July 2006

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William F. Kissinger
University of Nebraska - Lincoln

Raymond E. Massey
University of Missouri, Department of Agricultural Economics, 223d Mumford Hall, Columbia

Richard K. Koelsch
University of Nebraska - Lincoln, rkoelsch1@unl.edu

Galen E. Erickson
University of Nebraska - Lincoln, gerickson4@unl.edu

An ASABE Meeting Presentation

Paper Number: 064142

Economics of Manure Phosphorus Distribution from Beef Feeding Operations

William F. Kissinger, M.S.
University of Nebraska, Department of Biological Systems Engineering, 154 L. W. Chase Hall, Lincoln, Nebraska 68583-0726, wkissinger@diodecom.net

Raymond E. Massey, Ph.D.
University of Missouri, Department of Agricultural Economics, 223d Mumford Hall, Columbia, Missouri 65211, masseyr@missouri.edu

Richard K. Koelsch, Ph.D.
University of Nebraska, Department of Biological Systems Engineering, 213 L. W. Chase Hall, Lincoln, Nebraska 68583-0726, rkoelsch1@unl.edu

Galen E. Erickson, Ph.D.
University of Nebraska, Animal Science Department, C220 Animal Sciences, Lincoln, Nebraska 68583-0908, geericks@unlnotes.unl.edu

Written for presentation at the
2006 ASABE Annual International Meeting
Sponsored by ASABE
Portland Convention Center
Portland, Oregon
9 - 12 July 2006

Abstract. *An economic model was developed to evaluate cost and value of manure distribution. Feedlots ranging in size from 2,500 head to 25,000 head one-time capacities were used as case studies to calculate excretion amounts from cattle fed diets with a range of phosphorus. Diet P and subsequent costs of distributing the manure were used to analyze the corresponding costs of manure distribution, in addition to determining the required available land needed to be in compliance with a nutrient management plan based on utilization of manure P by the crops grown.*

The model illustrated when animals are fed diets of increasing P concentration, total distribution cost increased, ranging from $2.10 - $6.70/hd finished/yr, as did application time (186-2810 hrs) and required spreadable hectares (130-2520 ha), but the agronomic and market value of manure produced increased at a rate faster than the rate of increasing costs of distribution for feedlots ranging in size from 2,500 to 25,000 head capacity, and land availability as low as 50%.

Keywords. Phosphorus, Nitrogen, beef cattle feedlots, manure phosphorus concentration, cost of distribution, value of manure, P based land application

Introduction

Implementation of P management, as required of Concentrated Animal Feeding Operations (CAFOs) by environmental regulation, will continue to present unique challenges to beef feedlots. Recent commercial feedlot studies (Kissinger et al., 2005) suggest the amount of P harvested in manure from beef feedlots varies with 1) level of P in the diets, and 2) requirements for use of manure solids for surface maintenance prior to manure removal. These data indicated a positive correlation between P intake and P in harvested manure in beef feeding operations. In addition, previous data (ASABE, 2005; Geisert et al., 2005) suggested P excretion is positively correlated to P intake. It is important that correct estimates of P excretion are utilized by producers if nutrient management plans (NMPs) are based on utilization of manure P.

The handling of the manure solids from beef feedlot operations requires the scraping and cleaning of the pens, stockpiling during certain times of the year, and distribution of the manure solids to the fields for land application. Distribution cost discussed in this paper is defined as beginning with the loaded manure, and the transport of the manure from the feedlot pens or stockpile area to the fields, plus the spreading of the manure on the land after transport to the individual fields. Certain costs accompany these different phases of manure handling. The costs of distribution are separate from the costs of pen maintenance and manure removal from the feedlot pen. Manure in this study is defined as a mixture of excreta (feces/urine) and soil harvested from the pen surface. This definition applies to all open-lot beef feedlot production systems.

