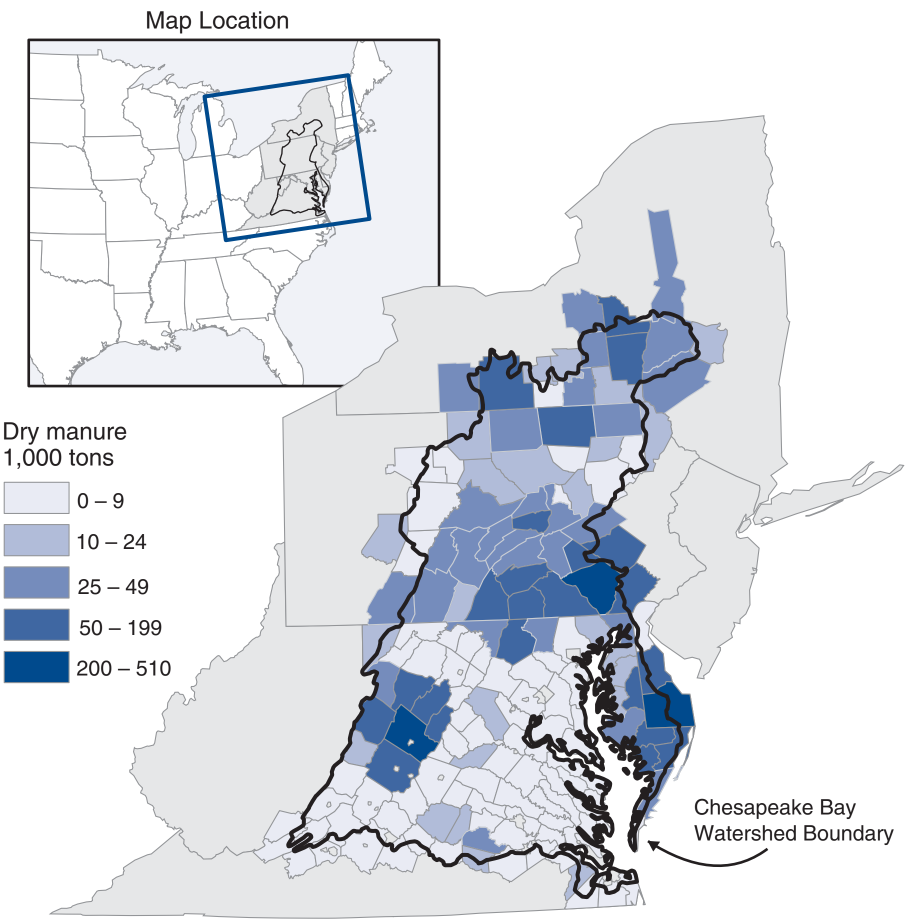
The costs associated with meeting USDA goals and U.S. EPA regulations for improved manure management depend not only on individual farm conditions and national markets, but on spatial considerations concerning the location of animal operations and cropland available for manure application. Where animal production is concentrated, producers may face competition for suitable land to apply manure, which can increase the cost of meeting application requirements by forcing manure to be hauled longer distances (Ribaudo et al., 2003). Implementing hypothetical ammonia emission controls on farms meeting nutrient standards could increase the competition for land by increasing the nutrient content of manure. Among U.S. areas where manure nutrient production exceeds the assimilative capacity of the land are several county clusters within the Chesapeake Bay watershed (Gollehon et al., 2001) (fig. 5-1). We present this case study to demonstrate how the costs of meeting Clean Water Act requirements might be affected if ammonia emission regulations are also imposed.

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 discharges to waters in the region have resulted in eutrophication and related ecological shifts that harm wildlife and aquatic resources (Preston and Brakebill, 1999). Manure from confined animal operations has been identified as a primary source of both nutrient runoff to water bodies and local air emissions (Follett and Hatfield, 2001). A joint effort by watershed States to reduce nitrogen loadings is addressing all sources of nitrogen. The potential cost is high. The plan to upgrade 66 of Maryland's major sewage treatment plants will cost between $750 million and $1 billion, and would provide only a third of the nitrogen reductions needed for Maryland to meet its commitment (Maryland Department of Natural Resources, 2004).

