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Summary

An economic model was developed to evaluate cost and value of manure distribution. A 2,500 head feedlot was used as a case study to calculate excretion amounts from cattle fed diets with a range of phosphorus. Diet P and subsequent costs of distributing that manure were used to analyze the corresponding costs of manure P distribution, in addition to determining the required acres needed to be in compliance with a nutrient management plan (NMP) based on use 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 $2.80 - $5.10/head finished/year, but the agronomic and market value of manure produced increased at a rate faster than the rate of increasing costs of distribution for a small feedlot.

Introduction

Implementation of P management, as required by environmental regulation, will continue to present unique challenges to beef feedlots. Recent work (*2006 Nebraska Beef Cattle Report*, pp 94-97) suggests the amount of P harvested in manure from beef feedlots varies with 1) level of P in the diets 2) individual pen conditions prior to and at time of manure harvesting, and 3) requirements for use of manure solids for surface maintenance prior to harvesting. These data indicated a positive correlation between P intake and P in harvested manure in beef feeding operations. In addition, previous data (*2005 Nebraska Beef Cattle Report*, pp51-53.) suggested P excretion is positively correlated to P intake. It is important that correct estimates of P excretion are used by producers if NMPs are based on use of manure P.

Costs of manure P 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 P. An economic model that reflects P excretion from P intake and retention for individual operations can assist in development of NMPs for feedlots. Thus, the important objective of our project was to develop an economic analysis for proper distribution of manure P relative to dietary P and agronomic use in various crop rotations.

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 P distribution. Software development incorporated appropriate features from existing models, previously developed by researchers at University of Nebraska and University of Missouri, for calculation of nutrient excretion amounts and analysis of manure distribution cost, respectively.

Equations used in the model were based upon the revised ASAE Standard D384.2, Manure Production and Characteristics. Nutrient intake was calculated using dietary nutrient concentration of each diet fed multiplied by 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 ASAE 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 such as average starting and finishing weights, average days on feed, feedlot capacity and turns of cattle/year; diet nutrient concentration; manure handling equipment values and capacities utilizing truck or tractor spreading equipment; fuel prices, fertilizer nutrient market values; loading time, travel speed, and spreading calibrations; various crop rotations; and, land available for distribution of manure nutrients, distance from the feeding operation, and crop removal rates of nutrients based upon crop and yield.

Case Study Feedlot Scenario

A case study was 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 study, a theoretical 2,500 head one-time capacity feedlot, averaging 750 lb in weight and 1250 lb finish weight in 153 days, with two turns of cattle per year, was used to quantify the manure and nutrients harvested from cattle fed various combinations of diet P and CP. Multiple situational scenarios were identified for analysis of the economics of distribution of manure P harvested from cattle fed diets with a range from 0.29-0.49 % P (DM basis), illustrating a range from a corn and forage base diet, to diets with 10%, 20%, 30%, and 40% corn replacement with by-product from ethanol production. Analyses were performed increasing the diet % CP and % P concurrently as by-product % increased. In addition, scenarios were developed for 2- and 4-year application rates for P with various CP and diet P levels. All of these

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

Initial BW, lb		750
Finish BW, lb		1250
Average days fed		153
Average DMI, lb		22.5
% of excreted N available after losses in pen		40%
% of excreted P available after losses in pen		95%
Wet manure, lb/head/d		15.9
NH_4-N:Total N		1:5
Nutrient availability		
NH_4-N	Continuous corn:	0%
Organic N	Continuous corn:	50%
Organic N	Corn-Soybeans	32%
Annual crop removal, lbs P_2O_5 (lbs P)		
185 bu. corn harvested for grain		83 lb (36 lb)
50 bu. soybeans		44 lb (19 lb)
Fertilizer market value, $/lb		
N		$0.19
P_2O_5		$0.26
Ownership and Operating Costs		
Tractor (160 hp) and spreader		$107,000
Years to replace		10 years
Salvage value		$34,000
Fuel		$1.50/gal
Labor		$10.00/hr
Interest (%/year)		8%
Insurance (%/year)		1%
Road speed		10 mph
Field speed		5 mph
Spreader capacity		16 ton
Swath width		12 feet

variables were compared for continuous corn (CC) and corn-soybean (C-SB) crop rotations to analyze the crop rotation effect.

Manure Nutrient Concentration

Based on the average values from previous studies (*2006 Nebraska Beef Cattle Report,* pp. 94-97*),* the model calculates annual manure production, and after accounting for open lot or feedlot scraped or stockpiled storage losses, manure nutrient concentration is determined.

