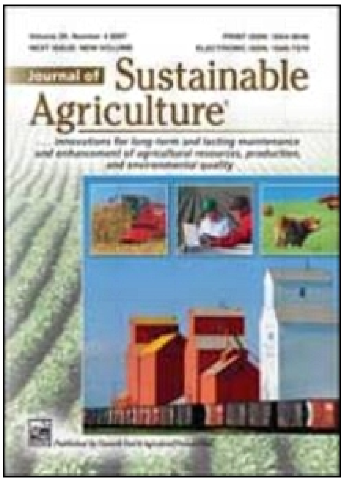

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The Economic Impacts of Alternative Manure Management Regulations on Hog Farms in the Heartland: An Individual-Farm Analysis

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The Economic Impacts of Alternative Manure Management Regulations on Hog Farms in the Heartland: An Individual-Farm Analysis

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ABSTRACT. A whole-farm modeling approach applied to survey data was used to assess the economic impacts of alternative regulations on manure application on Heartland hog farms. Results showed differential economic impacts depending on type and size of the hog operations. The P-based restriction would increase hog production costs and could affect the financial well-being of hog producers. Many large farms (over 2,500 hogs) had to lease additional land to meet restrictions on manure phosphorous application, with reductions in net crop returns exceeding those of medium size operations (750-2,500 hogs). Feeding hogs a phytase diet to lessen phosphorous in manure reduced the additional land needed and moderated the increase in manure application costs, but net crop returns still dropped for most operations. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com>]*

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The views expressed are those of the authors and do not necessarily represent the views of the U.S. Department of Agriculture.

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KEYWORDS. Hog manure, land application restrictions, net returns

INTRODUCTION

The environmental consequences of concentrated livestock feeding operations and their waste management are an increasing source of public policy concern (USEPA, 1999; USGS, 1999; Innes, 2000). This concern is particularly attributable to a trend in the U.S. hog industry toward fewer and larger farms with concentrated animal feeding operations (McBride, 1995). Recent survey results have shown that manure from those large operations is being disposed on cropland in quantities far exceeding the capacity of the cropland to absorb it (McBride and Christensen, 2000). Applications of manure nutrients in excess of crop uptake requirements have been associated with the impairment of surface and groundwater quality in some areas (USEPA, 1999; Litke, 1999). As a response to the concern about the manure produced by concentrated operations, USDA and EPA have developed a Unified National Strategy for Animal Feeding Operations (AFOs) (USEPA, 1999). This strategy calls for all AFOs to implement Comprehensive Nutrient Management Plans (CNMP) to minimize the impact on water quality and public health. As part of this strategy, EPA has recently proposed several changes to current NPDES (National Pollutant Discharge Elimination System) permit regulations (USEPA, 2001). The changes include redefining concentrated animal feeding facilities (CAFOs), which are subject to the NPDES regulation, and specifying permit requirements for CAFO manure at production and land application areas.

The most encompassing alternative that EPA is proposing for defining swine CAFOs is a three-tier structure which specifies a hog farm as a CAFO: (1) if the number of hogs (weighing over 55 pounds) is over 2,500, or (2) if it has between 750 and 2,500 hogs and meets certain conditions, or (3) if it has fewer than 750 hogs and is designated by the permit authority.[1] All facilities in the second group must either certify that they do not meet the conditions for being defined as a CAFO or must apply for a permit. This proposal would bring many more farms under regulation than the current situation, and could significantly impact the industry.

EPA's proposed new NPDES guidelines cover animal confinement and manure storage areas, and land application and off-site transfer of manure.[2] For land application, CAFO operators may need to follow phosphorous (P)-based nutrient management plans (NRCS, 2000), in which they must estimate the phosphorus (P) need of their crops based on realistic crop yields, sample soil to determine the existing P level in the soil, and then restrict application to quantities that do not exceed the net amount of P needed. In areas where P in soil is low, the operators must restrict nitrogen (N) application not to exceed the N need of their crops.

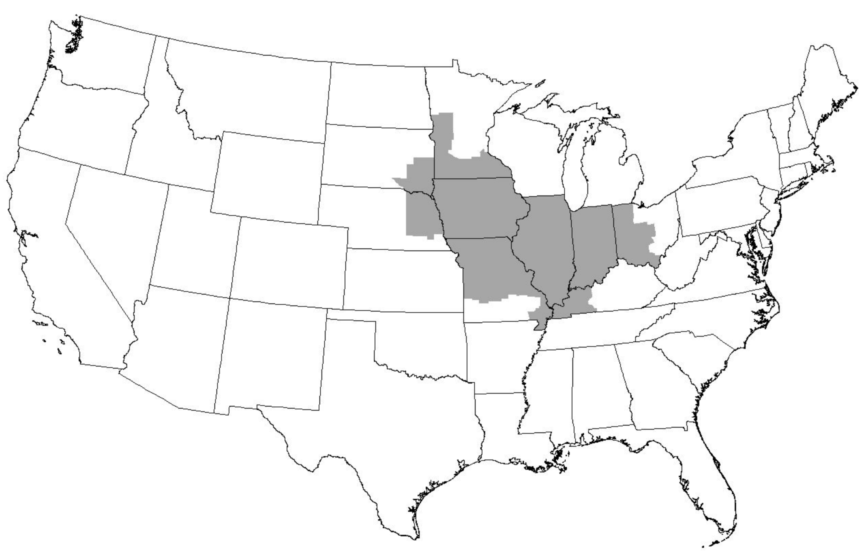
OBJECTIVE

Seventy percent of U.S. hog farms in 1998 were in the Heartland region (Figure 1) (McBride and Christensen, 2000).[3] Research reported here assessed the economic impact of three alternative restrictions on manure application by operations with 750 hogs or more on farms in this region. The research addressed the following questions: How many hog farms would have to lease additional land and what acreage would be needed? What would be the cost (reduction in net farm income) to the farms from complying with the restrictions? What would be the value to the farm from utilizing manure as a substitute for commercial fertilizer? What would be the marginal value to the farm from reducing the amount of manure?

