Estimating the Economic Potential for Off-Farm Manure Processing

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Abstract:
A Chesapeake Bay Watershed manure management model estimates the minimal regional cost of land applying manure at $110 to $130 million, depending on crop producers' willingness to accept manure and the nutrient standard enforced. Annualized capital costs of existing industrial plants indicate that off-farm options should be considered.

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Public attention has focused increasingly on the concentration of livestock waste and resulting potential impacts on water quality, aquatic resources, and public health. In 1999, the Environmental Protection Agency and U.S. Department of Agriculture issued joint guidelines for managing of livestock waste from confined animal feeding operations (U.S. EPA/USDA Joint Unified Strategy, 1999). The joint guidelines called for a review of current EPA regulations and voluntary USDA programs.

An EPA-proposed revision of the National Pollutant Discharge Elimination System (NPDES) Permit Regulation and Effluent Limitations Guidelines (ELGs) and Standards for Concentrated Animal Feeding Operations was published in the *Federal Register* on January 12, 2001. These proposed rules will determine whether an Animal Feeding Operation (AFO) will need a point-source discharge permit and specific requirements of the permit (U.S. EPA, 2001).

USDA has a stated goal that all AFOs develop and implement technically sound, economically feasible and site-specific Comprehensive Nutrient Management Plans (CNMPs). Achievement of this goal will minimize potential water pollutants from confined animal facilitates and land application of manure (USDA, 2000).

Both of these proposed policy approaches focus on the disposal of manure from confined animals on nearby crop and pastureland at agronomic rates. A proper application rate is the single most important manure management practice affecting the potential contamination of water resources by manure nutrients (Mulla et al., 1999).

The concentration of animal production and land available for manure application varies significantly across the nation. Kellogg, et al. (2000) and Gollehon, et al. (2001) identified counties where confined animals produce more manure nutrients than the county can assimilate when applied at agronomic rates. Among the regions of the Nation where manure nutrient production exceeds the assimilative capacity of the land were several county clusters in the Chesapeake Bay Watershed (Figure 1).

In areas of the Chesapeake Bay Watershed where confined animal production is concentrated, implementation of EPA and USDA policies on AFO manure poses tremendous challenges. If the manure produced exceeds local use potential, the only options are to: (1) transport the manure ever greater distances until enough land can be found for application; or (2) utilize a processing technology to transform the manure to a product amenable to profitable long distance transport or a product that entirely eliminates the need to transport.

In this paper we present a regional model of manure management for the Chesapeake Bay Watershed (CBW). The model is designed to capture the critical dimension of competition for land among animal producers under a nitrogen-based and the more restrictive phosphorus-based nutrient standard. While policies will encourage the transporting of manure from confined animal operations to nearby "manure deficit" farms, excess manure nutrients in areas with concentrated animal production can overwhelm the local land base. We apply the model to assess the total cost of meeting land application policy goals in the CBW. Using the minimal regional costs for land application as a point of reference, we examine model cost estimates to provide a preliminary assessment of off-farm industrial processes for manure utilization located in areas of manure nutrient "over supply".

Related Studies

Several studies have examined the onfarm cost of additional manure handling under changing policies for animal waste. Fleming, Babcock, and Wang (1998) developed a model for estimating the farm-level costs of land applying manure at agronomic rates, assuming no changes in manure handling technology. This model was used by Ribaudo, et al. (2002) to assess the impact of proposed EPA provisions on costs of land-applying hog manure in the U.S. Several researchers have used an optimization framework to assess the farm-level costs of meeting alternative environmental goals (Huang and Magleby, 2001; Huang and Somwaru, 2001; Yap, et al., 2001; Benson, et al., 2001). These models all predict how a representative farm's returns or costs would change under a nitrogen- and/or phosphorus-based restriction on manure applications. While these efforts generally incorporate restrictions on land availability, farm-level models do not endogenously consider the effects of competition from nearby farms also seeking land on which to spread manure.

At the other end of the spectrum from onfarm modeling, Kaplan, Johansson, and Peters (2002) apply a 10-region national agricultural sector model to examine the current EPA proposal on production levels and returns to animal operations. This approach used a spatial model of the U.S. agricultural sector linked to the USDA baseline that predicts future equilibrium prices and production levels given three levels of manure acceptance by non-livestock operations. The modeling effort focuses on aggregate commodity production and price impacts. The modeling framework does not have the ability to assess local impacts of individual farms competing for land on which to spread manure.

Some analysis has been done at the regional level, with desirable scale attributes to consider the impact of animal concentration on the cost of spreading manure. Wimberley and Goodwin (2000) examined the cost of exporting surplus poultry litter from the Eucha/Spavinaw watershed (ESW) in Arkansas and Oklahoma using an accounting framework. They considered the fact that litter must pass through other litter production areas, placing ESW at a competitive disadvantage relative to those other areas regarding litter export. They evaluated alternative ways of marketing litter, including coordinating litter supplies and off-farm management at the regional level, increasing prices paid for raw litter in target markets though buyer education efforts, and assessing value-added options such as composting and energy generation.

Modeling Manure Management in the Chesapeake Bay Watershed

We develop a regional modeling framework for evaluating the costs of livestock-waste management policies in the Chesapeake Bay watershed. Our model employs a cost-minimization structure designed to minimize total regional costs of manure transportation and disposal for 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 replicate area-specific conditions of a farm-level model. The region specification captures the critical element of competition for land in areas with significant animal concentration by endogenizing access to spreadable land and associated hauling costs. Explicit modeling of competition for land on which to spread manure is a central feature of the regional model that is not currently captured in existing models.