Crop Removal Value of Manure Nutrients

With the total N, P_2O_5, and K_2O lb/ton of manure determined, the manure application rate is calculated based upon the nutrient use of the desired crop in the specified rotation. In this study, for total N, the NH_4-N to organic N ratio was set at 0.20:0.80, and it was assumed that no NH_4-N would be available to the crop. The reasoning was the assumption, in most cases the manure would not be incorporated soon after surface application and any remaining NH_4-N would be lost. Fifty percent of the organic N is credited for crop use 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 specific crop grown. No nitrogen credit was given when applied to legumes; the only N value was credited for removal by growing corn.

Spreadable Acres Needed

The spreadable acres needed to use 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. The model did not incorporate the cost of additional land ownership, or expenses related to control of added land for manure distribution.

Average Distance to Fields

For simplicity, the assumption in this case study was that all land nearby the feeding operation was available for manure application. Thus, the average distance to fields is relatively low in the scenarios investigated. In reality, this may not be the case, but the model has the capability to adapt to individual field locations available for manure application for each individual feedlot. Likely, at most, only half the land would be available. This is easy to adjust in the model by increasing the average distance to fields variable. Doing so will increase the costs of distribution, and the results will be more conservative.

Equipment Ownership and Operating Costs

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. In addition, 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.

Costs of Distribution: Costs of Transporting and Spreading Manure

When the farm specific amount of manure P has been established for the individual diet P concentration used in an individual beef feedlot, and the equipment ownership and operating costs have been determined, the model is intended to be used by feedlot operators to estimate the cost of distributing the resultant manure P on land. For individual feeding operations, the costs of scraping the pens, storage, and loading the manure remain constant, regardless 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 use of manure P by the crops grown. In this model, cost of transport plus

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Table 2. Case study comparison of manure P distribution economics (annual basis) with various scenarios of diet percentage P and percentage CP levels for continuous corn (harvested as grain) and corn-soybeans on two year P manure application basis.[a]

Manure applied on:	---Two-year P basis---									
Phosphorus % in diet (DM basis)	0.29	0.34	0.39	0.44	0.49	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	13.00	13.60	15.30	16.90	18.70
Cropping system / Results	Continuous corn					Corn-soybeans				
Spreadable acres in fields	500	620	730	840	950	660	810	950	1100	1250
Average distance to fields (mile)	0.18	0.24	0.28	0.31	0.33	0.26	0.30	0.33	0.42	0.49
Manure application rate (ton/A)	12.0	9.8	8.3	7.2	6.4	9.2	7.5	6.4	5.5	4.9
Total application time (hours)	230	260	300	330	360	280	320	360	410	450
Total cost of distribution	$16,800	$18,200	19,500	$20,700	$21,900	$18,700	$20,300	$21,900	$23,600	$25,300
Total fertilizer value of manure	$31,300	$36,600	42,900	49,100	$55,500	$27,900	$33,000	$38,800	$44,500	$50,400
Fertilizer value of manure ($/ton)	$5.20	$6.00	$7.10	$8.10	$9.20	$4.60	$5.50	$6.40	$7.40	$8.30
Cost per animal finished per year	$3.40	$3.60	$3.90	$4.10	$4.40	$3.70	$4.10	$4.40	$4.70	$5.10
Net manure value[b]	$14,400	$18,400	$23,500	$28,400	$33,600	$9,000	$12,700	$16,900	$20,900	$25,100
Net manure value/head finished[c]	$2.90	$3.70	$4.70	$5.70	$6.70	$1.80	$2.50	$3.40	$4.20	$5.00

[a]Comparisons are for annual manure production of 6,000 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.
[c]Net manure value/head finished = fertilizer value of manure minus total cost of distribution divided by annually finished animals.

cost of spreading, together are defined as cost of distribution. The output is the variation in cost of distribution of manure P as a result of variation in diet P concentration. The value of the manure minus the cost of distribution equals the net manure value, as a function of diet P concentration. In addition, the cost of distribution per animal fed annually is determined.