AFFECTED INDIVIDUAL FARMS

The information obtained from a national survey of hog producers (USDA, 1998) was used to identify farms in the region that might be affected by alter-

FIGURE 1. Heartland Farm Resource Region (shaded area) in U.S.



native restrictions. The survey was conducted under the 1998 Agricultural Resource Management Study Phase III to obtain information on manure management practices of hog producers. The information included types of hog operations, types of manure storage, field application methods, types of crops grown and their yields, number of hogs, maximum hog capacity, number of acres receiving manure, and number of tillable acres on the farm. Hog operations in the survey were grouped into six categories: farrow-to-finish, farrow-to-feeder-pig, feeder-pig-to-finish, farrow-to-weaning, weaning-to-feeder pig, and mixed producers. Types of manure storage included settling tanks or basins, single-stage lagoon, two-stage lagoons or holding ponds, manure pits under the building, other manure pits, slurry or other manure tanks. Manure was either incorporated into the soil or spread on the soil surface.

A total of 1,633 hog farms responded to the survey, of which 259 were operations over 750 hogs (Table 1). These latter were grouped according to the size of hog production, the type of operation, the type of manure, the type of field application method, and the principal crops grown. The size of the farm operation was considered large if the number of the maximum hog capacity exceeded 2,500, and medium, if the number was over 750 but less than 2,500. The two major types of operations were farrow-to-finish and feeder-pig-to-finish. Manure types were slurry manure and lagoon liquid manure. Major field application methods were incorporation into soil, and spread on the soil without incorporation. Principal crops were corn, soybeans and wheat. Most farms used slurry manure for corn-soybean and corn-soybean-wheat rotations. Although 20 groups of farms were identified, only 8 with ten surveyed farms or more were analyzed in order to assure reliability. These 8 groups are marked with an asterisk in Table 1. Hog farms in the 8 groups totaled 137, representing 6,500 farms in the Heartland when expanded by survey weights.

ASSESSMENT MODELS

Hog farms facing a restriction on land application of manure based on plant nutrient needs can take various steps: (1) apply manure to crops that can utilize more nutrients; (2) expand existing manured acres; (3) lease additional acreage for manure application; (4) adopt technologies to reduce nutrient loading on existing land; (5) dispose manure off the farm; or (6) reduce the number of hogs on the farm, and hence the amount of manure, to comply with the regulation. This analysis limited itself to options (1) to (4), assuming the farm would maintain the same size of hog operation.[4, 5] Following the whole-farm analytical framework employed by Chase and Duffy (1991), an individual whole farm model (IWFM) was formulated for each of 137 selected farms by using

TABLE 1. Number of surveyed farms that would be affected by EPA's proposed CAFO rule, Heartland region.

Type of operation	Large farm (2,500 + hogs)	Medium farm (750-2,500 hogs)
Farrow-to-finish operations	Number (% of subtotal)	
Slurry manure		
Incorp-slurry on cs[1]	**18** (39%)*	**19** (29%)*
Spreading slurry on cs	1 (2%)	**12** (18%)*
Incorp-slurry on csw	**19** (41%)*	**24** (36%)*
Spreading slurry on csw	2 (4%)	7 (11%)
Others[2]	6 (13%)	4 (6%)
Subtotal	46 (100%)	66 (100%)
Lagoon liquid manure		
Incorp-manure on cs	2 (10%)	1 (4%)
Spreading manure on cs	5 (24%)	6 (24%)
Incorp-manure on csw	5 (24%)	2 (8%)
Spreading manure on csw	4 (19%)	6 (24%)
Others	5 (24%)	10 (40%)
Subtotal	21 (100%)	25 (100%)
Feeder-pig-to-finish operations		
Slurry manure		
Incorp-slurry on cs	**12** (52%)*	**23** (43%)*
Spreading slurry on cs	5 (22%)	7 (13%)
Incorp-slurry on csw	3 (13%)	**10** (19%)*
Spreading slurry on csw	1 (4%)	7 (13%)
Others	2 (9%)	6 (11%)
Subtotal	23 (100%)	53 (100%)
Lagoon liquid manure		
Incorp-manure on cs	3 (30%)	4 (27%)
Spreading manure on cs	3 (30%)	2 (13%)
Incorp-manure on csw	2 (20%)	5 (33%)
Spreading manure on csw	1 (10%)	3 (20%)
Others	2 (20%)	1 (7%)
Subtotal	10 (100%)	15 (100%)
Total of targeted farm	100	159
Total of targeted farms analyzed	**49**	**88**

1. Cs = corn-soybeans rotation. Csw = corn-soybeans-wheat rotation.
2. Others include farms growing minor crops and farms with missing data.
Source: data from 1998 Agricultural Resource Management Study survey of U.S. hog farms.

information from the survey. The following illustrates the components of the IWFM for a farm using manure for production of corn and soybeans.