Literature Review

Several studies have been conducted dealing with manure handling and management of the feedlot pen surface (Sweeten, 1990; Lott et al., 1994; Powell, 1994; Sweeten and Amosson, 1995). As reported in Sweeten and Amosson (1995), studies in Australia by Lott et al. (1994), using the data of Powell (1994), estimated total average costs of just over $2.10/ton for manure collection and loading (harvesting). This average harvesting cost was distributed as follows: box-scraper collection -- $1.13/ton; under-fence pushing and removal-- $0.38/ton; and loading-- $0.61/ton. The total cost range was from $0.84/ton to $3.40/ton.

An assessment of N-based manure application rates has been performed by Lory et al. (2004a) relative to swine operations in the U.S., in which they used a mechanistic model to characterize the manure management practices on 39 swine operations, both unagitated lagoons and slurry operations in five states. In addition, feasibility and costs of P application limits on U.S. swine operations were studied (Lory et al., 2004b), in which they evaluated the effect of N, annual P, and rotation P limits on the feasibility of manure management. They found that P limits increased potential manure value but would require operations to recover at least 61% of manure value through manure sales. They concluded that P limits are likely to shape the U.S. swine industry through differential effects on the various sectors of the swine industry.

Lesoing et al. (1997) reported that cost in 1994 and 1995 of turning compost was $1.25/ton, and spreading compost ranged from $2.50 to $4.75/ton, but value of N and P in compost generally ranged from $5.00 to $8.00/ton. They concluded that the value of N and P in compost usually equals or exceeds the cost of making and spreading the compost.

In review of the literature, no information was found relative to the cost of distribution of beef feedlot manure solids as a function of the inter-relationships of varying concentration of manure P, distance to haul, and application rate relative to crop needs. This information would be useful with the continued expansion of the ethanol industry; the additional by-products produced will be fed to livestock, resulting in increasing amounts of P excretion and manure P concentrations. It is important to understand the implications and effects of these higher concentrations of manure P on costs of distribution.

Objective

Costs of manure transport and distribution are critical information, but information is limited. The savings from least cost rations based on a corn processing by-product may be offset by the additional cost of handling manure. An economic model for manure distribution that reflects P excretion variation with P intake can assist in development of NMPs for feedlots. Thus, the objective of our project was to develop an economic analysis for proper distribution of manure P linked to dietary P and agronomic utilization in various crop rotations, in addition to land and time requirements for manure distribution.

Procedure

Software Model Development

An economic model was developed to calculate nutrient excretion amounts from cattle fed diets with a variable range of P, and analyze the corresponding costs of manure distribution. Software development incorporated appropriate features from existing models, previously developed by researchers at University of Nebraska (Koelsch et al., 2006) and University of Missouri (Lory et al., 2004a), for calculation of nutrient excretion amounts and analysis of manure distribution cost, respectively. Lazarus and Selley (2005) developed farm machinery economic cost estimates, which were referenced and used in the portion of the model previously developed by University of Missouri researchers.

Excretion equations used in the model were based upon the revised ASABE Standard (2005) D384.2, Manure Production and Characteristics. Nutrient intake was calculated using dietary nutrient concentration of each diet multiplied by dry matter intake (DMI). Cattle nutrient retention was calculated according to the retained energy and protein equations established by the National Research Council (1996) for beef cattle. Equations used for beef excretion characteristics were based upon a calculation of dietary intake minus animal retention, the approach used by the ASABE nutrient excretion standard.

Model Data Input Variables

The software is designed to have flexibility of application of input variables. Table 1 shows values assumed in the model as constants, which can be changed if desired.

The model allows the user to enter farm specific information for all variables listed in Table 1. For instance, the value used for the tractor and spreader was $94,000 for the160 hp tractor, and $13,000 for the 14.5 metric ton manure spreader. The value for the 300 hp truck chassis was $50,000, with $20,000 value placed on the 18.2 metric ton capacity mounted manure spreader. In discussion with equipment dealers, the author believed these values to be representative.

Table 1. Case study comparison model data input assumed values (constants).