Model data

Two primary data sources form the basis of the model data set: the 1997 Census of Agriculture and the National Land Cover Dataset from USGS. Farm-level Census data were used to generate county-level measures of livestock operations and animal-units, total manure production, excess 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 livestock operations.

Agricultural Census. Our analysis uses the farm balance of manure nutrient production relative to the farm's potential to utilize nutrients for crop production, based on farm-level data collected for the 1997 Census of Agriculture. Results from the farm-level calculations are then summed across animal types and aggregated at the county level.[1] From farm-level data, we used crop acres and crop production levels to determine potential manure nutrient use for crops specific to confined-animal producers (procedures in Kellogg, et al. (2000)).

Computation of manure nutrients, potential manure nutrient use by farms with animals, and potential assimilative capacity of farms without confined animals were computed following procedures in Gollehon, et al. (2001) and Kellogg, et al. (2000). Briefly, manure nutrients were estimated from Census reported end-of-year inventory and annual sales data and coefficients of manure production by animal type. Potentials for manure nutrient use were estimated based on reported yields and acres of 24 major field crops and permanent pasture.

National Land Cover Dataset. To assess availability and the spatial pattern of spreadable land for manure application, the analysis uses the National Land Cover Dataset developed by the U.S. Geological Survey. This dataset is based on 1992 Landsat thematic mapper imagery at 30m resolution, classified into 21 landuse categories. By combining the crop and pasture categories, we were able to assemble a maximum spreadable land base for all counties in the study region.

GIS Data. To estimate hauling distance requirements for spreading manure, a Geographic Information System (GIS) is used to create "area-to-distance" functions for each county and farm in the study region. These functions are a central component of the optimization model, linking the area needed for manure spreading with the distance farmers would be required to travel to dispose of excess manure.

Area-to-distance functions are specified separately for within-county and out-of-county transfers. Calculating the distance from all farms within a given county to spreadable land in that county generates within-county distance functions. With limited amounts of excess manure, spreadable land is relatively accessible and hauling distances are generally short. As manure spreading requirements increase, farms must compete increasingly for the same acreage—reducing accessibility and increasing the distance needed to access available acreage.[2] As Figure 2 suggests, the relationship between the spreadable acreage requirement and average distance hauled is upward sloping and fairly linear along much of the observed range. The slope of the function varies somewhat across counties, based on factors discussed below.

The out-of-county distance functions were generated somewhat differently than within-county functions. Out-of-county functions represent hauling distances for livestock operations in a source county to spreadable acreage in adjacent counties. Each inter-county function is unique; reflecting estimated distance from the source-county livestock farm and the spatial pattern of spreadable land in the destination county, as encountered from the direction of the source county. A two-stage process was used to generate the average distance functions. First, the distance from each farm in a source county to the edge of spreadable acreage in a destination county was calculated; this distance represents the intercept term for the area-to-distance functions. Second, the relationship between spreadable acreage to average hauling distance, or slope of the distance

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1 Our analysis meets all respondent confidentiality requirements of the published Census of Agriculture values.
2 The actual area of available spreadable acreage used for manure application in a given county is determined by the optimization model, reflecting manure flows within and across counties that minimize disposal costs, subject to physical land limits and specified "willingness-to-accept" manure.

function, was generated for the destination county by calculating hauling distance required for a given area of spreadable acreage, measured from the direction of the source county. Thus, out-of-county hauling functions are a combination of source-to-destination county intercept and slope of the area-to-distance relationship for destination counties.

The within-county and out-of-county distance functions are affected by three primary factors: 1) the spatial pattern of spreadable land; 2) the number of farms competing for spreadable land; and 3) the location of farms relative to spreadable land. The pattern of spreadable land is important when generating the area-to-distance functions in that it affects land accessibility. Where spreadable land is scattered throughout a county, average farmer access to spreadable land will be low relative to a county where cropland and pastureland are clustered.

The number of confined livestock farms in a county—obtained from the Agricultural Census—is also an important determinant in the calculation of area-to-distance functions. As the number of farms with excess manure in a county increases, average travel distance within-county decreases up to the point where competition occurs. As competition increases with the number of farms, average hauling distance increases and out-of-county exports become necessary.

While the number of confined livestock operations is available from the Agricultural Census, we do not know the specific locations of farms. Using the GIS, livestock operations were assigned randomly across the crop and pastureland portions of each county. Although livestock operations may be removed from arable land since animal production is not as sensitive to soil conditions, the majority of animal feeding operations tend to be located in proximity to crop and pasture land. The random farm location assumption probably yields conservative estimates of distance to spreadable land and related hauling costs, due to observed clustering of animal operations and resultant competition for land resources.

To integrate the GIS data into a format useable for the optimization model, regression coefficients for the area-to-distance functions were generated for intra-county and inter-county transfers. A single set of coefficients was produced for each intra-county function, by county. For inter-county functions, separate coefficients were generated for each source farm and destination county combination within a 60-km radius. The radius for the 16 counties with the largest quantities of excess manure was expanded to 150-km (93-miles). To reduce the number of manure source and destination combinations, livestock farms were aggregated (binned) by 12-km grid across the watershed area. Although the binning procedure reduces the precision of the intercepts for inter-county functions, this was necessary for tractability of the optimization problem. In addition, functions estimated from the GIS were linearized for modeling purposes by truncating the upper and lower tails of the distribution (10 percent of acreage) and fitting a linear function to the mid-range observations (80 percent). The use of linear representations reflects the high computer memory requirements for non-linear distance functions, and the fact that observed functions were very nearly linear over the relevant mid-range.