Objective Function

We assume that the hog farm operator will maximize the net return, Z, from the crop production portion of the operation for crop *i* (*i* = *rc* (rotation corn), = *rs* (rotation soybeans), and = *cc* (continuous corn)) given the availability of manure produced on the farm and a given crop acreage operated by the farm on which manure can be applied. The farm leases additional land for manure application if current acreage is insufficient. The farm determines acres, C_{im}, to receive manure and acres not to receive manure, C_{in}. The farm also determines the manure application rate, A_i, the amount of *j* nutrient from commercial fertilizers for crop i, F_{ij}. The objective function of the IWFM is specified as:

$$\underset{A_i,\, C_{im}\, C_{in}\, ,F_{ij}}{\text{Maximize } Z =} \quad [\Sigma_i(p_i \mathbf{y_i} - o_i)\, C_{im} - \Sigma_i\Sigma_j f_j\, F_{ij}\, C_{im} - MAC - r\, LS] + [(\Sigma_i\, (p_i\, \mathbf{y}_i - o_i - \Sigma_j f_j\, d_{ij} \mathbf{y}_i)\, C_{in}] \quad (1)$$

where p_i, is the price ($/bushel) of crop *i*, $\mathbf{y_i}$ is the crop yield (bushel/acre), o_i is production costs other than fertilizer and land ownership costs ($/acre). f_j is the cost ($/pound) of *j* nutrient of commercial fertilizer, and d_{ij} is the pounds of *j* nutrient needed to produce one bushel (ton) of *i* crop, *j* = n (nitrogen), p (phosphorus), *k* (potash); and *MAC* is the manure application cost ($) (to be defined later); *r is* the land rent ($/acre) and $\mathbf{y_i}$ is obtained from the survey. In the objective function (1), the terms in the first bracket define the net return from the manured acres and the terms in the second bracket define the net return from non-manured acres using only commercial fertilizers for crop production. The objective function is subject to the following set of restrictions:

Acreage Restrictions

$$\Sigma_i(C_{im} + C_{in}) - \mathbf{LO} - LS = 0 \quad (2)$$

where ***LO*** is the farm own tillable acres and *LS* is the acres leased by the farm for disposal of manure only. ***LO*** is known from the survey.

Manure Use Restriction

$$MA = m\, \mathbf{hog} \quad (3)$$

where *MA* is the total amount of manure (in 1,000 gallons) applied to cropland; and *m* is the amount of manure (in 1,000 gallons) produced annually by one animal unit (1,000 pounds = one animal unit) of hog capacity; and ***hog*** is the hog capacity, obtained from the survey and held constant, expressed in animal units.

Per-Acre Nutrients Required by Crops

$$F_{in} + u_n A_i - d_{in}\mathbf{y}_i + \mathbf{y}_{rs} \qquad 0 \textit{ for } i = rc, cc \textit{ and } rs \tag{4}$$

$$F_{ip} + u_p A_i - d_{ip}\mathbf{y}_i \qquad 0 \textit{ for } i = rc, cc \textit{ and } rs \tag{5}$$

$$F_{ik} + u_k A_i - d_{ik}\mathbf{y}_i \qquad 0 \textit{ for } i = rc, cc \textit{ and } rs \tag{6}$$

where F_{ij} is the pounds of j nutrient applied to crop i and u_j is the pounds of j nutrient in 1,000 gallons of manure; and d_{ij} is the pounds of j nutrient needed to produce one bushel of crop i. Restrictions 4, 5 and 6 state that the applied amount of each nutrient per acre from the commercial fertilizer and manure must meet the amount needed by the crop. Note that restriction 4 gives credit for N fixed ($\mathbf{y}_{rs}$) by soybeans in rotation with corn, assumed to be 1 pound of N fixed per bushel of soybeans harvested. Any excess amount of manure nutrients applied is assumed to have no value to the farm.

Nutrient Application Restrictions

$$F_{in} + u_n A_i - d_{in}\mathbf{y}_i + \mathbf{y}_{rs} + S_{in} \qquad 0 \textit{ for } i = rc, cc \textit{ and } rs \tag{7}$$

$$F_{ip} + u_p A_i - d_{ip}\mathbf{y}_i + S_{ip} \qquad 0 \textit{ for } i = rc, cc \textit{ and } rs \tag{8}$$

$$F_{ik} + u_k A_i - d_{ik}\mathbf{y}_i + S_{ik} \qquad 0 \textit{ for } i = rc, cc \textit{ and } r \tag{9}$$

where $S_{ij,}$ $j = n, p$ and k, is the amount of surplus manure nutrient j applied to crop i but not utilized by the crop and $S_{ij} > 0$. S_{ij} is the surplus nutrient, which has no value to the farm. S_{ij} is set to zero when nutrient j is restricted. For example, S_{in} becomes zero when N is restricted. Surplus manure nutrients can occur when the manure application rate is restricted based on one specific nutrient. Restricting the manure application rate for corn based on N, will result in a surplus of P from manure because one unit of manure provides more P than N.

Crop Rotation Relations

$$C_{i=rc\,k} = C_{i=rs\,k} \quad \text{for } k = m \textit{ and } n \tag{10}$$

Relation (10) sets acres of rotation corn equal to acres of rotation soybeans and this relation is used only for a corn-soybeans rotation.

Total Manure Applied

$$MA = \sum_i A_i \, C_{im} \tag{11}$$

The right-hand side of equation 11 is nonlinear because both A_i and C_{im} are decision variables.