Initial BW, kg[a]		340
Finish BW, kg[a]		567
Average days fed[a]		153
Average DMI, kg[b]		10.2
% of excreted N available after losses in pen		40%
% of excreted P available after losses in pen		95%
Wet manure, kg/hd/d		7.2
NH_4-N:Total N		1:5
Nutrient availability		
NH_4-N	Continuous corn:	0% (no incorporation)
Organic N	Continuous corn:	50%
Organic N	Corn-Soybeans	32%
Annual crop removal, kg P_2O_5 (kg P)		
11,612 kg/ha corn harvested for grain		37.6 kg (16.3 kg)
3,363 kg/ha soybeans		20 kg (8.6 kg)
Fertilizer market value[e], $/kg		
N		$0.086
P_2O_5		$0.118
Ownership and Operating Costs		
Tractor (160 hp) and spreader[c]		$107,000
Truck (300 hp) and spreader (18.2 metric ton)[d]		$70,000
Years to replace		10 years
Fuel[e]		$0.396/L.
Labor[e]		$10.00/hr
Interest (%/yr)		8%
Insurance (%/yr)		1%
Road speed	(tractors)	16.1 km/h
	(trucks)	72.9 km/h
Field speed		8.1 km/h
Spreader capacity	(pull type)	14.5 metric ton
	(truck mounted)	18.2 metric ton
Swath width		3.66 meters

[a]Assumed values based on similar values based on performance of approximately 14 million cattle fed from 1996 to 2002, as referenced by Erickson et al. (2003).

[b]Average dry matter intake is author's selection for assumed value based on average of commercial feedlot study reported by Kissinger et al. (2005).

[c]Lazarus and Selley, (2005)

[d]Pullen (2005)

[e]USDA (2005)

Case Study Feedlot Scenarios

Case studies were designed to help define the economic issues associated with feeding dietary P, and the costs of distributing manure on a P basis. In our case studies, theoretical 2,500 head, 10,000 head, and 25,000 head one-time capacity feedlots, averaging 340 kg in weight and 567 kg finish weight in 153 d, with two turns of cattle per year, were used to quantify the manure and nutrients harvested from cattle fed various combinations of diet P and crude protein (CP). The economics of distribution of manure based upon a P rate were evaluated. Cattle ration was varied to represent a corn and forage diet and diets containing 10%, 20%, 30%, and 40% corn replacement with distiller's grains from ethanol production. The resulting dietary P levels ranged from 0.29 to 0.49% (dry matter basis).

In addition, for the 2,500 head feedlot, scenarios were developed for 2-year and 4-year application rates for P with various CP and diet P levels. All of these variables were compared for continuous corn (CC) and corn-soybean (C-SB) crop rotations. These scenarios were initially run with the assumption of 100% access to land available for manure application.

Subsequent scenarios were studied for the 2,500 head, 10,000 head, and 25,000 head one-time capacity feedlots with 50% of the acres available for a C-SB crop rotation utilizing a 4-year application rate for P with the various CP and diet P levels.

Manure Nutrient Utilization

Excreted manure N and P levels were estimated based upon procedures from ASABE (2005). Based on the average values from the studies in commercial feedlots (Kissinger et al., 2005), the model calculates annual manure production. After accounting for open lot and stockpiled storage losses, manure nutrient concentration is determined.

With the total N, P_2O_5, and K_2O kg/metric ton of manure determined, the manure application rate is calculated based upon the nutrient utilization of the desired crop in the specified rotation. In this study, the NH_4-N to organic N ratio was set at 1:5. It was assumed that no NH_4-N would be available to the crop based upon the assumption that manure would not be incorporated. Fifty percent of the organic N is credited for crop utilization for continuous corn and 32% for corn-soybeans. The model has the flexibility to determine manure application rates, on either P basis or N basis, as a function of nutrient concentration of the manure and nutrient removal rates (Table 1) for the specific crop yield of the CC or C-SB crop rotation grown. A nitrogen value was assigned only for corn.

The spreadable hectares needed to utilize the annual manure produced were calculated from the annual manure produced divided by the average manure application rate for the rotation crops. This information is needed in a NMP.