The Chesapeake Bay watershed (CBW), spanning over 160 counties in 6 States, includes 66,600 farms with an estimated 8.5 million acres of land potentially available to receive manure. Approximately 15,900 farms in the CBW had 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, 44,000 tons of recoverable manure phosphorus, and 100,000 tons of ammonia-N annually. Even if confined animal operations fully utilized the crop and pasture land under their control for manure application, excess nutrients would remain. Applying manure at agronomic rates to meet water quality goals would require moving significant quantities of manure off animal producing farms.

Figure 5-1

Location of manure production in Chesapeake Bay watershed, 1997



Source: Economic Research Service, USDA.

The effect of alternative behavioral assumptions on the willingness of farmers to accept manure as a substitute for commercial fertilizer was examined in Ribaudo et al. (2003) for all confined animal operations in the CBW. Results from that study indicate that if farmland application is the primary disposal method, implementing nutrient management regulation poses significant challenges where animal production is concentrated. Only about half the manure produced CBW-wide can be used onfarm given current technologies and crop mixes. The feasibility of land application as a regional manure management strategy depends on the willingness of landowners to accept manure on farmland, the nutrient assimilative capacity of the regional cropland base, and the nutrient standard in effect. Ribaudo et al. estimated that more than 30 percent of CBW crop farms would need to accept manure in order to land-apply all the manure produced in the CBW at a rate based on the nitrogen needs of crops (under reasonable hauling distance assumptions).

The CBW case study uses a regional modeling framework designed to capture spatial considerations in manure production and land availability for manure spreading (see Appendix C, web only). The model and its results reflect a regional planning perspective in evaluating key cost determinants and alternative policy strategies at the watershed scale.

We assume that farms meeting nutrient application standards will apply manure at a rate based on a **nitrogen** standard for cropland and pastureland. Farms in locations with high phosphorus concentrations in the soil and runoff vulnerability may be required to base manure applications on a phosphorus standard, which generally decreases manure applied per acre (Ribaudo et al., 2003). While the effects of manure land application on phosphorus-limiting soils is an important concern in the Chesapeake Bay region, air emission controls interact primarily with manure-nitrogen concentrations. Thus, our focus is on changes in costs to meet a nitrogen standard.[1] We assume the willingness to accept manure by crop producers is 30 percent.

[1]Increasing the nitrogen content of manure by adopting emission controls does not increase the acreage needed for land application when meeting a phosphorus standard. In fact, the increased nitrogen in the manure reduces the supplemental nitrogen usually required.

Determining the effect of emission control technologies on representative manure handling systems for the CBW required two steps. First, the quantities of total manure excreted were estimated from quantities of recoverable manure nitrogen available in the watershed (Aillery et al., 2005) and estimates of ammonia-N losses at the facility and field levels (appendix table D-1). This estimation process—from the field back to the animal—provides consistent estimates of manure nitrogen and ammonia emissions for a baseline situation. (Estimated values for selected systems commonly used in the CBW are provided in appendix table D-2.) In the second step, quantities of manure nitrogen available for plant use and changes in ammonia emissions were estimated from the animal to the field with the addition of emission control technologies by a manure-handling system. Nitrogen losses by system (see chapter 2) were converted to losses as a share of recoverable manure for direct inclusion in the model (appendix table D-3). An example of the estimation process to calculate nitrogen losses and crop availability under alternative emission control technologies is provided in appendix table D-4.