Manure Application Cost (MAC)

The cost of transporting manure by wagon from storage to the field and then applying it includes a base charge for manure application plus a mileage charge (Fleming et al., 1998). Specifically, the cost is:

$$MAC = [(bc)\ (MA)] + [(mc)\ (MA)\ TD] \tag{12}$$

where *MA* is the total volume (in 1,000 gallons) of manure applied to the manured field, *bc* is the field application cost (in \$ per 1,000 gallons), and *mc* is the manure transportation cost (in \$ per 1,000 gallons per mile). The travel distance (*TD*) is the sum of travel miles to each block of the manured field. For example, $TD = (0.25)\ \{(\sum_i C_{im})/160 + (\sum_i C_{im}/160)\ (\sum_i C_{im}/160 - 1)/2\}$, assuming the farm can divide each one square mile (640 acres) manured field into 4 160-acres rectangular blocks. Each block is 0.25 mile by 1 mile. The total travel distance then is the sum of distance from the storage to each of blocks. The survey data provided the following inputs: ***hog and*** $\boldsymbol{y_i}$, and the upper bounds of ***LO***.

TECHNICAL DATA AND ASSUMPTIONS

The empirical research performed in this study makes several key assumptions. The assumptions are listed bellow:

1. All farms using a similar manure system were assumed to have the same coefficients for manure production, nutrients in manure, manure transportation and field application costs, and nutrients required by crops. These coefficients were obtained from published and unpublished sources (Tables 2 and 3). Manure from manure pits under the building, other manure pits, slurry or other manure tanks was assumed to be slurry, with relatively high nutrient content. Manure from single and two-stage lagoons was assumed to be liquid with low levels of nutrients. Manure from each operation was considered all incorporated if more than 50 percent was incorporated, according to the survey. Otherwise it was assumed to be surface spread.

2. The operation maintained the same number of hogs, type of hog operation, and manure storage and application system regardless of the manure application restrictions. Increasing the size of storage in response to the restrictions could incur a higher cost to a farm than expanding the land application (Boland, Preckel and Foster, 1998).
3. The operation leased additional land when needed to meet manure nutrient application restrictions, and cropped and harvested this land the same as existing land. Cash rent paid for additional land was $100 per acre (NASS, 1999). This assumption is reasonable because of relatively large cropland base in the Heartland.
4. Rotations of corn-soybeans and corn-soybeans-wheat were the two major cropping patterns, and the only ones included in the modeling. Surveyed yields of those crops were used as the realistic yields to determine the amounts of nutrients needed for crop growth and the maximum amount of nutrients allowed to be applied on the field to comply with the restrictions. The same levels of crop yields were assumed for both manured and non-manured acres.
5. Crop prices used were the loan rates for Heartland crops in 2001: $1.89/bu for corn, $5.26/bu for soybeans, and $2.54/bu for wheat (USDA, 2001). Fertilizer nutrient prices used were $0.27/lb for nitrogen, $0.31/lb for phosphate, and $0.17/lb for potash, based on April 2000 USDA published prices except the nitrogen price was adjusted upward to reflect higher natural gas prices in April 2001 (NASS, 2000). These fertilizer nutrient prices also include application costs. Crop production costs excluding fertilizer and land ownership costs were $228/ac for corn, $156/ac for soybeans, and $105/ac for wheat in 1999 in the Heartland (ERS, 2001).
6. Phytase-supplemented feed was assumed to reduce P in hog excretion by 27.75 percent at a cost of $0.31 per hog for feeder-pig-to-finish operation (Bosch, Zhu and Kornegay, 1998). These coefficients also were used for farrow-to-finish operations.

SCENARIOS AND INDICATORS

One baseline scenario and three restriction scenarios were specified for assessing the farm-level impacts:

> *Baseline:* Manure application rate was unrestricted and manure was applied to the same number of acres reported by the survey farms. This simulated the actual land application of manure by surveyed farms in 1998.

N-restriction: Manure application rate was restricted to not exceeding the nitrogen needs of individual crops and acres receiving manure were bounded by tillable land owned and leased by the farm. This restriction is part of CNMP for the areas where P in soil is low (NRCS, 2000).

P-restriction: Manure application rate was restricted not to exceed the phosphorous needs of an individual crop and acres receiving manure were bounded by tillable land owned and leased by the farm. This restriction is part of CNMP for areas where P in soil is high.

P-restriction/phytase diet: Same as P-restriction but phytase added to hog feed to reduce the P content of manure and thus the land acres needed for manure disposal.

Four indicators were used to assess the farm-level impacts: (1) additional acres needed to lease to comply with the restrictions, and (2) net farm income from crop production, (3) manure utilization net costs per hog sold, and (4) marginal cost of manure (in 1,000 gallons) to the farm. Net crop return was the sum of crop returns from both manured and non-manured acres of the farm. Net cost to utilize manure was calculated by subtracting the commercial fertilizer cost savings from manure application costs. Marginal cost of manure is a reduction in net farm income from applying the last 1,000 gallons of manure on the farm. The average and the range (the maximum and minimum) are shown for each indicator. The economic impacts on the farm are the changes of these four indicators between the baseline scenario and the two P-restriction scenarios, as well as between the N-restriction scenario and the two P-restriction scenarios.