Average Distance to Fields

For simplicity, it was initially assumed that 100% of the land nearby the 2,500 head feeding operation was available for manure application. Thus, the average distance to fields is relatively low. In reality, this may not be the case, but the model has the capability to adapt to individual field locations available for manure application. In subsequent scenarios, comparisons were made for the 2,500 head, 10,000 head, and 25,000 head feedlots with the assumption of 50% of the land available for manure application.

With a four-year planning horizon for land needed for manure application, the distances to the necessary fields for the case studies were determined in each of the four quadrants surrounding the feedlot, with the feedlot at the center point. Thus, in year one of the planning horizon, the land available for manure application was located in Quadrant I; year two, Quadrant II, etc. The model calculated travel time for transport and spreading of the manure as a function of road travel and field travel speeds of the tractors or trucks.

Economic Procedures

The model tracts the equipment ownership and operating costs (Table 1) relative to value of the tractor(s), or truck chassis(s), and spreader(s), years to replace, salvage value, depreciation, interest, insurance, repair, and costs of fuel and labor (Lazarus and Selley, 2005). In addition, loading time, equipment capacities and swath width, road travel time, field travel time, total loaded miles, and total road miles are variables which affect costs of transporting and distributing manure.

The model is intended to be used by feedlot operators to estimate the cost of distributing the resultant manure on land. For individual feeding operations, the costs of scraping the pens, storage, and loading the manure remain constant, regardless of the P concentration in the manure. Thus, those costs were not included in this study and this model. As the manure P concentration varies, the other variables in the model are distance required to transport the manure, and the necessary spreading of the manure to be in compliance with a NMP based on utilization of manure P by the crops grown. It is important to emphasize, in all case studies in this model, cost of transport plus cost of spreading, together are defined as total cost of distribution. The output is cost of distribution of manure specific to diet P concentration. The value of the manure minus the cost of distribution equals the net manure value.

Results and Discussion

As example of the numerous case study scenarios investigated, Table 2 shows a representative comparison of manure distribution economics on an annual basis for a 2,500 head feedlot.

Table 2. Comparison of manure distribution economics (annual basis) for five diets fed at 2,500 head feedlot. Land application of manure assumes 1) continuous corn, 2) two year P-based application rate and 3)100% of land is available. [a]

Distiller's grains displacement of corn	0%	10%	20%	30%	40%
Phosphorus % in diet (DM basis)	0.29	0.34	0.39	0.44	0.49
Crude protein % in diet (DM basis)	13.00	13.60	15.30	16.90	18.70
Required hectares per yr	200	250	300	340	380
Average distance to fields (km)	0.29	0.39	0.45	0.50	0.53
Manure application rate (metric ton/ha)	26.9	22.0	18.6	16.1	14.3
Total application time (hours)	230	260	300	330	360
Total cost of distribution	$16,800	$18,200	$19,500	$20,700	$21,900
Total fertilizer value of manure	$31,300	$36,600	$42,900	$49,100	$55,500
Net manure value[b]	$14,400	$18,400	$23,500	$28,400	$33,600

[a] Comparisons are for annual manure production of 5,450 metric tons from case study 2,500 head one time capacity cattle feedlot with open dirt pens, 5,000 head annual production.

[b] Net manure value = fertilizer value of manure minus total cost of distribution on fields for various crops.

In the 2,500 head case study with 100% land available (Table 2), as the manure P concentration increased as a result of increased diet P concentration, the manure application rate decreased and the required hectares increased. Correspondingly, the total application time and average distance to the fields increased as diet P concentration increased. The downside of these factors was the resultant increase in total cost to distribute the manure.

A feedlot will need to have access to increased land (up to 90%) and additional labor (increase by 45 to 65%) to meet the increased requirements for manure application to manage the additional P. On the positive side, high P diet increased the fertilizer value of manure faster than it increased the cost of distribution.

It must be reiterated that the total cost of distribution is defined herein as the costs of transport to and spreading of the manure on the necessary fields in the land application process. Distinctly, the costs of handling the manure prior to transport are not included in the total costs of distribution. They are not a function of diet P level, whereas costs of transport and spreading are directly related to diet P level, and fluctuate as a function P concentration in the diet.