Results

In all scenarios in this case study (Tables 2 - 4), as the spreadable P manure concentration increased as a result of increased diet P concentration, the manure application rate decreased and the spreadable acres required for all crop rotations 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. This ranged from a low cost (Table 3) of $14,000 for the four-year continuous corn scenario with 0% by-product to a high cost (Table 2) of

Table 3. Case study comparison of manure P distribution economics (annual basis) with various scenarios of diet percentage P and percentage CP levels for continuous corn (harvested as grain) on four year P manure application basis.[a]

Manure applied on:	---Four-year P basis---				
Phosphorus % in diet (DM basis)	0.29	0.34	0.39	0.44	0.49
Crude protein % in diet (DM basis)	13.0	13.60	15.30	16.90	18.70
Cropping system / Results	Continuous corn				
Spreadable acres in fields	250	310	360	420	480
Average distance to fields (mile)	0.18	0.24	0.28	0.31	0.33
Manure application rate (ton/A)	24.1	19.7	16.7	14.4	12.7
Total application time (hours)	160	180	200	210	230
Total cost of distribution	$14,000	$14,800	$15,500	$16,300	$17,000
Total fertilizer value of manure	$29,800	$36,400	$42,900	$49,100	$55,500
Fertilizer value of manure ($/ton)	$4.90	$6.00	$7.10	$8.10	$9.20
Cost per animal finished per year	$2.80	$3.00	$3.10	$3.30	$3.40
Net manure value[b]	$15,800	$21,600	$27,400	$32,900	$38,500
Net manure value/head finished[c]	$3.20	$4.30	$5.50	$6.60	$7.70

[a]Comparisons are for annual manure production of 6,000 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.
[c]Net manure value/head finished = (fertilizer value of manure minus total cost of distribution)/annually finished animals.

Table 4. **Case study comparison of manure P distribution economics (annual basis) with various scenarios of diet percentage P and percentage CP levels for corn-soybeans on four year P manure application basis.[a]**

Manure applied on:	---------------------------Four-year P basis---------------------------				
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
Cropping system / Results	Corn-soybeans				
Spreadable acres in fields	330	400	480	550	620
Average distance to fields (mile)	0.26	0.30	0.33	0.42	0.49
Manure application rate (ton/A)	18.4	15.0	12.7	11.0	9.7
Total application time (hours)	190	210	230	260	280
Total cost of distribution	$15,100	$16,000	$17,000	$18,000	$19,000
Total fertilizer value of manure	$27,800	$33,000	$38,800	$44,500	$50,400
Fertilizer value of manure ($/ton)	$4.60	$5.50	$6.40	$7.40	$8.30
Cost per animal finished per year	$3.00	$3.20	$3.40	$3.60	$3.80
Net manure value[b]	$12,700	$17,000	$21,800	$26,600	$31,400
Net manure value/head finished[c]	$2.60	$3.40	$4.40	$5.30	$6.30

[a]Comparisons are for annual manure production of 6,000 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.
[c]Net manure value/head finished = fertilizer value of manure minus total cost of distribution divided by annually finished animals.

Table 5. **Case study comparison of annual total fertilizer value[a] with selected diets (increasing CP and P concentrations), crops, and basis of P manure application.[b]**

		Continuous corn		C-SB	
Base Scenarios:		P2[c]	P4[d]	P2[c]	P4[d]
0% By-product	13.0 % CP, 0.29% P	$31,300	$29,800	$27,900	$27,800
10% By-product	13.6 % CP, 0.34% P	$36,600	$36,400	$33,000	$33,000
20% By-product	15.3 % CP, 0.39% P	$42,900	$42,900	$38,800	$38,800
30% By-product	16.9 % CP, 0.44% P	$49,100	$49,100	$44,500	$44,500
40% By-product	18.7 % CP, 0.49% P	$55,500	$55,500	$50,400	$50,400

[a]Total fertilizer value = total fertilizer N and P_2O_5 market value of manure.
[b]Comparisons are for annual manure production of 6,000 tons from case study 2,500 head one time capacity cattle feedlot with open dirt pens, 5,000 head annual production.
[c]P2 = Phosphorus application rate for two years' crop use.
[d]P4 = Phosphorus application rate for four years' crop use.

Table 6. **Case study comparison of annual P value[a] with selected diets (increasing CP and P concentrations), crops, and basis of P manure application.[b]**

		Continuous Corn		C-SB	
Base Scenarios:		P2[c]	P4[d]	P2[c]	P4[d]
0% By-product	13.0 % CP, 0.29% P	$21,800	$21,800	$21,800	$21,800
10% By-product	13.6 % CP, 0.34% P	$26,700	$26,700	$26,700	$26,700
20% By-product	15.3 % CP, 0.39% P	$31,500	$31,500	$31,500	$31,500
30% By-product	16.9 % CP, 0.44% P	$36,400	$36,400	$36,400	$36,400
40% By-product	18.7 % CP, 0.49% P	$41,300	$41,300	$41,300	$41,300

[a]Annual P value = Total P value to the crop per year by application basis.
[b]Comparisons are for annual manure production of 6,000 tons from case study 2,500 head one time capacity cattle feedlot with open dirt pens, 5,000 head annual production.
[c]P2 = Phosphorus application rate for two years' crop use.
[d]P4 = Phosphorus application rate for four years' crop use.