RESULTS OF THE ANALYSIS

Additional Acres Needed

Restriction on application of P in manure had a larger impact on large-sized hog CAFO farms than on medium-sized CAFO farms (Table 4). The greatest impacts occurred on large-sized farms with feeder-pig-to-finish operations. One particular farm in this group had to lease 1,652 additional acres to comply with the P-restriction because of a high hog-to-land ratio and low crop yields. The majority of the medium-sized hog farms (less than 40 percent of farms needed to lease additional land) had adequate land without leasing additional land to comply with the restrictions because of their relatively low hog-to-land ratios.

TABLE 2. Technical coefficients used in all individual whole farm models.

Annual manure produced (Sutton et al.)[a]			
Type of operation		**Slurry manure**	
		per pig sold	**per AU capacity**
		gallons	1,000 gallons
Feeder-pig-to-finish		176	3.52
Farrow-to-finish		252	3.04
Nutrient content of manure incorporated into the soil (Sutton et al., 1994)			
		Slurry manure	
	N	P_2O_5	K_2O
		Pounds/1,000 gallons	
	31.82	26.40	25.40
Nutrient content of manure spread on soil surface (Sutton et al., 1994)			
		Slurry manure	
	N	P_2O_5	K_2O
		Pounds/1,000 gallons	
	26.24	26.40	25.40
Nutrients needed by selected crops (Sutton et al., 1994)			
	N	P_2O_5	K_2O
Corn (lbs./Bu)	1.20	0.39	0.43
Soybeans (lbs./Bu)	4.00[b]	0.91	1.91
Winter wheat (lbs./Bu)	1.00	1.42	0.70

[a] The average weight of pigs in the inventory for a feeder-pig-to-finish operation is assumed to be 150 pounds with 3 production cycles per year, and the average weight of pigs in the inventory for a farrow-to-finish operation is 133 pounds with 2 production cycle per year. The average pig weight in the inventory for a farrow-to-finish operation is 166 pounds, which is the sum of 133 pounds (the average weight of a hog to be sold) and 33 pounds (the shared average weight of a sow for each hog sold annually) (Zeroing et al., 1999).

[b] This is the maximum amount of manure N that can be absorbed by soybeans. If manure N is not available, soybeans can fix N for own use. Therefore, manure N is assumed no value to soybeans.

TABLE 3. Costs of manure transportation and field application of manure.

	Slurry manure ----- Dollars/1,000 gallons -----
Base charge rate for spreading manure on soil	
Incorporation into soil	8.8
Without incorporation	7.9
Mileage charge rate	1.7

Source: Fleming et al. (1998).

TABLE 4. Additional leased acres needed by Heartland farms to comply with restrictions on land application of manure for crop production.

Operation type and size group	N-restriction	P-restriction	P-restriction with phytase
Farrow-to-finish operations	Acres/farm (percent of surveyed farms in group)[1]		
Large-incorp-slurry on cs[2]			
Average[3]	0.6 (1%)	157 (60%)	43 (38%)
Maximum	43	845	397
Minimum	0	0	0
Medium-incorp-slurry on cs			
Average	0 (0%)	38 (26%)	9 (5%)
Maximum	0	481	254
Minimum	0	0	0
Medium-spreading slurry on cs			
Average	13 (8%)	38 (25%)	6 (25 %)
Maximum	65	97	20
Minimum	0	0	0
Large-incorp-slurry on csw			
Average	28 (10%)	120 (31%)	46 (10%)
Maximum	139	695	225
Minimum	0	0	0
Medium-incorp-slurry on csw			
Average	0 (0%)	4 (8%)	0 (0%)
Maximum	0	30	0
Minimum	0	0	0
Feeder-pig-to-finish operations			
Large-incorp-slurry on cs			
Average	97 (36%)	892 (72%)	526(72%)
Maximum	462	1,652	1,129
Minimum	0	0	0
Medium-incorp-slurry on cs			
Average	22(8%)	132 (26%)	62 (17%)
Maximum	192	765	513
Minimum	0	0	0
Medium-incorp-slurry on csw			
Average	0 (0%)	11 (11%)	0 (0%)
Maximum	0	81	0
Minimum	0	0	0

1. Percent of farms in group that had to lease additional land.
2. Cs = corn-soybeans rotation. CSW = corn-soybeans-wheat rotation.
3. Averages are weighted using survey weights.
Source: Results of individual whole farm modeling.

More farms needed to lease land for manure application with the P-restriction than with the N-restriction. For example, about 1 percent of large-sized farms incorporating slurry on the corn-soybeans rotation needed to lease additional land to comply with the N-restriction, while about 60 percent of them needed to lease land to comply with the P-restriction.

Feeding hogs a phytase diet would reduce the additional acreage needed when compared with the P-restriction scenario. It had a larger effect on large farms with feeder-pig-to-finish operations than on the large farms with farrow-to-finish operations. Because most feeder-pig-to-finish farms have higher hog-land ratios, use of phytase did not reduce the number of farms needing to lease additional land.

In the study, we assumed that farms leased additional land to utilize manure if they had inadequate cropland to comply with manure application restrictions. Farms could have their excess hog manure removed from their operations. The result form hog survey indicated that 21 percent of hog farms in the Heartland in 1998 had some of their manure removed from their operations. About 85 percent of them gave away their hog manure free of charge, 12 percent paid for the hauled-off, and 3 percent sold the manure.