Another interesting perspective is to compare these scenarios on the basis of net value of manure per animal finished per year, defined as follows:

$$\left(\frac{manure\ fertilizer\ value}{annually\ finished\ animals}\right)-\left(\frac{distribution\ cost}{annually\ finished\ animals}\right)=\left(\frac{net\ manure\ value}{annually\ finished\ animals}\right)$$

If a true fertilizer market value is placed on the manure and the cost of distribution of the manure is evaluated, then the net manure value per head can be determined by the model.

The results of the second set of scenarios studied in the economic model are summarized in Tables 3–9. In this group of scenarios, it was assumed that 50% of the land surrounding the case study feedlots was available for land application of the manure P, replacing the initial assumption of 100% available land. Table 3 shows a comparison of manure distribution economics on an annual basis, with various scenarios of distiller's grains displacement of corn in the diet for corn-soybeans rotation on a four-year P manure application basis for a 2,500 head feedlot with 50% land availability. In addition to the 2,500 head capacity feedlot, a 10,000 head, and a 25,000 head one-time capacity case study feedlots were included in subsequent scenarios studied.

Table 3. Comparison of manure distribution economics (annual basis) with various scenarios of distiller's grains displacement of corn in the diet for corn-soybeans rotation on four year P manure application basis for 2,500 head feedlot with 50% land availability.[a]

Distiller's grains displacement of corn	0%	20%	40%
Manure application equipment:[b]	1 Tractor/ Spreader	1 Tractor/ Spreader	1 Tractor/ Spreader
Cropping system / Results		Corn-soybean	
Spreadable hectares in fields/yr	130	190	250
Average distance to fields (km)	0.44	0.81	1.18
Manure application rate (metric ton/ha)	41.2	28.4	21.7
Total application time (hours)	186	244	302
Total cost of distribution	$15,200	$17,500	$19,600
Total fertilizer value of manure	$27,900	$38,800	$50,400
Fertilizer value of manure ($/metric ton)	$5.10	$7.10	$9.20
Cost per animal finished per year	$3.00	$3.50	$3.90
Net manure value[c]	$12,700	$21,300	$30,800
Net manure value/hd finished[d]	$2.50	$4.30	$6.10

[a] Comparisons are for annual manure production of 5,450 metric tons from case study 2,500 head one time capacity cattle feedlot with open dirt pens, 5,000 head annual production.

[b] 160 hp. tractor pulling 14.5 metric ton capacity manure spreader.

[c] Net manure value = fertilizer value of manure minus total cost of distribution on fields.

[d] Net manure value/hd finished = (fertilizer value of manure minus total cost of distribution)/annually finished animals.

As size of feedlot and numbers of annually fed cattle increased, resulting increased distances and time required for transport of manure dictated the use of larger and speedier manure application equipment in the model. The case studies attempted to keep the equipment matched to realistic windows of opportunity for application of manure within realistic time constraints and capabilities to handle the material. These various scenarios are described in the tables as a function of P concentration in the diets resulting from various levels of distiller's grain.

Table 4 compares the manure distribution economics (annual basis) for a 10,000 head one-time capacity feedlot with 50% land availability, as a function of various diets and manure application equipment. It becomes apparent that the equipment capabilities and investment need to be matched to the requirements for manure application, as a function of diet P concentration. For example, in the scenario with 0.29% P concentration in the diet (0% distiller's grains), one tractor and 14.5 metric ton manure spreader requires 1070 hours for application. The window of opportunity dictated by seasons and annual management practices is unlikely to afford such time. When a second tractor/spreader unit was included to land apply the manure, the application time was divided between the two units (535 hrs each). But, net manure value per annually finished animal decreased from $3.40 down to $2.50/animal finished, due to increased cost. On the other hand, when two trucks with 18.2 metric ton capacity mounted spreaders replaced the two tractor/spreader units, the net manure value increased to $3.50/ finished animal. This was a function of the increased road travel speed and manure hauling capacity, and lower capital investment assumed for the truck/spreader units listed in Table 1 (72.9 km/h, 18.2 metric ton, and $70,000, respectively) compared to the tractor/spreader units (16.1 km/h, 14.5 metric ton, and $107,000, respectively).