Regional model structure

The focus of the baseline model development was to: 1) construct a mechanism that tracks manure and related nutrient flows within the basin, from manure source to site application/disposal, and 2) provide a framework for evaluating alternative policy mechanisms, including addition or expansion of industrial manure uses.

The county is the most effective modeling unit for the regional model. The county-level specification provides consistency with Census data and other county-level data, while permitting differentiation of institutions and regulatory conditions across county and State political boundaries within the watershed.

A county may be both a 'source' county and a 'destination' county. Manure is produced in a source county and applied (or disposed of) in a destination county. 'Model' counties include all non-municipality counties within the watershed with farmland. The full watershed model includes 160 model counties, representing potential 'source' and 'destination' counties. 'Sink' counties refer to 'destination' counties outside the modeled area that serve as a potential sink for manure from 'model' counties, subject to net assimilative capacity after accounting for in-county manure applications. There are 104 sink counties included in the full watershed model, comprising non-municipality counties within 60 kilometers (37 miles) of a 'model' county (measured from the edge of the source model-county cropland base). Model values for 'edge' counties, or those that straddle the watershed boundary, are apportioned based on the share of crop and pastureland within the watershed to account for manure flows at the basin level.

The optimization model is designed to minimize the land application cost of excess manure disposal, subject to land availability for manure applications and other disposal options. The model allocates manure flows across the watershed to minimize the objective function expression:

Minimize cost =

$$(1) \quad \sum_{ct} \sum_{ct2} \left[HC_{ct,ct2} + ST_{ct} + AP_{ct2} + NM_{ct2} - FC_{ct2} \right]$$

Disposal costs for excess manure encompass a range of costs incurred across source (ct) and destination (ct2) counties. These include manure hauling cost (HC), penalty cost for manure levels exceeding the regional ability for land application, ie. "storage cost" (ST), land application cost (AP), and nutrient management plan charges[3] (NM). Aggregate costs may be adjusted to reflect cost savings due to chemical fertilizer reductions (FC). The objective function is readily customized to reflect various combinations of cost components.

'Manure transfers' represent the primary activities in the model. Transfers refer to movement of manure (and nutrients) from source to destination counties, and include both within-county transfers and out-of-county exports. Potential transfer county combinations were developed based on a maximum average hauling distance of either 60 kms (37 miles) or 150 kms (93 miles), measured from edge of source cropland base.[4] There are 4,060 county-level transfer possibilities in the full watershed model, including within-county and out-of-county transfer combinations; transfers are further disaggregated by substate grid, manure storage system, and distance interval resulting in over 300,000 transfer alternatives.

The primary decision variables in the model represent 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 livestock farms (manure sources), and manure-nutrient use; and 3) various cost accounting equations.

Assimilative capacity, or the capacity of the land to utilize land-applied manure-nutrients, is a major determinant of manure flows in the model. Factors affecting assimilative capacity include the extent of spreadable acres and nutrient uptake rate of receiving fields. The nutrient content of the manure and the nutrient standard applied—either N-standard or P-standard—combine with assimilative capacity to determine manure application levels. In general, manure

3 These costs account for nutrient management planning, soil testing, manure testing, record keeping, facility inspections, equipment calibration, record keeping, training and certification.

quantities are the basis of model costs, while manure nutrients determine the volume and direction of manure flows.

Primary manure transfer equations are as follows:

$$(2) \quad M\_TRAN_{ct,ct2} = M\_APPL_{ct,ct2} * AC\_SPR_{ct,ct2}$$

$$(3) \quad \sum_{ct} AC\_SPR_{ct,ct2} \leq AC_{ct2}$$

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

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

where *gr* is county grid location, *sy* is manure system (lagoon, slurry, dry), and *ds* is distance interval in kilometers (<.5, .5-2, 2-10, >10).

In Equation (2), manure by county transfer (M_TRAN) is defined as the product of manure application rate (M_APPL) and receiving acres (AC_SPR) in the destination county. Manure application rate was estimated for each individual county transfer based on 1) average nutrient content of manure from the source county; 2) average uptake rates for N and P in the destination county, weighted across cropland and pasture for each of three farm types; and 3) the nutrient standard in effect. Data specification by county and farm type--non-livestock farms, non-confined livestock farms, and confined livestock farms--was important in order to capture potential variation in uptake rate due to differences in cropping/pasture mix and yield.

Equation (3) restricts applied manure from all potential source counties to total spreadable acreage (AC) in the destination county. Assumptions on the willingness of landowners to accept manure (willingness to accept or WTA) is captured through automated

4/ The actual distance for individual hauls may exceed the weighted-average distance threshold for a given out-of-county transfer. The maximum average hauling threshold of 150 kms could be relaxed, but at a cost of model dimensionality.

adjustments in both the quantity of spreadable acreage and the slope of area-to-distance functions. Total spreadable acreage was parameterized from 10 to 100 percent of the acreage in non-livestock and non-confined livestock farms. All acreage in confined livestock farms was assumed available for manure spreading under all scenarios.