Land Application of Manure With Ammonia-N Reductions

We compare costs to the CBW animal sector of land-applying manure, and the water quality impacts, of four scenarios:

Case A—CAFOs meet nitrogen-based land application standards for water quality improvement, without consideration of ammonia-N emissions (current Clean Water Act policy);

Case B—CAFOs meet nitrogen-based land application standards for water quality improvement, with the addition of ammonia-N reducing technologies and practices;

Case C—All AFOs adopt ammonia-N emission controls for air quality improvements, while CAFOs continue to meet land application standards;

Case D—All AFOs adopt ammonia emission controls and meet land application standards.

For purposes of this analysis, methods of controlling ammonia emissions include the following:

- ***Incorporation/injection.*** Manure is incorporated or injected on 100 percent of acres receiving manure from poultry, dairy, and feedlot beef operations in the included farm set. We assume that lagoon liquid from dairies and feedlot beef operations is surface applied so that it is possible to inject the liquid with current technologies; swine lagoon waste is generally sprayed and is not typically incorporated. Under current conditions, incorporation is assumed to occur on 40 percent of CBW cropland for soil-nutrient retention and odor control, based on data from the ARMS hog and dairy surveys. This practice reduces ammonia emissions on acres currently treated. We assume the crop mix on land receiving manure does not change.
- ***Lagoon covers.*** Impervious lagoon covers are added to all dairy, swine, and feedlot beef operations using lagoon-based manure storage systems. The base model assumption is that no lagoons are covered.
- ***Alum.*** Alum is added to all poultry operations as an additive to the manure in the poultry house. The base model assumption is no alum use.

Case A—CAFO land application standards, with NO ammonia controls. The annual cost of meeting regulations for improved manure management to protect water quality is estimated to be $30 million[2] when only CAFOs meet land application standards (fig. 5-2). CAFOs account for roughly 19 percent of the total modeled manure in the CBW. The distribution of CAFO farms varies significantly across CBW counties, with the share of AUs on CAFO operations ranging from 0 (for about half the counties) to as high as 80 percent in some counties. The manure from non-CAFO farms is assumed to be applied on the source farm without the benefit of a nutrient management plan. Ammonia-N emissions from manure produced on all AFOs in the watershed total an estimated 100,000 tons, including 78,000 tons from animal production and manure storage facilities and 22,000 tons from field applications (fig. 5-3).

[2]Results here are very similar but not identical to those in Ribaudo et al., with the differences due to model and data improvements.

Case B—CAFO land application standards, with CAFO ammonia controls. The estimated cost to CAFOs for managing manure increases by $18 million relative to Case A (fig. 5-2). This reflects both the cost of implementing ammonia-controlling practices ($9 million) and the increased cost of applying manure according to a nutrient management plan ($9 million). Land application costs increase as a larger land area (more than doubled) is required to accommodate the nitrogen-enriched manure (fig. 5-4).

The addition of ammonia emission controls on CAFOs would reduce emissions by about 12,000 tons, relative to Case A, representing 12 percent of total animal emissions basinwide (fig. 5-3).

Case C—All AFO ammonia controls, with CAFO land application standards. Requiring all AFOs to control ammonia emissions would result in a CBW-wide reduction in emissions of 43 percent, 30,000 tons more than in Case B (fig. 5-3). The additional cost to implement air emission controls through expanded use of alum, lagoon covers, and incorporation on all AFOs, relative to Case A, is an estimated $41 million (fig. 5-2).