Table 4. Comparison of manure distribution economics (annual basis) with various scenarios of distiller's grains displacement of corn in the diet for corn-soybeans rotation on four year P manure application basis for 10,000 head feedlot with 50% land availability.[a]

Distiller's grains displacement of corn	0%	0%	0%	20%	40%	40%
Manure application equipment:[b,c]	1 Tractor	2 Tractors	2 Trucks	2 Trucks	2 Trucks	3 Trucks
Cropping system / Results			Corn-soybean			
Spreadable hectares in fields/yr	530	530	530	770	1010	1010
Average distance to fields (km)	2.19	2.19	2.19	2.75	3.40	3.40
Application rate (metric ton/ha)	41.2	41.2	41.2	28.4	21.7	21.7
Total application time (hours)	1 070	1070	675	860	1038	1038
Total cost of distribution	$43,000	$62,000	$42,000	$53,000	$65,000	$81,000
Total fertilizer manure value	$111,000	$111,000	$111,000	$155,000	$201,000	$201,000
Manure fertilizer value ($/metric ton)	$5.10	$5.10	$5.10	$7.10	$9.20	$9.20
Cost per animal finished per year	$2.10	$3.10	$2.10	$2.70	$3.30	$4.10
Net manure value	$69,000	$49,000	$69,000	$102,000	$136,000	$121,000
Net manure value/hd finished	$3.40	$2.50	$3.50	$5.10	$6.80	$6.00

[a] Comparisons are for annual manure production of 22,000 metric tons from case study 10,000 head one time capacity cattle feedlot with open dirt pens, 20,000 head annual production.

[b] 160 hp. tractor pulling 14.5 metric ton capacity manure spreader.

[c] 300 hp. trucks with mounted 18.2 metric ton capacity manure spreaders.

Another example of matching equipment to the demand to spread the manure in a timely manner (within the seasonal windows of opportunity) is illustrated (Table 4) in the 0.49% diet P concentration (40% distiller's grains). Three truck/spreader units can distribute the 22,000 metric tons of manure in 350 hrs/truck compared to 520 hrs/ truck with just two units. However, the additional investment in the third unit to handle the same value of manure results in a reduction of net manure value from $6.80 to $6.00/animal finished for the 10,000 head capacity feedlot.

Likewise, Table 5 illustrates the comparison of manure distribution economics (annual basis) for a 25,000 head one-time capacity feedlot with 50,000 head fed annually, utilizing a corn-soybean rotation and a four-year P manure application basis, with 50% land availability. Again, the effect of different manure application equipment investment and ability to distribute the 55,000 metric tons of manure is illustrated.

The use of four trucks instead of three units at the 0% distiller's grains level, and five trucks utilized in place of four units at the 40% distiller's grains scenario further illustrate how enough equipment, sized to handle the proper distribution of the amount of manure produced within the window of opportunity, can increase the total cost of distribution. In this case, the net manure value/hd finished decreased $0.50 and $0.90/hd finished at the 0% and 40% distiller's grains level, respectively, as the number of application units increased by one unit. The advantage of this increase is that each truck/spreader increase took pressure off of completing the manure application task, better enabling the job to be accomplished within the limited window of opportunity provided by environmental and management conditions.

Table 5. Comparison of manure distribution economics (annual basis) with various scenarios of distiller's grains displacement of corn in the diet for corn-soybeans rotation on four year P manure application basis for 25,000 head feedlot with 50% land availability.[a]

Distiller's grains displacement of corn Manure application equipment:[b]	0% 3 Trucks	0% 4 Trucks	20% 4 Trucks	40% 4 Trucks	40% 5 Trucks
Cropping system / Results		Corn-soybean			
Spreadable hectares in field/yr	1330	1330	1930	2520	2520
Average distance to fields (km)	4.1	4.1	5.0	5.8	5.8
Application rate (metric ton/ha)	41.2	41.2	28.4	21.7	21.7
Total application time (hours)	1840	1840	2330	2810	2810
Total cost of distribution	$128,000	$152,000	$215,000	$288,000	$336,000
Total fertilizer value of manure	$278,000	$278,000	$388,000	$504,000	$504,000
Manure fertilizer value ($/metric ton)	$5.10	$5.10	$7.10	$9.20	$9.20
Cost per animal finished per year	$2.60	$3.00	$4.30	$5.75	$6.70
Net manure value	$150,000	$127,000	$173,000	$216,000	$168,000
Net manure value/hd finished	$3.00	$2.50	$3.50	$4.30	$3.40