Equation (4) sets county-level transfers (M_TRAN) equal to the sum of manure transfers by system type *sy* and distance interval *ds*. Equation (5) bounds manure transfers by the share (SHR) of total county-level manure production (M_PRD) across system type *sy* and `source-county grids *gr*, based on allocation procedures used in the GIS system.

A series of equations used to balance manure production, use, excess, and the quantity of manure "stored" at the county level are defined in equations (6) – (8).

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

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

$$\text{(8)} \quad M\_STOR_{ct} = M\_EXCESS_{ct} - \sum_{sy} M\_IND_{ct,sy} - \sum_{ct2} M\_TRAN_{ct,ct2}$$

Equation (6) sets excess manure (M_EXCESS) as manure production (M_PROD) less that used onfarm (M_ONFRM) in the manure-producing county. Equation (7) sets manure use (M_USE) as the onfarm manure use plus that quantity imported (M_TRAN) in the manure-using county. Equation (8) sets the manure that cannot be land applied in a manure-producing county (M_STOR) due to insufficient assimilative capacity within the transport radius equal to the excess less the sum of industrial uses by system (M_IND) and the sum of manure transfers out of county. Quantities of stored manure were minimized in the model through the use of a penalty cost.

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

$$\text{(9)} \quad DS_{ct,gr,ct2} = [\alpha_{ct,gr,ct2} + (\beta_{ct,ct2} * AC\_SPR_{ct,ct2})] * ADJ_{ct,ct2}$$

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

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

In Equation (9), average hauling distance (DS) from source county *ct* and grid *gr* is calculated as a function of spreadable acres in the destination county *ct2*, based on α and β coefficients from the GIS-derived econometric functions. A circuity parameter (ADJ) is used to convert linear distance to road miles. In Equation (10), average hauling distance represents a weighted-average of hauling distances by manure-waste 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 or phosphorus—are tied to manure quantities as follows:

$$(12) \quad NP\_PRD_{ct,ct2,np} = M\_PRD_{ct,ct2} * NP\_M_{ct,np}$$

$$(13) \quad NP\_TRN_{ct,ct2,np} = M\_TRN_{ct,ct2} * NP\_M_{ct,np}$$

$$(14) \quad NP\_EXC_{ct,ct2,np} \leq M\_EXC_{ct,ct2} * NP\_M_{ct,np}$$

Manure nutrients are computed for total manure produced (Equation 12) and total manure transferred (Equation 13), based on county-average nutrient content per dry ton of manure (NP_M) from the Census data. Total excess nutrients N and P were obtained from farm-level Census data on manure production and onfarm assimilative capacity aggregated to the county level. Excess manure (manure subject to off-farm disposal) is calculated in Equation (14) based on excess N or excess P, depending on the nutrient standard in effect.

Manure hauling cost, the primary cost component in the model, is computed for onfarm, intra- and inter-county transfers based on base rate (including application costs) per ton hauled (C1), hauling cost per ton-mile (C2), actual distance hauled (DST), quantity of manure hauled in dry tons (M_TRN), manure moisture content (MS) and a bedding adjustment (BED).

$$(15)\quad HC_{ct,ct2} = \sum_{gr} \sum_{sy} \sum_{ds} [\, C1_{sy,ds} + (C2_{sy,ds} * \; DST_{ct,gr,ct2,sy,ds})\,]$$

$$*\;(\, M\_TRN_{ct,gr,ct2,sy,ds} \;/\; (\, 1 - (MS_{sy} + BED)\,]$$

Hauling costs vary substantially across animal waste systems—lagoon, slurry, and dry—reflecting differences in manure moisture content and equipment complement by system. The model simulates a stepwise cost function for manure hauling cost, with cost coefficients defined by waste-system type and distance interval hauled.

Model Results

The model was applied to the Chesapeake Bay Watershed for a range of 'willingness to accept' (WTA) manure levels under both a nitrogen and phosphorus-based nutrient standard. Landowner willingness to accept manure has an important bearing on the availability of spreadable area and resulting manure hauling distances required. Because of the uncertainty associated with selecting a single WTA, results are presented for the widest set possible. Incentives to increase manure acceptance may be an important consideration in implementing the proposed federal guidelines. Similarly, the share of spreadable land required to meet the more stringent phosphorus-based nutrient standard is not known. Proposed policies require a P-based standard (P-standard) on fields with high soil phosphorus levels, and an N-based standard (N-standard) elsewhere. Under a P-standard, manure application rates are reduced (relative to an N-standard) such that manure phosphorus is not applied in excess of crop uptake requirements. The P-standard implies greater spreadable acreage requirements and hauling distances for a given quantity of manure. Since data are not available on the share of acres requiring a P-standard, we present model results for the extreme-cases that *none* or *all* acres will require a P-standard in order to bracket the actual cost.

Model estimates for total land application cost, projected total costs, and the quantity of manure that exceeded the regional ability to land-apply manure are presented in Figures 3 and 4. The results indicate that there was insufficient land to apply manure within the assumed transportation radius (60 km for low manure-density areas and 150 km for high manure-density areas) when landowners' WTA manure drops below 60 percent of acreage for a P-standard and 30 percent for an N-standard. The quantity of manure that cannot be land applied (hereafter, "stored" manure) is shown in the bar-chart portion of figures 3 and 4.

