

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 on Heartland hog farms of alternative manure management regulations on manure application. Results showed differential economic impacts on the hog operations. 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.

Key Words: *Hog manure, land application restrictions, net returns*

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Introduction

The environmental consequences of livestock production and waste management are an increasing source of public and policy concern (USEPA; GAO; Innes). The concern is particularly attributable to a trend in the U.S. hog industry toward fewer and larger farms with concentrated animal feeding operations (McBride). Recent survey results have shown that manure from those large operations is being disposed of on cropland in quantities far exceeding the capacity of the cropland to absorb it (McBride and Christensen). Applications of manure nutrients in excess of crop uptake requirements have been associated with the impairment of surface and ground water quality in some areas (USEPA; Litke). In response to the concerns about the manure produced by concentrated operations, USDA and EPA have developed a Unified National Strategy for Animal Feeding Operations (AFOs). This strategy called 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. 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 specifying 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 must meet certain conditions, or (3) if it

has fewer than 750 hogs and is designated by the permit authority. 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. For land application, CAFO operators may need to follow phosphorous (P)-based nutrient management plans (NRCS), 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. This restriction would increase hog production costs and could affect the financial well-being of hog producers.

Objective

Seventy percent of U.S. hog farms in 1998 were in the Heartland region (McBride and Christensen). Research reported here assessed the economic impact on farms in this region of three alternative restrictions on manure application by operations with 750 hogs or more. 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 hog survey was used to identify farms in the region that might be affected by alternative 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 in the farm. Types of 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.

In this study, surveyed farms affected are 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 is over 750 but less than 2,500.¹ Types of operations were farrow-to-finish and feeder-pig-to-finish. Manure types were slurry manure and lagoon liquid manure. Field application methods were incorporation into soil and spread on the soil without incorporation. Principal crops were corn (c), soybeans (s) and wheat (w). A total of 259 observations were operations in the Heartland with over 750 hogs (Table 1). Most farms

¹ CAFO farms that have fewer than 750 hogs were not included in this study because the information needed to identify these farms was not available

used slurry manure for corn-soybean and corn-soybean-wheat rotations. In total, 20 groups of farms were identified, but only 8 with ten surveyed farms or more were analyzed in order to assure reliability. These 8 groups are marked with an asterisk in the table. 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 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 the existing manured acres; (3) lease additional acreage for manure application; (4) adopt technologies to reduce nutrient loading on existing land; (5) dispose of 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.² Following the whole-farm analytical framework employed by Chase and Duffy, an individual whole farm model (IWFM) was formulated for each of 137 selected farms by using 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

² Number of hogs and quantity of manure were held constant for each farm across the scenarios to avoid difficulty in the assessment. 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 stop hog operation. Generally, under the

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:

$$(1) \text{ Maximize } Z = \left[\sum_i (p_i y_i - o_i) C_{im} - \sum_i \sum_j f_j F_{ij} C_{im} - MAC - r LS \right] + \left[\sum_i (p_i y_i - o_i - \sum_j f_j d_{ij} y_i) C_{in} \right]$$

where p_i is the price (\$/bushel) of crop i , 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 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

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

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.

scenario of normal pork price, reducing the number of hogs to reduce surplus manure would incur much higher cost

Manure Use Restriction

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

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 (1000 pounds = one animal unit) of hog capacity; and \mathbf{hog} is the hog capacity, obtained from the survey and held constant, expressed in animal units.

Per-acre Nutrients Required by Crops

$$(4) \quad F_{in} + u_n A_i - d_{in} \mathbf{y}_i + \mathbf{y}_{rs} \geq 0 \text{ for } i = rc, cc \text{ and } rs$$

$$(5) \quad F_{ip} + u_p A_i - d_{ip} \mathbf{y}_i \geq 0 \text{ for } i = rc, cc \text{ and } rs$$

$$(6) \quad F_{ik} + u_k A_i - d_{ik} \mathbf{y}_i \geq 0 \text{ for } i = rc, cc \text{ and } rs;$$

where F_{ij} is the pounds of j nutrient applied to crop i and u_j is the pounds of j nutrient in 1000 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

$$(7) \quad F_{in} + u_n A_i - d_{in} \mathbf{y}_i + \mathbf{y}_{rs} + S_{in} \leq 0 \text{ for } i = rc, cc \text{ and } rs$$

$$(8) \quad F_{ip} + u_p A_i - d_{ip} \mathbf{y}_i + S_{ip} \leq 0 \text{ for } i = rc, cc \text{ and } rs$$

$$(9) \quad F_{ik} + u_k A_i - d_{ik} \mathbf{y}_i + S_{ik} \leq 0 \text{ for } i = rc, cc \text{ and } rs;$$

to the farms than expanding land application of manure (Roka and Hoag, Boland et al., Howard).