Net Crop Returns

The P-restriction reduced the average net crop returns from the crop production portion of the hog operation for all the farms in all 8 groups, compared with the N-restriction (Table 5). Under the P-restriction, farms must purchase additional N-fertilizer to meet the crops' need and may have to lease additional acres to utilize the manure. Farms may face a higher transportation cost to spread manure on the expanded acres. As shown in the table, large operations had the greatest relative and absolute drops in net crop return. While some individual farms experienced negative crop returns, many were still in the positive column. A few medium-size feeder-pig-to-finish farms with the corn-soybean rotation utilized manure efficiently. Neither the N nor the P-restriction would have a large impact on their net crop return. Of farms in medium-sized groups, 62-87 percent maintained a positive net crop return. For the large-sized farm groups, the proportions dropped to 33 to 56 percent. Most farms in the large feeder-pig-to-finish groups incurred high application costs and small crop returns because of relatively low crop yields.

The P-restriction had minor impacts on medium-sized farms incorporating slurry into soil for the corn-soybeans-wheat rotation because these farms had a low hog-to-land ratio. The restriction would little change their allocation of manure to crops. Although most farms had negative manure value (not shown in this paper) (manure application costs exceeded the fertilizer value of manure), many of these farms had positive crop net returns from manured acres.

TABLE 5. Net crop returns under various manure application scenarios.

Operation type and size group	Baseline	N-restriction	P-restriction	P-restriction with phytase
Farrow-to-finish operations	$/farm (percent of surveyed farms in group)[1]			
Large-incorp-slurry on cs[2]				
Average	37,977 (16%)	42,696 (11%)	12,868 (44%)	30,313 (28%)
Maximum	126,305	130,551	82,391	109,937
Minimum	−21,065	−28,183	−212,963	−113,812
Medium-incorp-slurry on cs				
Average	10,694 (21%)	14,213 (11%)	8,435 (26%)	11,607 (21%)
Maximum	50,566	55,292	55,135	53,560
Minimum	−15,482	−20,314	−117,614	−54,688
Medium-spreading slurry on cs				
Average	18,844 (17%)	22,286 (17%)	20,748 (25%)	20,901 (17%)
Maximum	72,548	76,760	76,692	75,302
Minimum	−10,595	−13,218	−45,464	−30,574
Large-incorp-slurry on csw				
Average	6,376 (47%)	97 (47%)	-27,787 (53%)	−8,477 (47%)
Maximum	54,247	62,893	61,544	60,048
Minimum	−49,292	−117,628	−342,705	−192,076
Medium-incorp-slurry on csw				
Average	4,070 (50%)	6,523 (33%)	5,380 (38%)	5,288 (33%)
Maximum	85,597	88,456	88,452	86,829
Minimum	−12,048	−11,008	−19,036	−14,270
Feeder-pig-to-finish operations				
Large-incorp-slurry on cs				
Average	16,427 (42%)	8,017 (42%)	−128,178 (67%)	−57,477 (67%)
Maximum	158,653	161,921	156,612	157,357
Minimum	−18,381	−55,507	-380,420	−190,990
Medium-incorp-slurry on cs				
Average	21,384 (13%)	24,593 (9%)	8,498 (13%)	17,097 (13%)
Maximum	337,396	337,396	337,280	335,416
Minimum	−9,571	21,138	−94,531	−59,287
Medium-incorp-slurry on csw				
Average	27,565 (20%)	32,469 (20%)	31,000 (20%)	30,273 (20%)
Maximum	73,556	81,696	81,651	79,343
Minimum	−6,018	−2,874	−12,123	−4,761

1. Percent of farms in group that had a negative net income.
2. Cs = corn-soybeans rotation. CSW = corn-soybeans-wheat rotation.
3. Averages are weighted using survey weights.
Source: Results of individual whole farm modeling.

This indicates that most farms might be able to absorb the net cost of manure utilization. A few farms, in fact, would improve their crop net returns by substituting manure for commercial fertilizer.

Feeding hogs a phytase diet to reduce P in manure reduced income losses from the P-restriction when land was the limiting factor for manure application. It increased the income loss when land was not the limiting factor. For example, the average net crop returns per farm decreased slightly from $31,000 to $30,273 for medium-size feeder-pig-to-finish farms incorporating slurry on the corn-soybean-wheat rotation because most of these farms had adequate cropland.

Most farms in the baseline scenario could have improved their net crop returns by applying manure to available land at the level to utilize fully the N in manure. In this case, the fertilizer value of the additional manure applied exceeded the added manure application costs

Net Cost to Utilize Manure per Hog Sold

Knowledge of the net cost to utilize manure per hog sold helps a farmer assess the disadvantage (or advantage) of using the current manure management system over use of commercial fertilizer to supply nutrients for crop needs. A positive value indicates that manure utilization costs exceeds the fertilizer value of manure. A large net cost indicates the need to develop an alternative manure management system to reduce the cost. The average net cost to utilize manure per hog sold (CPHS) for the baseline situation was around $1/hog sold for all 8 groups (Table 6). Under the N-restriction, the averages were from $0.02 to $1.77 per hog sold and under the P-restriction the averages increased to $0.45 to $12.03 per hog sold. A few farms had a positive return from utilizing manure. For example, 21 percent of farms in medium-sized group incorporating slurry on a corn-soybeans-wheat rotation had a fertilizer value of manure applied that exceeded the manure application costs. One particular farm in this group had a net gain of $0.39 per hog sold. The estimates of CPHS for the N-restriction scenario were in the range reported by Fleming, Bacock and Wang (1998), but the estimates for the P-restriction scenario were higher than theirs, because of differences in land restriction assumptions.