The total land application cost is estimated at $108 million under an N-standard with 100 percent of crop and pastureland available for spreading (WTA = 100). The costs climb as the WTA declines, reaching $116 million at a WTA of 30 percent shown by the rising line-graph portion of figure 3. As the WTA drops to 20 and 10 percent, a significant quantity (more than 5 percent) of manure exceeds the land application potential within the transportation radius and was forced into storage. Thus, land application costs decline as reduced quantities of manure are land applied while quantities of stored manure mount.

At WTA levels of 20 and 10 percent projected total manure management costs are land application costs ***plus*** the costs of hauling or disposing of the stored manure. A cost for long-distance hauling (beyond the model's transportation radius) was estimated by simply trending the per ton transport cost across the WTA levels. The projected total costs for the 20 percent WTA was the land application costs plus the calculated long-distance hauling cost, based on the per ton hauling cost. Options other than long-distance hauling for reducing the quantity of (or disposal of) the stored manure, include increasing industrial processing, increasing crop nutrient uptake, and reducing the quantity of manure nutrients produced. The current model specification, however, focuses on an option of primary policy focus—land application. Total manure management costs will depend on option(s) selected to address the stored manure quantity that exceeds the land application potential in the model. We include a projected cost to convey that the total cost of manure management will rise, even while land application costs fall. The last section of this paper presents a preliminary assessment of the current industrial options for processing of manure.

The costs of land application under a P-standard follow a pattern similar to the N-standard. However, the costs under the P-standard were greater, increased faster, and reached their maximum much sooner due to the lower per-acre application rates and resulting increased hauling distances to spread a given quantity of manure (figure 4). At a WTA of 100 percent, land application costs totaled $118 million. Costs increased to $131 million at a WTA of 60 percent when the stored manure quantity reached 4 percent of total manure production. At WTA levels below 60 percent the quantities of stored manure rise, and the cost of land application falls, until at the 10 percent WTA more than half of the manure is stored and projected total costs rise to over $180 million. Clearly at this WTA level, most of the total costs of manure management will depend on the disposal method of the stored manure and not the costs of land application.

As the distribution of acres requiring application at a P-standard is not known, the model indicates that at least 30 to 60 percent of spreadable area will be required if all manure is land applied at a cost of between $115 and $130 million dollars. Actual costs for land application depend on the shares of land under each standard.

Model results indicate that onfarm hauling and distribution of manure represent the largest component of land application costs, accounting for 45 to 48 percent of total costs of land application under an N-standard (figure 5). This value is fairly constant across WTA levels, since nearly all land on confined farms are used for manure application regardless of the WTA. Non-hauling costs associated with manure management were also fairly constant, accounting for about 20 percent of the total regional costs across all WTA levels. (Note that these costs do not include the capital improvement costs that may be necessary to improve onfarm manure storage and handling systems, which may be desirable or even necessary to meet policy goals.)

Off-farm hauling cost—intra-county and inter-county—follow expected patterns as the WTA declines, with intra-county costs declining and inter-county costs increasing, both in absolute terms and as a share of total costs. Intra-county costs decline from 17 percent of total ($19 million) at 100 WTA to only 6 percent ($7 million) at a WTA of 30 percent. This decline is consistent with the decline in manure used as a result of intra-county transfers from 28 percent to 10 percent as the WTA declines from 100 to 30 percent. Inter-county costs increase from 15 to 33 percent of total costs as WTA declines from 100 to 30, or from $16 to $38 million. Decreasing the WTA from 100 percent effectively exhausts available spreadable land in a county sooner, causing a reduction in the quantity of manure spread off-the-farm but nearby, increasing the quantity of manure moved out-of-county, and increasing the hauling distance traveled.

The distribution of total costs for the P-standard follow a similar pattern to the costs reported for the N-standard in figure 5. Onfarm hauling and non-hauling costs are stable and together account for about $67 million or just over half or the costs. Intra-county hauling follows the same pattern as the N-standard, but the costs are lower in both absolute and relative terms. Since the application rate for P is lower than for N, fewer tons of manure can be applied on a given land base with resulting lower costs for intra-county hauling. On the other hand, inter-county hauling costs are larger both in absolute and relative terms, because a lower per acre application rate means more acres must be covered and spreadable acres are further from the manure-producing farm.

Figure 6 focuses on the intra- and inter-county hauling costs for the alternative standards and WTA levels, because these costs vary significantly by standard and WTA level. At the theoretically convenient (but impossible to achieve level) of 100 WTA for the N-standard, off-farm hauling was $35 million and P-standard was $55 million. The N-standard, off-farm hauling increased in total reaching $46 million at a 30 percent WTA. At the same time the share of hauling dollars used for inter-county transport increased from 45 percent to 84 percent of the total off-farm transport cost. For the P-standard, off-farm hauling costs increased to $72 million at the 60 percent WTA while the share costs associated with inter-county transport increased from 76 percent to 90 percent. Initial cost levels are consistent with the need for more acres to receive manure under a P-standard and fewer of those acres being near the farm. Changes in cost levels are consistent with the need to haul more manure greater distances as WTA declines.

Alternatives to Land Application

Numerous alternative manure management technologies currently exist or are under development. However, their applicability varies with species-type, regions of the country, and stage of development. One certainty is that none of these technologies offer a universal solution. Several require significant investment and marketing efforts, although they may become more attractive as restrictions on land spreading are implemented.