[a] Comparisons are for annual manure production of 55,000 metric tons from case study 25,000 head one time capacity cattle feedlot with open dirt pens, 50,000 head annual production.

[b] 300 hp. trucks with mounted 18.2 metric ton capacity manure spreaders.

Again, as had occurred with the 2,500 head capacity feedlot with 100% land availability, with the 25,000 head feedlot scenario, even with 50% land availability and the need to transport the manure farther, the high P diet increased the fertilizer value of manure faster than it increased the cost of distribution. This trend did not change as the size of the feedlot increased from 2,500 to 25,000 head capacity, and as the manure transport requirement was increased. As diet P increased from 0.29% to 0.49% (0% to 40% distiller's grains replacement of corn) for the 25,000 head yard (Table 5), the cost per animal finished ranged from $2.60 to $6.70 and the net manure value ranged from $2.50 to $4.30/hd.

Table 6. Comparison of annual fertilizer value[a] (50% land available) with selected diets (increasing CP and P concentrations), C-SB crop rotation, and four-year basis of P manure application.[b]

Base Scenarios: C-SB rotation Feedlot capacity (hd., one time):		2,500[c]	10,000[d]	25,000[e]
0% By-product	13.0 % CP, 0.29% P	\$27,900	\$111,000	\$278,000
20% By-product	15.3 % CP, 0.39% P	\$38,800	\$155,000	\$388,000
40% By-product	18.7 % CP, 0.49% P	\$50,400	\$201,000	\$504,000

[a] Fertilizer value = total fertilizer N and P_2O_5 market value of manure.

[b] Phosphorus application rate for four years' crop utilization.

[c] Comparisons are for annual manure production of 5,450 metric tons from case study 2,500 head one time capacity cattle feedlot with open dirt pens, 5,000 head annual production.

[d] Comparisons are for annual manure production of 22,000 metric tons from case study 10,000 head one time capacity cattle feedlot with open dirt pens, 20,000 head annual production.

[e] Comparisons are for annual manure production of 55,000 metric tons from case study 25,000 head one time capacity cattle feedlot with open dirt pens, 50,000 head annual production.

Table 7. Comparison of annual P value[a] (50% land available) with selected diets (increasing CP and P concentrations), C-SB crop rotation, and four-year basis of P manure application.[b]

Base Scenarios: C-SB rotation Feedlot capacity (hd., one time):		2,500	10,000	25,000
0% By-product	13.0 % CP, 0.29% P	\$21,800	\$87,200	\$218,000
20% By-product	15.3 % CP, 0.39% P	\$31,500	\$126,000	\$315,000
40% By-product	18.7 % CP, 0.49% P	\$41,300	\$165,000	\$413,000

[a] Annual P value = Total P value to the crop per year by application basis.

[b] Phosphorus application rate for four years' crop utilization.

Tables 6–8 show a comparison of annual total fertilizer value, annual P value, and annual net manure value, respectively, for the three different sized feedlots with the increasing levels of CP and P in the diets, and 50% of land available for manure spreading for crop fertilization, utilizing a four-year basis of P manure application.

In Tables 6 and 7 (50% land available, C-SB rotation), the values for annual fertilizer manure value (total fertilizer N and P_2O_5 market value of manure), and annual P value (total P value to the crop per year by application basis), increase as the diet CP and P levels increase. It is interesting to also note the rapid increase in these values as the capacities and annual production of the feedlots increase. It should be noted that at the higher P concentrations the contribution of fertilizer value by the P relative to the total annual fertilizer value of the manure surpasses 80%.