Marginal Costs (Shadow Prices) of Manure

The marginal cost (the reduction in net income or the shadow price of the manure restriction (equation 3)) to the farm of applying the last 1000 gallons of manure is shown in Table 7. Information on the marginal cost can help operators determine whether to expand or to contract the number of hogs on the farm. It also can help a farmer assess the economic feasibility of using alternative waste management technologies to reduce excess nutrients in the manure.

TABLE 6. Cost per hog sold of utilizing manure under various application scenarios.

Groups of operations	Baseline	N-restriction	P-restriction	P-restriction with phytase
Farrow-to-finish operations	$/hog sold (percent of surveyed farms in group)[1]			
Large-incorp-slurry on cs[2]				
Average[3]	1.64 (100%)	0.79 (89%)	6.06 (100%)	2.68 (100%)
Maximum	2.29	2.27	20.26	10.20
Minimum	0.86	−0.104	1.48	0.63
Medium-incorp-slurry on cs				
Average	1.43 (95%)	0.77 (69%)	2.88 (100%)	1.34 (100%)
Maximum	2.91	3.25	15.43	7.23
Minimum	−0.67	−0.68	0.18	−0.08
Medium-spreading slurry on cs				
Average	0.70 (67%)	1.39 (83%)	3.26 (100%)	1.60 (100%)
Maximum	1.90	3.67	5.76	3.97
Minimum	−0.54	−0.02	0.54	0.44
Large-incorp-slurry on csw				
Average	1.30 (100%)	1.77 (95%)	5.20 (95%)	2.72 (95%)
Maximum	2.68	6.64	20.3	11.11
Minimum	0.67	−0.13	−0.46	−0.01
Medium-incorp-slurry on csw				
Average	0.81 (83%)	0.02 (63%)	0.45 (79%)	0.62 (92%)
Maximum	6.27	1.25	2.19	1.95
Minimum	−1.22	−0.66	-0.39	−0.11
Feeder-pig-to-finish operations				
Large-incorp-slurry on cs				
Average	1.23 (100%)	1.74 (92%)	12.03 (100%)	6.78 (100%)
Maximum	2.17	3.89	19.3	11.14
Minimum	0.98	0.00	1.48	0.77
Medium-incorp-slurry on cs				
Average	1.25 (100%)	0.79 (83%)	3.56 (100%)	2.08 (100%)
Maximum	9.68	2.80	12.91	7.96
Minimum	0.40	−0.12	0.20	0.21
Medium-incorp-slurry on csw				
Average	1.11 (90%)	0.12 (70%)	0.48 (90%)	0.54 (100%)
Maximum	5.66	0.37	2.00	0.77
Minimum	−0.55	−0.07	−0.02	0.38

1. Percent of farms in the group that had manure application costs exceeding fertilizer value of manure applied.
2. Cs = corn-soybeans rotation. CSW = corn-soybeans-wheat rotation.
3. Averages are weighted using survey weights.
4. A negative value indicates a net gain, instead of a loss from utilizing manure (fertilizer value of manure exceeds manure application costs).
Source: Results of individual whole farm modeling.

TABLE 7. Marginal costs of manure (shadow prices) under various application scenarios.

Operation type and size group	Baseline	N-restriction	P-restriction	P-restriction with phytase
Farrow-to-finish operations	$/1,000 gallons (percent of surveyed farms in group)[1]			
Large-incorp-slurry on cs[2]				
Average[3]	9.98 (100%)	7.42 (95%)	51.43 (95%)	26.50 (95%)
Maximum	16.37	25.65	206.9	124.07
Minimum	8.33	−11.65[4]	−11.65	−9.53
Medium-incorp-slurry on cs				
Average	6.79 (100%)	4.23 (95%)	35.02 (95%)	6.79 (95%)
Maximum	15.51	25.93	214.67	81.37
Minimum	0.08	−1.13	−0.51	−2.26
Medium-spreading slurry on cs				
Average	8.77 (100%)	1.20 (75%)	8.53 (75%)	5.11 (75%)
Maximum	11.34	17.00	85.26	50.39
Minimum	2.10	−3.35	−3.35	−4.41
Large-incorp-slurry on csw				
Average	10.76 (100%)	24.11 (100%)	64.39 (100%)	31.30 (100%)
Maximum	16.37	79.50	242.04	130.52
Minimum	8.80	0.58	0.58	1.27
Medium-incorp-slurry on csw				
Average	8.56 (100%)	5.86 (79%)	15.15 (79%)	6.69 (92%)
Maximum	10.86	19.06	50.63	25.19
Minimum	1.04	−7.94	−7.94	−6.27
Feeder-pig-to-finish operations				
Large-incorp-slurry on cs				
Average	10.19 (100%)	26.00 (100%)	132.89 (100%)	74.95 (100%)
Maximum	14.48	48.92	287.39	162.30
Minimum	8.97	6.48	8.43	9.34
Medium-incorp-slurry on cs				
Average	10.91 (100%)	6.54 (70%)	41.56 (84%)	17.43 (87%)
Maximum	51.21	52.93	160.98	108.09
Minimum	1.48	−10.51	−10.51	−8.64
Medium-incorp-slurry on csw				
Average	8.05 (100%)	5.88 (100%)	14.19 (100%)	5.12 (100%)
Maximum	9.60	12.44	63.19	10.89
Minimum	0.55	0.59	0.81	1.80

1. Percent of farms in group that have marginal manure application costs exceeding the marginal fertilizer value of manure applied.
2. Cs = corn-soybeans rotation. CSW = corn-soybeans-wheat rotation.
3. Averages are weighted using survey weights.
4. A negative value indicates marginal value of manure to the farm is positive (net farm income increases with the last 1000 gallons of manure available for land application).
Source: Results of individual whole farm modeling.