Alternative technologies can be generally classified as “supply prevention” or “output utilizing”. Supply prevention strategies seek to reduce the amount of nutrients excreted per unit of livestock output, resulting in fewer pounds returning to the environment. Output utilization practices, convert manure into a more valuable product, for use either on or off the farm. The output utilization practices, where manure is used as a feedstock for industrial uses will likely be important in managing animal waste in the CBW. Off-farm manure processing is especially attractive for a manure product that is relatively low in moisture content and easy to transport, such as broiler or turkey litter. Manure from cattle and hogs may also be processed for industrial uses, but at a higher cost due to the initial higher moisture content. Off-farm industrial uses for broiler litter includes power generation, as a base for organic fertilizer, or for conversion into a stabilized form that is more amenable to broader usage and for transport from nutrient surplus areas, such as pelletization.

Two major poultry producing areas are included in the Chesapeake Bay area: the northern portion of Virginia's Shenandoah Valley and the Delmarva Peninsula (Delaware, Eastern Shore of Maryland, and Eastern Shore of Virginia). It is estimated that there are more than 6,000 poultry houses in the Delmarva area, housing chickens that produce approximately 600,000 to 800,000 wet tons of manure annually.

Several industrial processes that use poultry litter produced in the Chesapeake Bay area have recently begun operation or are under consideration. These include manure processed into a pelletized organic fertilizer, into a blended fertilizer product, and as an input for power generation. It appears that about 200,000 tons of litter will be used by industrial systems by 2002-2003 in the CBW. Expansion of these processes, plus addition of one or more power generating projects, could significantly increase the use of liter in industrial applications. However, many technical and economic questions would need to be addressed before these possibilities became a reality. This is particularly true for the proposal of a highly capital-intensive, large-scale power plant designed to burn poultry litter as its primary fuel source.

Construction on several project alternatives to land spreading of poultry litter have been completed in the Bay area in the past year and are in the operational phase. An industrial plant is now operating in Delaware with a capacity to process 94,000 tons of broiler litter per year into pellets for transport to the Midwest and New England states as an organic fertilizer. Capital cost estimates for this plant approach $14 million. Another plant is beginning operation in the Shenandoah Valley that uses about 60,000 tons per year of poultry litter as both an energy source for plant operation and as input in the manufacturing of a blended organic-inorganic fertilizer for the turf and landscape market. Capital cost estimates for this plant near $10 million.

When there is a concentration of confined animals, with a shortage of available cropland for the spreading of manure and high hauling costs, industrial use alternatives become more feasible. For this analysis, we compared the costs of manure hauling for land application with the annual capital costs of processing the litter into an organic or blended fertilizer product. We focus on only the comparison of annual costs, not net revenues.

Preliminary analysis indicates that investment in plants to convert litter into fertilizer offers an economical alternative to certain situations where litter is hauled from surplus to deficit areas. Based on a capital cost of $10-14 million, and assuming a 20 year life and a 10 percent interest rate, the amortized capital cost converts to a cost of $1.20 to $2.10 per ton of raw litter used, depending upon the type of operation, cost and percent of operating capacity utilized.

Using the model, we estimate both intra- and inter-county hauling costs (without any industrial use) across the spectrum of willingness to accept levels. We assume the cost of acquisition and hauling manure to an industrial plant is approximated by the average intra-county hauling, and the difference between average inter- and intra-county costs is an estimate of the transportation costs that could be saved by hauling to a local industrial plant rather than a distant field. We estimate the cost savings in the $9 to $23 dollars per ton range, based on a P-standard and the reported WTA range. Additional model runs will identify the changes in transportation costs associated with use of litter in fertilizer manufacturing rather than being spread on land. These values do not consider potential operating losses (or gains) from an industrial plant. These comparisons should not be interpreted as definitive, but rather as starting points for discussion of industrial options and the determination of when it is in the best interest of the regional agricultural economy to encourage industrial uses with industry or tax dollars.

Summary

Management of livestock waste is an important issue in the Chesapeake Bay watershed (CBW) given the concentration of livestock production in areas of the basin and the major State and Federal commitment to the protection of Bay's resources. Proposed policies on the handling of animal waste are likely to have a significant impact on the livestock sector. This is particularly true in the CBW, where counties with concentrations of excess manure nutrients rank among the highest in the nation.

The regional modeling framework, combining farm-level Census data with GIS spatial data coverages, provides a framework for evaluating potential livestock sector impacts from regulations governing animal-waste disposal. Our model design captures the critical dimension of competition for land to apply manure among animal producers under both nitrogen- and phosphorus-based nutrient standards. The resulting total cost estimates for hauling and land application provides a baseline reference for analysis of alternatives to land application such as pelletizing, fertilizer production, and power generation.

The willingness of property owners to accept manure on eligible acres is an important consideration. In fact, our results indicate this could be the most important consideration in determining whether land application is feasible in the CBW. We find that at willingness to accept (WTA) levels less that 60 percent there is an insufficient land base to land apply all the manure under a P-standard, given a transport limitation of 150 km. Similarly, all manure cannot be land applied under an N-standard, but this threshold is reached at a lower 30 percent WTA.

The model's minimal costs for land application were estimated at $110 to $130 million over the set of solutions where application of all manure was feasible. Projected total manure land application costs rise to over $180 million when long-distance hauling is used to transport the manure beyond 150 km. Almost half of the estimated costs were for onfarm hauling and distribution of manure. The expected relationship was observed in the off-farm hauling costs between intra- and inter-county exports. As the WTA manure declined, intra-county costs fell as inter-county costs increased. These costs were estimated in the $35 to $70 million range depending on the nutrient standard in effect and landowner willingness to accept manure—critical policy variables.

