Costs of Land Applying Manure with Increased Off-Farm Processing Capacity: A Regional Assessment

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Increasing public, legislative, and regulatory attention has focused on the concentration of animal production and the resulting potential impacts of manure on water quality, aquatic resources, and public health. Recent policies implemented to protect water-quality resources by requiring the land application of manure at often lower than historic rates have heightened interest in the off-farm processing of animal waste. The potential for increased diversion of manure to off-farm processing facilities will be determined in part by the alternative costs of manure hauling and land application faced by animal producers.

In January, 2000, the Environmental Protection Agency and U.S. Department of Agriculture issued guidelines governing management of animal waste from confined feeding operations (U.S. EPA/USDA Joint Unified Strategy, 1999). As part of this strategy, the EPA promulgated final regulations in 2003, affecting an estimated 15,500 operations (U.S. EPA, 2003). Also as part of this strategy, a national performance expectation was established that all animal-feeding operations develop and implement technically sound, economically feasible, and site-specific Comprehensive Nutrient Management Plans (USDA, NRCS, 2000). Both the EPA regulations and USDA guidelines for improved manure management limit the amount of manure applied to cropland to the rate at which crops utilize nutrients. These "crop-based" manure application rates will be based on crop nitrogen uptake for many producers, while others will need to limit their manure applications to crop phosphorus uptake—usually at substantially lower per-acre application rates. The regulations are expected to have significant impacts in areas with substantial concentrations of confined animal production, including portions of the Chesapeake Bay Watershed (CBW). Counties within the watershed rank among the highest in excess manure nutrients produced in the U.S. (Gollehon et al., 2001).

The U.S. Department of Agriculture has established a program of research to evaluate effects of proposed regulations on the animal industry and resource quality. One research initiative involves development of a regional modeling framework, applied initially to the Chesapeake Bay Watershed. The Chesapeake Bay regional model examines potential manure-nutrient flows and costs to the livestock and poultry sectors with manure management policies proposed under the EPA/USDA Unified Strategy (Ribaudo et al., 2003). Primary policy focus is on land application of recoverable manure at agronomic rates, under both a nitrogen (N) and more restrictive phosphorus (P) based standard. The regional optimization model minimizes the cost of manure management across the basin, subject to land available for manure spreading and other options including use in industrial processes.

In this paper we present a regional model of manure management for the Chesapeake Bay Watershed. We then apply the model to assess the total cost of meeting land application policy goals in the CBW with an emphasis on current and proposed off-farm industrial processing. The model is designed to capture the critical dimension of competition among animal producers for land to apply manure, under either a nitrogen-based or 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.

Prior Studies

Results from the application of this model to the Chesapeake Bay Watershed are found in Ribaudo et al. (2003), which assumes application of all manure produced in the region to agricultural land. The results for a P-standard indicate that unless the majority of cropland acres will accept manure, not all manure can be applied to land within 150 km of the source farm. While land application is feasible for all manure under a N-standard if at least one in four acres in the basin will accept manure, the costs to transport manure long-distances exceed $120 million annually.

Ribaudo et al. (2003) utilized national USDA data on swine and dairy production to evaluate the farm-level costs of land applying manure at a crop-based rate using a simulation approach. This approach was used previously by Fleming, Babcock, and Wang (1998) who estimated the farm-level costs of land applying manure at crop-based rates, assuming no changes in manure handling technology. 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.

Ribaudo et al. (2003) also presents results of a 10-region national agricultural sector model used to examine the affect of meeting nutrient application standards. 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.

A much more limited set of analysis has been done at the regional level, with 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. Gollehon et al. (2002) applied the same regional model reported in Ribaudo et al. (2003) specifically to examine the issue of off-farm manure processing. The earlier studies by both Gollehon and Ribaudo considered only existing off-farm industrial operations that were in various stages of development. This study expands both the scale of the plants in operation and analyzes the impacts of adding new industrial plants on the regional costs of land applying manure.

Modeling Manure Management in the Chesapeake Bay Watershed

We have developed a regional modeling framework for evaluating the costs of livestock-waste management policies in the CBW using a structure designed to minimize total regional costs of manure transportation and management. County and local data are used to capture heterogeneity in technologies and land-quality conditions across the region. (The regional model will not replicate area-specific conditions of a farm-level model.) The regional 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)).

Estimates 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 land use 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.

<u>GIS Data</u>. 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 land apply 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]

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

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.