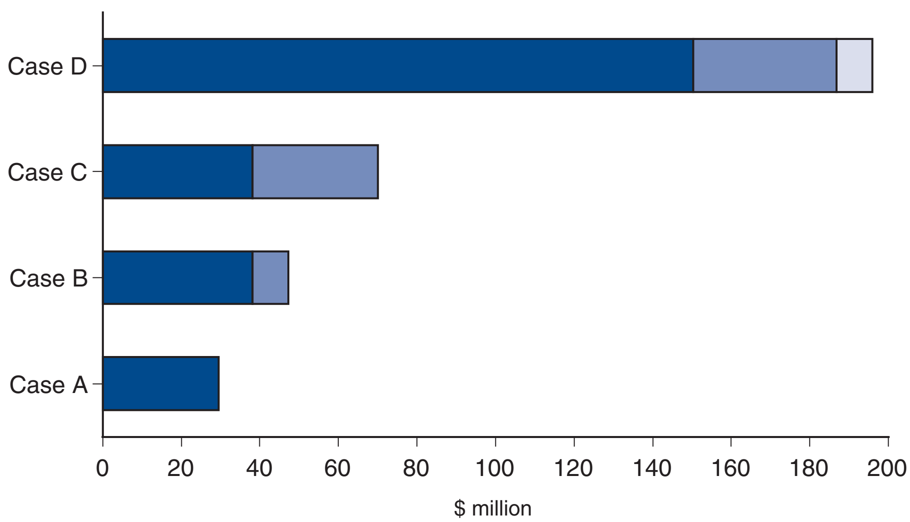
The threat of nitrogen runoff from CAFOs remains unchanged because the change in nitrogen content of manure is considered in the development of the nutrient management plans (fig. 5-3). However, the same cannot be said for non-CAFOs, which are not required to follow a nutrient management plan. Non-CAFOs are assumed to spread their manure on land near the production facility without a nutrient management plan, at an estimated cost of $80 million (not shown in fig. 5-2). If these operations do not adjust the amount of land receiving manure, the doubling of the nitrogen content of manure would increase the threat of runoff to the Bay.[3] Potential impacts on water quality would be an unintended consequence of the air quality policy if additional steps are not taken to address manure nutrient over-application.

[3]The actual effect on water quality in the Bay will depend on the rate of nutrient loading from applied (and over-applied) manure, and the rate and location of nitrogen deposition from air emissions. The science behind these issues continues to evolve.

Case D—All AFO ammonia controls, with AFO land application standards implemented simultaneously. A requirement that all AFOs follow a nutrient management plan in conjunction with meeting ammonia controls would likely limit the threat to water quality in the Bay while reducing ammonia emissions, but at an increased cost to producers. The decline in ammonia emissions is about 9,000 tons more than achieved under Case C (fig. 5-3). The lower field emissions under Case D reflect the overall reduction in field losses achieved by applying all manure at agronomic rates, in contrast to Case C where most of the manure (81 percent) is assumed to be applied at rates substantially above crop needs. The total estimated cost for

Figure 5-2

Annual costs of meeting nutrient application standards with alternative emission controls on CAFOs and AFOs, Chesapeake Bay Watershed*



- Costs to meet water-based land application standards (hauling, application, and planning)
- Costs for air emission controls (facility and field)
- Projected costs to manage manure exceeding land application levels

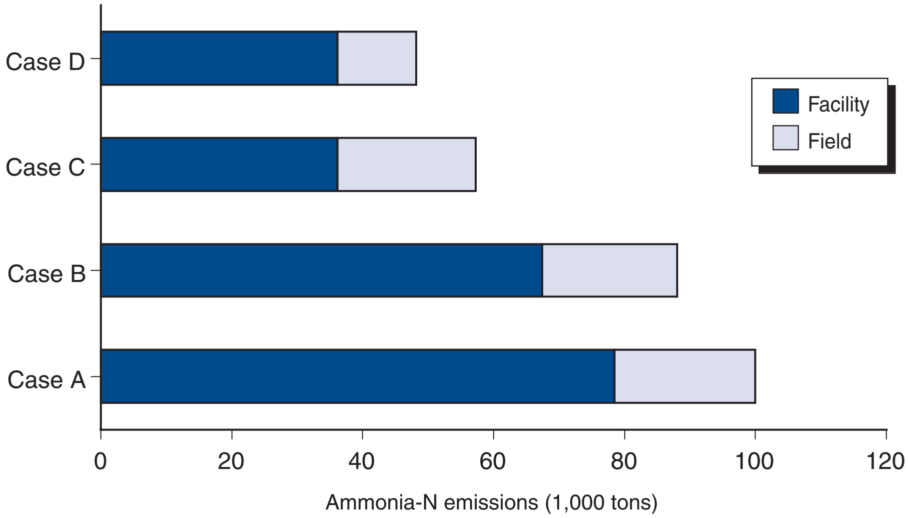
Case A – CAFOs meet water standards, no ammonia controls
Case B – CAFOs meet water standards, CAFOs adopt ammonia-N controls
Case C – All AFOs adopt ammonia-N control, CAFOs meet water standards
Case D – All AFOs adopt ammonia-N controls, all AFOs meet water standards