Preliminary analysis comparing the annual cost of inter-county manure transport with annualized capital costs of industrial facilities finds that industrial alternatives for processing litter were economical viable. A P-standard scenario for land application identified a cost saving of $9-23 per ton when comparing the costs of bringing materials to an industrial plant instead of hauling to a distant site. These preliminary values provide a starting point for in-depth investigation of industrial options, their potential for the regional agricultural economy, and the consideration of government encouragement or financing.

Figure 1. The Chesapeake Bay Watershed

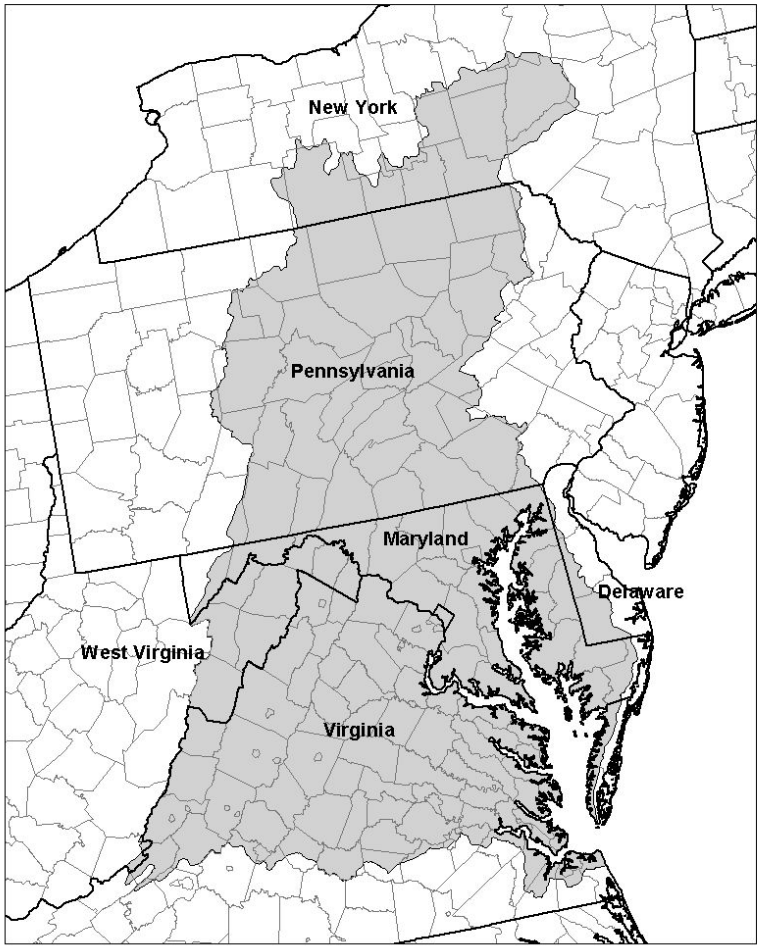

Figure 2. Representative area-to-distance function

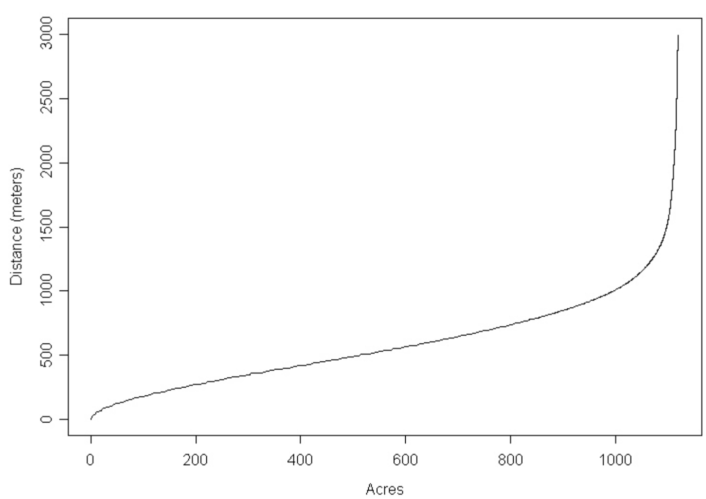

Figure 3. Effect of Willingness to Accept Manure on Manure Stored, Land Application Costs, and Projected Total Manure Disposal Costs in the Chesapeake Bay Watershed

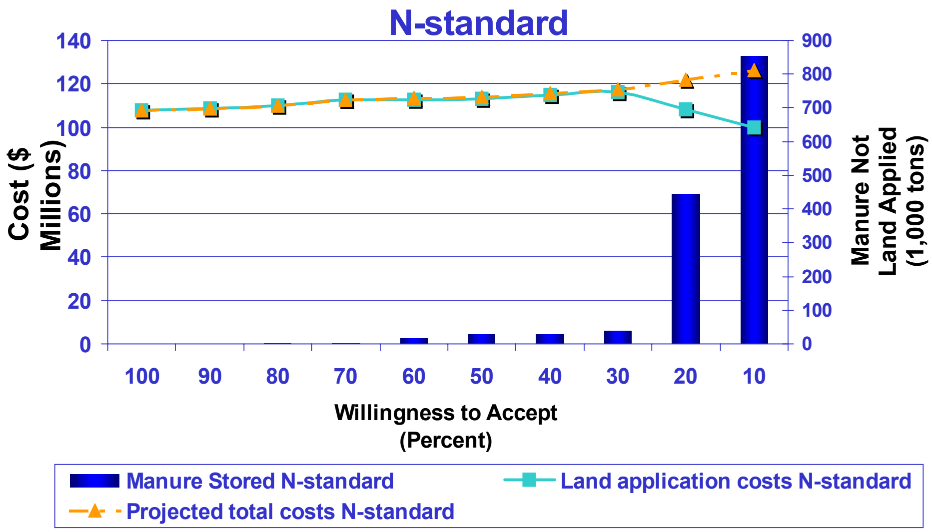

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Figure 4. Effect of Willingness to Accept Manure on Manure Stored, Land Application Costs, and Projected Total Manure Disposal Costs in the Chesapeake Bay Watershed