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 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 low 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 24-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 =

$$(1) \quad \sum_{ct} \sum_{ct2} [HAC_{ct,ct2} + INC_{ct2} + NM1_{ct} + NM2_{ct2} + ELA_{ct} - FS_{ct2}]$$

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

'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.

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—combines with assimilative capacity to establish manure application levels. In general, manure 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:

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

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

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

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

where N^* represents a nitrogen standard and P^* represents a phosphorus standard, *gr* is county grid location, *sy* is manure system (lagoon, slurry, dry), and *ds* is distance interval in miles (<.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.

Equation (3) restricts applied manure from all potential source counties to total spreadable acreage (A) in the destination county. Assumptions on the willingness of landowners to accept manure (willingness to accept or WTA) is captured through automated adjustments in both the quantity of spreadable acreage and the slope of area-to-distance functions. Total spreadable acreage was parameterized for 30 and 60 percent of the acreage in non-livestock and non-confined livestock farms. All acreage in confined livestock farms was assumed available for manure spreading. Land on confined livestock farms greater than the individual farms need for spreading site produced manure was considered spreadable area and parameterized.

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).

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

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

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

Equation (6) sets County surplus manure to be moved off the farm (M_SRP) equal to 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 'exceeds land application capacity' (M_ELA) within the assumed transport radius of a source county equal to the manure surplus in the source county less the sum of industrial uses (M_IND) and the sum of manure transfers out of county. Quantities of ELA manure are minimized in the model through the use of a penalty cost parameter that assigns a high cost to manure that is not land applied.

Hauling distances for off-farm transfers are computed based on Equations (9) – (11).

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

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

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

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)*. Intercept α and slope coefficient β are estimated from the GIS-derived linear regressions for within-county and out-of-county transfers. The intercept term, representing linear hauling distance from the source farm for out-of-county transfers, is adjusted (δ^1) for selected county-to-county transfers to reflect significant natural barriers (e.g., large bodies of water). In addition, a circuity parameter (δ^2) 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:

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

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

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

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

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).

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

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.

Background and Assumptions about Off-farm Industrial Uses

Manure diverted to off-farm industrial uses is no longer in "competition" for land, reducing the land application costs to meet nutrient application standards. Because the model is minimizing regional costs, the manure diverted to industrial processes is that which is transported the greatest distance from the location of the off-farm plant. That manure is the highest cost to land apply and represents the marginal cost of the last ton transported.

Historically the primary off-farm industrial use of manure in the Chesapeake Bay Watershed has revolved around composting poultry litter. However, new developments have resulted in changes in both the form of industrial uses and the volume of poultry litter processed. The amount of poultry litter in the CBW processed by industrial facilities has increased significantly with the recent construction of a large-scale industrial facility that uses poultry litter, PerdueAgriRecycle TM[3], located at Seaford, Delaware. This plant is designed to annually process 94,000 tons of litter into pelletized organic fertilizer for agricultural and landscaping uses.

The impacts of several levels of off-farm industrial uses on the land application costs of manure are estimated; current uses, expanded current uses, and three additional scenarios, each consisting of the expanded current uses plus the construction of biomass power plants at three locations within the CBA.

Our estimate of the current diversion of poultry litter to industrial alternatives is 139,000 tons per year. This incorporates the permitted amount of 94,000 tons of litter annually from PerdueAgriRecycle TM[4] plus 45,000 tons of small-scale, off-farm composting.

We estimate an expanded annual diversion of poultry litter to industrial alternatives to be 376,000 tons within five years. This estimate reflects projected growth in current technologies, including composting operations, output expansion to design capacity of the PerdueAgriRecycleTM plant, and the completion of other industrial uses in the planning or construction stage. It also assumes the restarting of the Harmony Farms Shenandoah Valley (HSV), located in the Shenandoah Valley of Virginia. This plant operated for several years at less than full capacity before ceasing operation in 2004. The plant is designed to process 60-65,000 tons per year of poultry litter as both an energy source and a feedstock in the manufacture of a blended organic-inorganic fertilizer.

The largest annual diversion of poultry litter considered is 626,000 tons. This is based on the expanded usage with current technologies with the addition of a biomass power plant using

3 No endorsement by USDA of the process or product is implied or inferred.
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250,000 tons. We assume three locations for such a plant, the Delmarva region, Rockingham, County VA and Lancaster, County PA, and evaluate each one separately.