$25,100 for the two-year corn-soybean rotation with 40% by-product in the diet. 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. In the case study scenarios in this report, the annual net market value of manure (Table 7) increased in all cases as the P concentration of the diet increased.

Tables 5 and 6 summarized the comparison of annual total fertilizer value and phosphorus value, respectively, by crop and variation in diet CP and P. There is little difference in fertilizer values when comparing 2-year to 4-year P application rates. Likewise, the cost comparison between 2-year and 4-year P application rates change a little, but not a lot, with slightly more expense in the 2-year than the 4-year. The surprise is the increase in net manure value as the diet P concentration increases.

An interesting bench mark is the cost per animal finished per year, calculated as total cost of distribution divided by total animals finished per year (Tables 2 - 4). These values ranged from $2.80/head finished/year in Table 3 for continuous corn with 0.29% P and 4-year P rate, to a high value of $5.10/head finished/year in Table 2 for C-SB at 0.49% P and 2-year P basis application rate.

Another interesting perspective is to compare these scenarios on the basis of net value of manure per animal finished per year. 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. For instance, from the case study data (Table 2 - 4), this value calculated from a low of $2.60/head (Table 4) to a high of $7.70/head (Table 3) for net manure value per annually finished animal.

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In 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 (Tables 2 - 4) and required spreadable acres (Table 8) receiving the increasing P manure concentrations, due to the decreasing rates of manure application. On the upside, the agronomic and market value of manure produced increased at a rate faster than the rate of increasing costs of distribution. This has a potential positive implication to the beef cattle industry, with the 2500 capacity feedlot in this study. Further scenarios need to be investigated with different sized feedlots, and available fields for manure distribution at much greater distances from the feedlot. This model has the ability to investigate such individual feedlot situations.

The observed benefits of feeding higher rates of distiller by-products can be applied only to the following situations until further investigation is completed:

1. Feedlots with 2,500 head capacity or less
2. Feedlots with access to 100% of the land closest to the animal housing
3. Feedlots where manure is applied at a P-based rate only.

In this case study, from the perspective of cost of distribution/head finished/year, lower diet P concentration is better than higher diet P values. However, due to the fertilizer value, increased diet P results in higher manure value. This higher manure value offsets the distribution cost by a range of $2.60/head to $7.70/head finished annually in the scenarios studied in this model. 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.

Table 7. Case study comparison of annual net manure value[a] with selected diets (increasing CP and P concentrations), crops, and basis of P manure application.[b]

		Continuous Corn		C-SB	
Base Scenarios:		P2[c]	P4[d]	P2[c]	P4[d]
0% By-product	13.0% CP, 0.29% P	$14,400	$15,800	$ 9,200	$12,700
10% By-product	13.6% CP, 0.34% P	$18,400	$21,600	$12,700	$17,000
20% By-product	15.3% CP, 0.39% P	$23,500	$27,400	$16,900	$21,800
30% By-product	16.9% CP, 0.44% P	$28,400	$32,900	$20,900	$26,600
40% By-product	18.7% CP, 0.49% P	$33,600	$38,500	$25,100	$31,400

[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]Comparisons are for annual manure production of 6,000 tons from case study 2,500 head one time capacity cattle feedlot with open dirt pens, 5,000 head annual production.
[c]P2 = Phosphorus application rate for two years' crop use.
[d]P4 = Phosphorus application rate for four years' crop use.

Table 8. Case study comparison of total acres needed in a four-year planning horizon[a] with selected diets (increasing CP and P concentrations), crops, and basis of P manure application.[b]

		Continuous Corn		C-SB	
Base Scenarios:		P2[c]	P4[d]	P2[c]	P4[d]
0% By-product	13.0 % CP, 0.29% P	1000	1000	1320	1320
10% By-product	13.6 % CP, 0.34% P	1240	1240	1600	1600
20% By-product	15.3 % CP, 0.39% P	1460	1460	1900	1900
30% By-product	16.9 % CP, 0.44% P	1680	1680	2200	2200
40% By-product	18.7 % CP, 0.49% P	1900	1900	2500	2500

[a]Total acres needed = annual acres multiplied by the number of years in the application rate limit.
[b]Comparisons are for annual manure production of 6,000 tons from case study 2,500 head one time capacity cattle feedlot with open dirt pens, 5,000 head annual production.
[c]P2 = Phosphorus application rate for two years' crop use.
[d]P4 = Phosphorus application rate for four years' crop use.

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