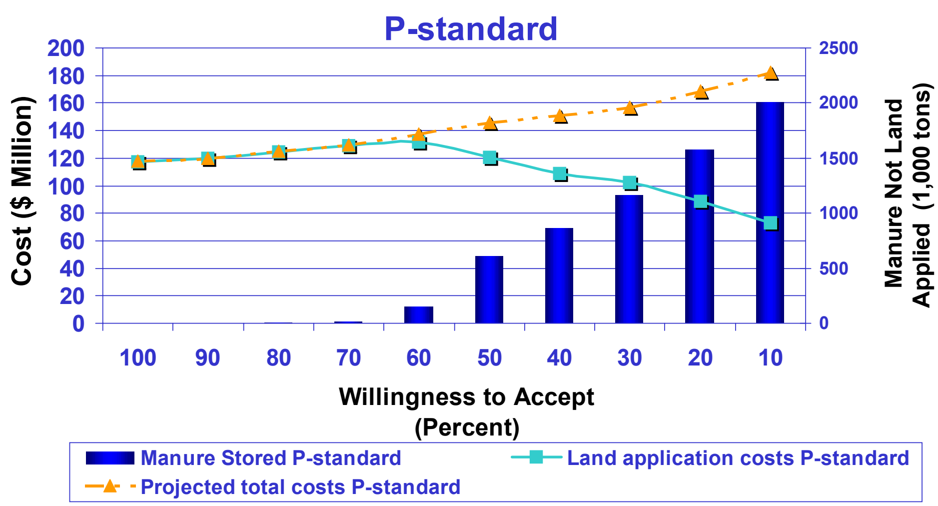

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Figure 5. Effect of the willingness to accept manure on the land application cost distribution in the Chesapeake Bay Watershed, based on a nitrogen standard

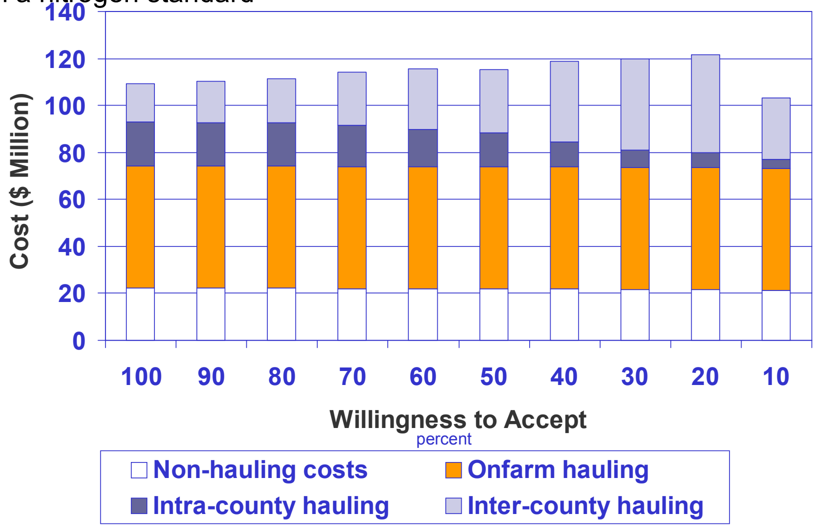
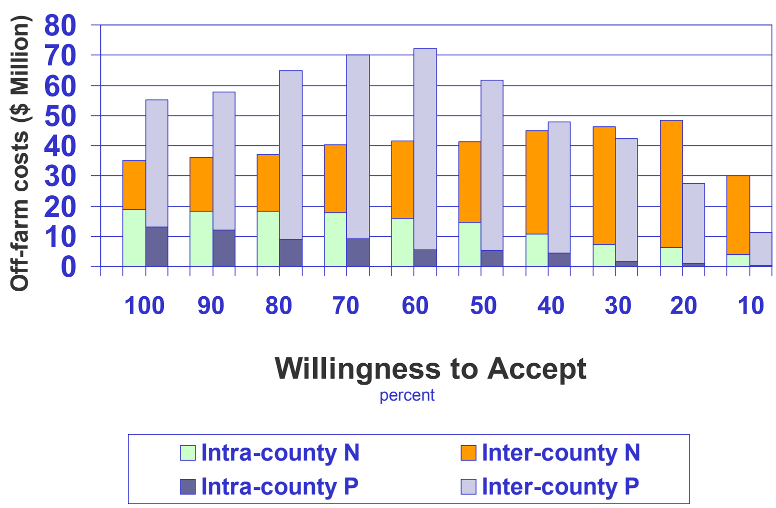


Figure 6. Off-farm hauling costs for land application of manure for both nitrogen and phosphorus standard, Chesapeake Bay Watershed, by willingness to accept manure



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