Manure use as a biomass feedstock to generate steam to produce electric power offers an alternative use of manure other than applying it to cropland (Christensen, 1999). One of the processes that can be used to convert manure biomass to energy was developed and applied in the United Kingdom by FibroWatt LLC[5] (Sheeley, 1998). The process has been proposed for use in the United States, particularly in areas with high concentrations of poultry relative to the amount of land available for spreading poultry litter. This technology was selected for use in Minnesota where construction on a plant is anticipated to begin in the spring/summer of 2004. The Minnesota project, named FibroMinn[6], is a "green power plant" designed to burn primarily turkey litter for the production of energy.

The FibroWatt technology can be applied at different scales. The latest plant built in the UK is designed to use approximately 440,000 tons of broiler litter annually and generate 38.5MV of electricity annually. The FibroMinn plant design uses 500,000 tons of poultry litter per year to generate 50MW of electricity (FibroMinn, 2004). Biomass will also be used in the FibroMinn facility, with 50,000 tons per year of alfalfa stems or other biomass used as a secondary fuel source. The ash resulting from the burning process to generate steam may be sold as a concentrated, nutrient-rich fertilizer.

A plant using FibroWatt technology has been proposed for Maryland's Eastern Shore, termed FibroShore[7] (FibroShore, 2004). The proposed FibroShore plant uses a similar process, but at a smaller scale burning from 200,000-300,000 tons per year of poultry litter per year (Atlantic Resources Management, 2002). The plant would also consume 50,000-100,000 tons of

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forest residues (to improve combustion efficiency) producing up to 28-40MW of electricity annually. The plant would cost between $60 million and $90 million, depending upon the final size and design parameters.

The developers of the FibroShore project argue that its existence would eliminate the need for the litter hauling program developed by the Maryland Department of Agriculture (MDA). MDA's Manure Transportation Pilot Project was established to transport 20% of the poultry litter produced on the lower Shore to other areas as a means to help facilitate compliance with the Maryland Water Quality Improvement Act. Over 24,000 tons of litter was transported from the lower Shore since the Project's inception in 1999. Assuming a tractor-trailer can haul 25 tons of litter, 3,000 truckloads annually would have to be moved from Maryland's Eastern Shore to meet the goal of the Manure Transport Pilot Project. A FibroShore plant designed to use 250,000 tons would remove a quantity of litter equaling approximately 10,000 truckloads annually, eliminating the hauls under the Litter Transport Program.

While the discussion of a large scale combustion energy plant has focused on the Maryland's eastern shore on the Delmarva Peninsula, there are other areas in the CBW with large quantities of manure. We utilized the model to consider alternative locations of a FibroShore-type plant considering a location in Rockingham County, Virginia, and Lancaster County, Pennsylvania, as well as the Delmarva. This paper assumes the scale and characteristics represented in the FibroShore proposal for our modeling purposes and estimates that an additional 250,000 tons of manure would be diverted to off-farm processing above the expanded current estimates, for a total of 626,000 tons diverted to industrial uses.

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7 No endorsement of this process by USDA is implied.

Results and Findings

The model was applied to the Chesapeake Bay Watershed for selected 'willingness-to-accept manure' (WTAM) levels of 30 and 60 percent. Landowner willingness to accept manure has an important bearing on the availability of spreadable area and resulting manure hauling distances required and was the focus of the CBW analysis in Ribaudo et al. Also discussed in Ribaudo was the impact of adopting both an N- and P-standard. Because the focus of this paper is on off-farm industrial options, we have simplified the discussion to focus on the N-standard at two WTAM levels.

Modeled regional disposition of manure is shown in Figure 2 with zero industrial use, current alternatives, an expansion of current options, a new FibroShore-type plant located in the Delmarva or a similar new plant in Lancaster County, Pennsylvania, or Rockingham County, Virginia. The regional manure disposition shown in Figure 2 is based on an N-standard with a 30 and 60 percent WTAM. On-farm manure application accounts for about half of all manure produced under all options. On-farm manure utilization remains the lowest cost option for manure disposition and enables recycling the nutrients directly on the farm of production. However, about half the manure produced is transported off the source farm to land both within and out of the county of production. Under the reported standard and WTAM levels there is adequate land within the transport radius to utilize all the manure produced, however significant transport is required. Current off-farm industrial processing accounted for less than 2 percent of total dry manure, less than 5 percent with expansion of current options, and up to 9 percent of manure with addition of a new energy production plant of 250,000 tons. The slight variation in the reported dry manure disposition with the addition of a new plant is due to the variation in the source of the manure and the conversion from the manure that is moved off the farm as litter to the zero moisture dry manure shown in Figure 2.