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

$$(10) \quad C_{i=rc\ k} = C_{i=rs\ k} \text{ for } k=m \text{ and } n$$

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

$$(11) \quad MA = \sum_i A_i C_{im}$$

The right 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.). Specifically, the cost is:

$$(12) \quad MAC = [(bc) (MA)] \\ + [(mc) (MA) TD]$$

where MA is the total volume (in 1000 gallons) of manure applied to the manured field, bc is the field application cost (in \$ per 1000 gallons), and mc is the manure transportation cost (in \$ per 1000 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. The survey data provided the following inputs: **hog and y_i**, and the upper bounds of **LO**.

Technical Data and Assumptions

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-stage lagoon, and two-stage lagoon 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 respond to the restriction could incur a higher cost to a farm than expanding the land application (Boland, Preckel and Foster).
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). 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 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).

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, et al). 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).

P-restriction: Manure application rate was restricted to not exceeding 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 1000 gallons) to the farm. The 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 1000 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 farms than on medium-sized 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 (generally over 70 percent of farms) had adequate land without leasing additional land to comply with the restrictions because of their relatively low hog-to-land ratios.

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 farrow-to-finish operations than on the large farms with feeder-pig-to-finish operations. The feeder-pig-to-finish farms have higher hog-land ratios.

Net Crop Returns

The P-restriction reduced the average net crop returns from crop production portion of the hog operation for all the farms in all 8 groups, compared with the N-restriction (Table 5). Large operations had the greatest relative and absolute drops. 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 small impacts on medium-sized farms incorporating slurry into soil for the corn-soybeans-wheat rotation because these farms have 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) to most farms, many of these farms had positive crop net returns from manured acres. This indicates that most farms might be able to absorb the net cost of manure utilization. A few farms, in fact, would increase crop net returns by substituting manure for commercial fertilizers.

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.

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

Cost to Utilize Manure per Hog Sold

Knowing cost to utilize manure per hog sold can help a farm assess the viability of their hog operation. The average 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 et al, but the estimates for the P-restriction scenario were higher than theirs, due to 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 are shown in Table 7.

Farms can reduce this cost by reducing the amount of manure produced on farm or by disposing

manure off the farm. If the marginal cost is negative, farms improved net income from the last 1000 gallons applied on the farm. 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 in large farrow-to-finish operations and corn-soybeans rotation had a negative marginal cost.

The P-restriction caused a large increase of 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.

Conclusions

The environmental impacts of concentrated animal feeding operations have been an increasing source of public concern in the Heartland as elsewhere. A whole-farm approach and the information from the 1998 national hog survey were used to assess the economic impacts on Heartland hog farms of alternative manure management regulations of operations over 750 hogs. Assessment results indicate that most hog farms in the region will have higher manure application costs and lower crop net 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. The P-restriction would increase costs and reduce returns more than an N-restriction. 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.

Many assumptions were used to simplify the analysis. Changes in the assumption may impact our reported results. For example, a lower level of nutrient contents in manure (than the level assumed in this study) can significantly reduce the number of additional acres needed for the 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 would not alter our conclusions. Manure management regulations can have different economic impacts on hog producers of an integrator-operator animal production system. For further information, see Kaplan.

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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.

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

Annual manure produced (Sutton et al.)¹

<u>Type of operation</u>	<u>Slurry manure</u>		<u>Liquid (lagoon) manure</u>	
	per pig sold	per AU capacity	per pig sold	per AU capacity
	-gallons-	-1000 gallons-	-gallons-	-1000 gallons
Feeder-pig-to-finish	176	3.52	316	6.32
Farrow-to-finish	252	3.04	430	5.18

Nutrient content of manure incorporated into the soil (Sutton et al.)

<u>Slurry manure</u>			<u>Liquid (lagoon) manure</u>		
N	P2O5	K2O	N	P2O5	K2O
--- Pounds/1,000 gallons---			---Pounds/1,000 gallons--		
31.82	26.40	25.40	4.85	3.00	4.00

Nutrient content of manure spread on soil surface (Sutton et al.)

<u>Slurry manure</u>			<u>Liquid (lagoon) manure</u>		
N	P2O5	K2O	N	P2O5	K2O
---Pounds/1,000 gallons---			---Pounds/1,000 gallons---		
26.24	26.40	25.40	4.00	3.00	4.00

Nutrients needed by selected crops (Sutton et al.)

	N	P ₂ O ₅	K ₂ O
Corn (lbs./bu)	1.20	0.39	0.43
Soybeans (lbs./bu)	4.00 ²	0.91	1.91
Winter wheat (lbs./bu)	1.00	1.42	0.70

¹ 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)

² 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	Liquid (lagoon) manure
	-----Dollars/1000 gallons-----	
Base charge rate for spreading manure on soil		
Incorporation into soil	8.8	7.1
Without incorporation	7.9	5.7
Mileage charge rate	1.7	1.4

Source: Fleming et al.

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.

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.

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	-0.10 ⁴	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	\$/1000 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.