*Assumes a nitrogen standard for manure land application with 30 percent of farmland accepting manure.

Source: Economic Research Service, USDA.

Figure 5-3

Ammonia-N emissions with alternative emission controls for CAFOs and AFOs, Chesapeake Bay Watershed*



Case A – CAFOs meet water standards, no ammonia controls
Case B – CAFOs meet water standards, CAFOs adopt ammonia-N controls
Case C – All AFOs adopt ammonia-N control, CAFOs meet water standards
Case D – All AFOs adopt ammonia-N controls, all AFOs meet water standards

*Assumes a nitrogen standard for manure land application with 30 percent of farmland accepting manure.

Source: Economic Research Service, USDA.

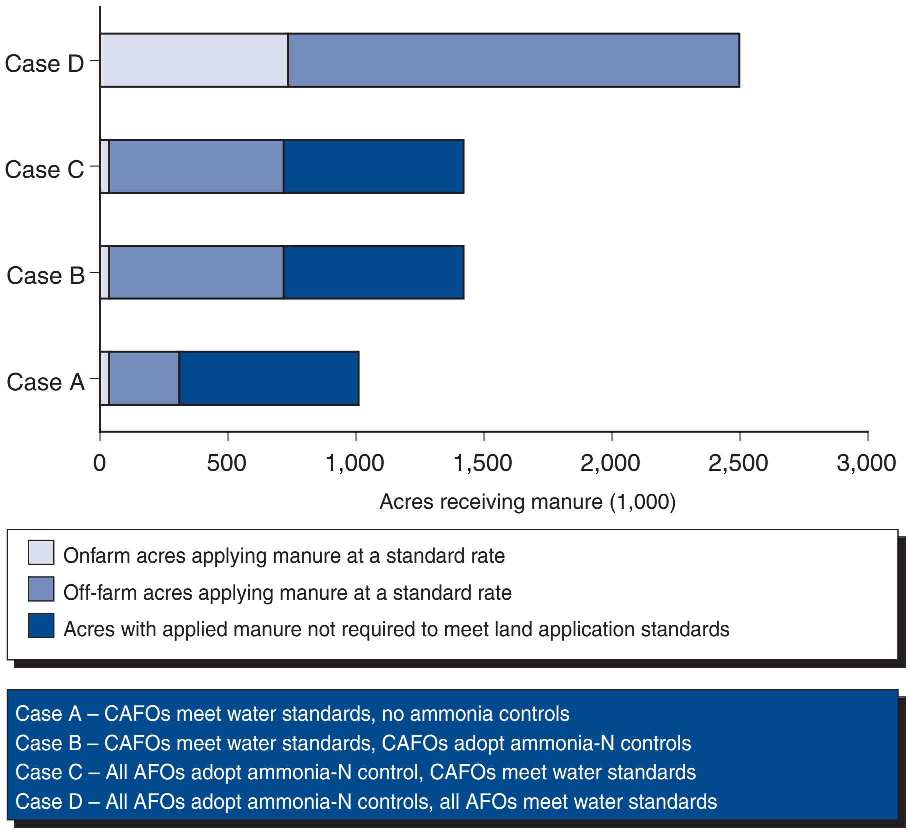
managing manure to meet ammonia control and land application requirements exceeds $186 million (fig. 5-2). Most of this reflects the implementation of nutrient management plans on all AFOs and a 75-percent increase in the number of acres receiving manure in an environment of intense competition for land (fig. 5-4). Land application costs on non-CAFO operations increase by an estimated $32 million.