Model estimates for total regional cost of land applying all manure produced, the potential value of the manure nitrogen and phosphorus nutrients, and the net regional costs are presented in Figure 3. The total land application cost is estimated at $127.28 million under an N-standard with 30 percent of crop and pastureland available for spreading (WTAM = 30) and $122.45 million at a WTAM of 60 percent[8].

The regional costs for off-farm industrial manure processing alternatives are also presented in Figure 3. Costs of land applying manure with the quantities reduced by the amount of the off-farm processing decline by 1.3 to 7.5 percent ($1.6 to $9.6 million annually) when the WTAM is 30 percent. When the WTAM increases to 60 percent, savings from shifting manure to an off-farm plant decline to a maximum of 6.8 percent or $8.4 million. Declines in land application costs represent the savings associated with having less manure needing land application in areas with surplus manure. These land application costs savings do not assure financial feasibility of an off-farm processing facility with less capitalized cost. Feasibility of an off-farm processing plant depends on more than just the savings in land application costs. Feasibility also depends on the distribution of the costs savings among the poultry growers and the owners of a processing facility.

Three locations were examined for an energy combustion plant using the equivalent of 250,000 tons of litter. The minimal regional cost for land application occurs when the plant is located in Rockingham County, Virginia. A plant located in Rockingham reduces regional land application costs $5-$6 million per year over the planned expanded facilities with current

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8 The costs in this paper will differ slightly from those reported in Ribaudo et al., (2003) because of model improvements and a larger scaling of the grids that underlie the transportation costs.

technology. A plant in either Lancaster County, Pennsylvania, or the Delmarva area produces savings of $1 to $2 million per year over planned expanded facilities, depending on WTAM level. The minimal cost regional model, however, does not assess the political support and overall feasibility of an off-farm processing facility.

The reduced costs of manure land application stems from two forms of cost adjustment. Figure 2 shows the amount of manure requiring off-source-farm disposition under an N-standard. One aspect of the reduced costs is shown by the share of manure that is no longer being land applied. There is a net cost to land applying manure and simply not applying the manure will result in saving. The second aspect of the reduced costs is the reduced cost per ton of manure transported because the off-farm processing absorbs the most expensive manure to transport. Figure 4 shows the average per acre cost to transport manure in dollars per "wet" ton. (Wet tonnage is the raw manure as cleaned from barns and facilities without mechanical water separation or drying.)

The effect of the competition for land on which to spread manure is shown in the $9 per ton average cost to haul manure when the WTAM is 30 percent. Even a slight reduction in the amount of manure for land application, as in the case of the current industrial alternative, drops the average cost by over $2 per ton. Alternatively an increase in the share of land where manure spreading would be allowed, such as the 60 percent WTAM, drops the average cost by over $3 per ton, by more than one-third. All industrial options greatly decrease the average per ton transport cost.

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 the Bay's resources. New 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 disposition. 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 provide a baseline reference for analysis of alternatives to land application such as pelletizing, fertilizer production, and power generation.

The model's minimal regional costs for land applying all manure produced based on an N-standard were $122 to 127 million depending on crop producers' willingness to accept manure. All the off-farm processing options examined lowered the cost of land application. Costs of land application decline by up to $9 million annually for an off-farm processing scenario utilizing 676,000 tons of manure in an expansion of current processing options plus an energy production plant located in Rockingham County, Virginia. Other locations (Lancaster County, Pa. and Maryland's Eastern shore) evaluated for the energy production facility did not produce the level of cost savings as the Rockingham location.

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. The feasibility depends on many factors, one of which is the potential savings associated with reduced manure hauling and land application costs. In this analysis, we compared the costs of manure hauling to meet land application requirements with alternative industrial options.

Future extensions of this analysis could focus along two lines of research. First, the model could be modified to endogenize the plant capacity and location decisions. There appears to be sufficient differences in the land application costs savings by area to justify further investigation of optimal plant size and location. Second, a more thorough assessment of the feasibility of off-farm processing is needed that would consider plant construction and operating costs, as well as the potential market premiums for "green" power and fertilizer, in addition to the potential cost savings to agricultural producers examined here. Such an assessment should address the distribution of the gains (or costs) from off-farm manure processing among producers, integrators, plant owners, energy buyers, and taxpayers, since public subsidies are often discussed as a financing option.