Table 8. Comparison of annual net manure value[a] (50% land available) with selected diets (increasing CP and P concentrations), C-SB crop rotation, and four-year basis of P manure application.[b]

Base Scenarios: C-SB rotation Feedlot capacity (hd., one time):		2,500	10,000	25,000
0% By-product	13.0 % CP, 0.29% P	\$12,700[c]	\$69,000[c] \$49,000[d] \$69,000[e]	\$150,000[f] \$127,000[g]
20% By-product	15.3 % CP, 0.39% P	\$21,300[c]	\$102,000[e]	\$173,000[g]
40% By-product	18.7 % CP, 0.49% P	\$30,800[c]	\$136,000[e] \$121,000[f]	\$216,000[g] \$168,000[h]

[a] Net manure value = (total fertilizer N and P_2O_5 market value of manure) minus total cost of distribution on fields for various crops.

[b] Phosphorus application rate for four years' crop utilization.

[c] Utilized one 160 hp tractor pulling 14.5 metric ton manure spreader.

[d] Utilized two 160 hp tractors pulling 14.5 metric ton manure spreaders.

[e] Utilized two 300 hp truck with mounted18.2 metric ton manure spreaders.

[f] Utilized three 300 hp trucks with mounted18.2 metric ton manure spreaders.

[g] Utilized four 300 hp trucks with mounted18.2 metric ton manure spreaders.

[h] Utilized five 300 hp trucks with mounted18.2 metric ton manure spreaders.

Table 8 compares the annual net manure value (total fertilizer N and P_2O_5 market value of manure minus total cost of distribution on fields for various crops). It is important to remember, the total cost of distribution is defined here only as the cost of transport to and spreading on the fields, and does not include the costs associated with handling the manure within the pen or stockpile area. It should also be noted, again, the net manure value decreased for a given diet scenario when additional application equipment was owned and operated in order to handle the manure properly within the window of opportunity.

The comparison of total land area needed in a four-year planning horizon, with increasing P concentrations and a C-SB crop rotation is shown in Table 9 for the range in feedlot sizes in our study with 50% available land. The total acres needed are the annual acres multiplied by the four year planning horizon, which is dictated by the P application rate for four years' corn-soybeans crop rotation utilization of P. As the P concentration increases in the diet the amount of land required for proper distribution of the manure also increases. In real-world situations, the increase in land base for manure application would come from purchase and ownership, easements to apply manure on others' land, or selling the manure to a second party.

Table 9. Comparison of total hectares needed[a] (50% land available) in a four-year planning horizon with selected diets (increasing CP and P concentrations), C-SB crop rotation, and four-year basis of P manure application.[b]

Base Scenarios: C-SB rotation Feedlot capacity (hd., one time):		2,500	10,000	25,000
0% By-product	13.0 % CP, 0.29% P	530	2,100	5,300
20% By-product	15.3 % CP, 0.39% P	770	3,100	7,700
40% By-product	18.7 % CP, 0.49% P	1000	4,100	10,000

[va] Total acres needed = annual acres multiplied by the number of years in the application rate limit.

[b] Phosphorus application rate for four years' crop utilization.

Conclusion

The model illustrated that when animals are fed diets of increasing P concentration, there are positive and negative aspects.

- On the downside, there was an increase in application time and required spreadable hectares receiving the increasing P manure concentrations, due to the decreasing rates of manure application. From the perspective of cost of distribution, lower diet P concentration is better than higher diet P values.
- On the upside, increased diet P results in higher manure fertilizer value. The agronomic value of manure produced increased at a rate faster than the rate of increasing costs of distribution resulting in a continued positive net manure value. This has a positive implication to the beef cattle industry.
- With 50% land availability, this trend did not change as the size of the feedlot increased from 2,500 to 25,000 head capacity, and as the manure transport requirement was increased.
- As higher diet P concentrations from feeding increasing amounts of by-products from ethanol production result in higher manure P concentrations, it is potentially beneficial to distribute the higher value manure in compliance with the nutrient management plan based on utilization of manure P by the crops grown.

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