An additional cost is for dealing with excess nitrogen for which no land is available within the CBW. Based on model simulations, the CBW has insufficient land to receive all manure when all AFOs are both controlling ammonia emissions and following a nutrient management plan, given an assumed farmer willingness to accept manure of 30 percent.

Various disposal strategies exist for handling this basinwide surplus, like increasing the willingness of crop farmers to accept manure (assumed to be 30 percent in this case study), increasing manure diverted to industrial processes, adjusting the diet of animals to reduce manure nutrients, reducing the number of animals, or transporting manure beyond the 100-mile limit assumed in the model. The latter option may be the least expensive. States have recognized the need to move manure extended distances to comply with nutrient regulations, and some offer a transportation subsidy. Delaware, for example, provides transportation assistance of $18 per ton (Rohrer, 2004). For illustrative purposes, if we assume that all the surplus manure in the model could be transported to land outside the CBW for application

Figure 5-4

Acres receiving manure from CAFOs and AFOs with alternative air emission controls, Chesapeake Bay Watershed*



*Assumes a nitrogen standard for manure land application with 30 percent of farmland accepting manure.

Source: Economic Research Service, USDA.

and/or other disposal at $18 per ton, disposal of all AFO manure produced in the CBW would exceed $9 million annually (fig. 5-2).

Reducing the region's animal units to a level where all manure could be land applied is a costly alternative. This approach would require as much as a 7-percent reduction in the number of animals in the CBW. With an average regional return per animal unit of $1,339[4], the annual costs of reducing the number of animals, plus land application of the manure produced, would total about $150 million at a willingness to accept of 30 percent.

Conclusions

Our analysis brings to light a key challenge in achieving air and water quality goals: strides to meet one goal may impede the other, as nitrogen is either applied to farmland via manure or emitted to the atmosphere. Animal producers in the Chesapeake Bay watershed required to meet regulations and guidelines for water quality protection face significant costs for managing manure. New air emission controls, if implemented, would increase costs to the animal sector. The higher nitrogen content of applied manure would pose a challenge to those producers with limited land,

[4]The value of production by animal unit is determined by using USDA baseline projections for 2010 (USDA. 2003). These projections are in turn processed through the USMP model (see Appendix B, web only) to convert animal production into animal units and to account for production cycles. For our purposes, we use gross value minus variable costs per AU to represent the opportunity cost of decreasing production.

requiring longer hauling distances to access adequate land. For other farmers needing nutrients, the nutrient-rich manure can be a resource.

Widely adopted ammonia emission controls could encourage overapplication of manure-nitrogen on non-CAFOs, to the detriment of water quality. Extending land application standards to non-CAFOs would substantially reduce nitrogen available for runoff, but substantially increase the total cost of air and water pollution abatement. The actual effect on water quality in the Bay will depend on nutrient loadings from applied (and overapplied) manure, and the deposition from airborne nitrogen.

Under current Federal regulations for land application of manure, the cost of air emission control reflects both the cost of control practices as well as the increased costs of meeting land application standards due to the higher nitrogen content of manure. Assessments that address practice implementation costs alone may substantially underestimate the full impact of air emissions control on the animal sector.

Cost impacts would be greatest where animal production is concentrated and manure quantities approach or exceed the assimilative capacity of the existing land base, increasing competition for land needed for manure spreading. Under these conditions, reliance on land application alone as a regional manure management solution may not be feasible. Other measures—such as increasing landowner willingness to accept manure, developing industrial applications for manure, subsidizing the long-range transport of manure out of the watershed, or even reducing animal stocks—may play a role in dealing with a regional surplus of manure nutrients.