A positive marginal cost implies that the farm can reduce this cost either by reducing the number of hogs on the farm and hence the amount of manure produced, by moving manure off the farm to neighboring farms, or by private waste management if such costs less. If the marginal cost is negative, farms could further improve their net income by applying additional manure from expanded hog numbers, or purchasing manure from other farms. While most farms had a positive marginal cost, a few farms had a negative marginal cost. For example, 5 percent of farms with large farrow-to-finish operations and corn-soybeans rotation had a negative marginal cost.

The P-restriction caused a large increase in the marginal cost of manure. The averages of marginal costs were much higher under the P-restriction scenario than under the baseline and the N-restriction scenarios. Most large-sized farms generally had larger marginal costs than most medium-sized farms.

For those farms with large marginal cost under the P-restriction, off-site disposal of their hog manure can be a viable option to reduce their operation costs. The 1998 survey results showed that many farms in the Heartland were able to give away their hog manure free of charge, a few farms were able to sell it for small amount of money (less than $0.3/1,000 gallons), and some farms had their manure hauled off for a fee. The fees ranged from $2.38 to $100 per 1,000 gallons with an average of $22 per 1,000 gallons. It is possible for some farms in the Heartland to minimize costs of complying with the P-restriction by giving away their manure to their neighboring farmers or paying them to utilize it.

CONCLUSIONS

The environmental impacts of concentrated animal feeding operations have been an increasing source of public concern in the Heartland and in other regions within the United States. EPA has recently proposed several changes to the current NPDES permit regulations. The changes include redefining CAFO facilities, which are subject to the NPDES regulation and specifying permit requirements for CAFO manure at production and land application areas. A whole-farm approach and the information from the 1998 national hog survey were used to assess the economic impacts of EPA's proposed changes in manure management regulations on Heartland hog farms. Our analysis shown that the P-based restriction would increase hog production costs and could affect the financial well-being of hog producers.

Of the 137 hog operations analyzed in this study, compliance with EPA's proposed rule would cause most farms to have higher manure application costs and lower net crop returns. The impacts would be relatively greater on the large-sized farms (over 2,500 pigs) than on the medium-sized (between 750 to

2,500 pigs) farms. Moving from presumably current N-based restriction to the P-based restriction would increase costs and reduce returns for most farms. Although feeding hogs a phytase diet to reduce the P content of manure would moderate the impact of the P-restriction, the reduction in crop net return could be very substantial for most large-sized farms. Medium-sized farms would also experience reduced net crop returns under the P-restriction. Most farms still would have positive returns from crop production.

One possible way for the farms in the Heartland to reduce their compliance costs would be to move excess manure off the farm to neighboring farms. Most counties in the Heartland have sufficient cropland to assimilate nutrients from the excess hog manure (Kellogg, et al. 2000). For those farms with a high marginal cost of utilizing manure, giving excess manure to the neighboring farms free of charge or paying them to utilize the manure could cost less than leasing additional land on which to apply the excess manure. If farms had the option of giving away their manure, the economic impact of the proposed CAFO's rule would likely to be less. An increase in businesses contracting to haul manure off the farm would be expected. Assessment of these impacts was not part of this study and would be needed.

Many assumptions were used to simplify the analysis. Future research can examine how changes in the assumptions may impact the results. For example, a lower level of nutrient content in manure (than the level assumed in this study) can significantly reduce the number of additional acres needed for manure application. Higher commercial fertilizer prices can improve the fertilizer value of the manure and therefore improve the net crop return from manured acres. Higher crop prices can improve net crop return. However, changes in these assumptions may not alter the qualitative conclusions that the P-based restriction would increase hog production costs and could affect the financial well-being of hog producers, and that the restriction would have a larger impact on large hog operations than on medium size operations.

NOTES

1. Farms that have fewer than 750 hogs can be classified as CAFOs under certain conditions (USEPA, 2001). Such farms were not included in this study because the information needed to identify them was not available from the survey.

2. EPA is proposing two options for offside transfer of CAFO manure: (1) The recipients of CAFO manure must certify that they are land-applying at proper agronomic rates; or (2) no certification is required, but the CAFO operator must maintain records of manure transfer.

3. USDA's Economic Research Service recently constructed 9 farm resource regions in U.S., depicting geographic specialization in production of U.S. farm commodities. The delineation of regions is not simply based on hog production characteristics.

In this study, it is assumed that the hog farms in each hog operation group in the Heartland used the same production practices.

4. Number of hogs and quantity of manure were held constant for each farm across the scenarios in order to focus on short-term effects. By allowing number of hogs as a decision variable, the optimal solution of the baseline scenario might have determined number of hogs quite different than the constant observed in the survey. For example, under the scenario of low pork prices in 1999, the optimal solution would be to cease hog operation. Generally, under the scenario of normal pork price, reducing the number of hogs to reduce surplus manure would incur much higher cost to the farms than expanding land application of manure (Roka and Hoag, 1996; Boland, Preckel and Foster, 1998; Howard, 1999).

5. Some CAFO farms with feeder-pig-to-finish operations are contracted operators and those do not solely determine their supply of pigs. A different type of model would be needed to analyze the effect of proposed CAFO rule on supply of hogs that could affect the domestic hog prices. This is beyond our study.

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