Figure 1. The Chesapeake Bay Watershed

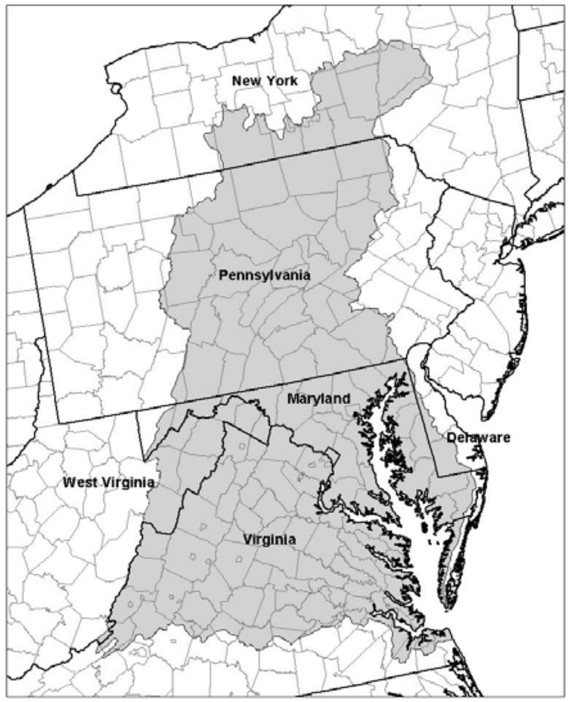


Figure 2. Chesapeake Bay Watershed disposition of manure under an N-standard with selected willingness-to-accept-manure levels and alternative off-farm industrial manure processing options

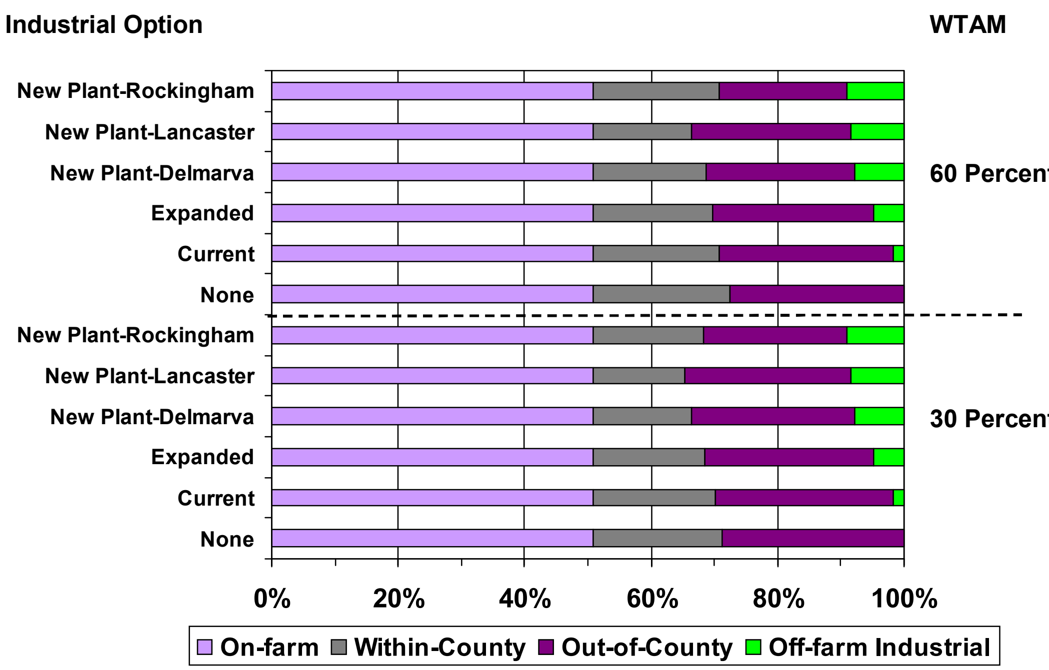


Figure 3. Chesapeake Bay Watershed costs of meeting an N-standard with selected willingness-to-accept-manure levels and alternative off-farm industrial manure processing options

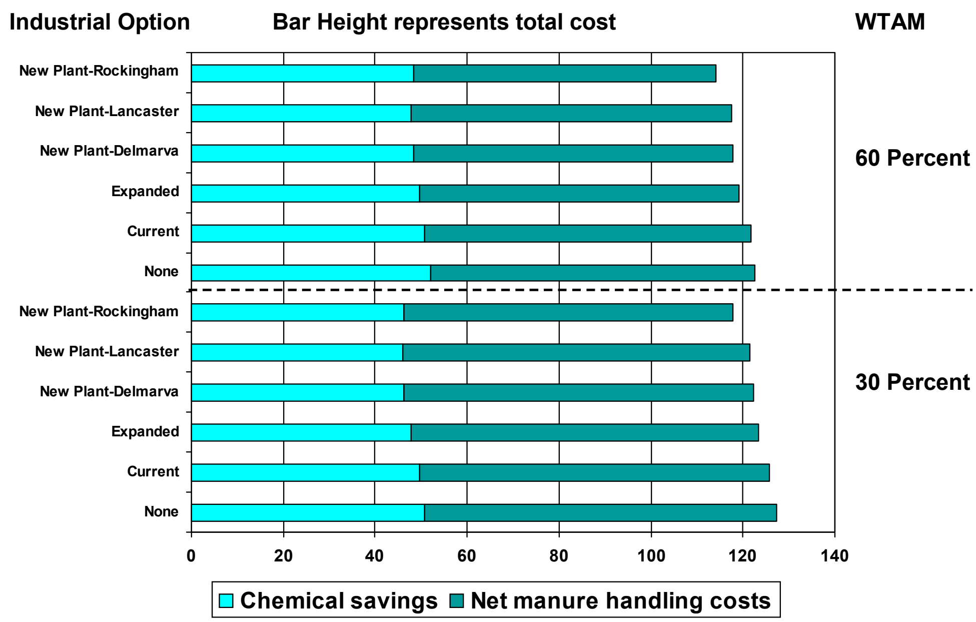
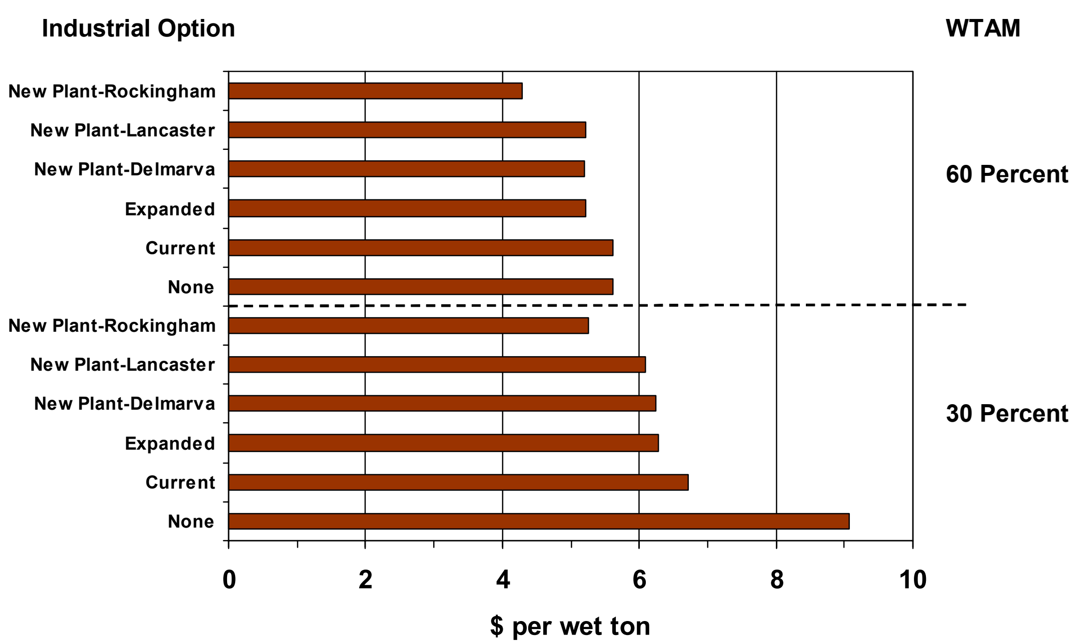


Figure 4. Chesapeake Bay Watershed average hauling costs per ton of manure for an N-standard with selected willingness-to-accept-manure levels and alternative off-farm industrial manure processing options



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