Phosphorus-Based Nutrient Management Planning on Dairy/Poultry Farms: Implications for Economic and Environmental Risks

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Abstract

The effects of phosphorus (P)-based nutrient management plans on economic and environmental risks of dairy and dairy-poultry farms in Virginia were evaluated. Phosphorus-based nutrient management plans can greatly reduce P runoff risk but also reduce farmers' returns. P-based plans cause greater reductions in returns and P runoff on the dairy-poultry farm than on the dairy only farm.

Keywords

nutrient runoff, cost, mathematical programming, simulation, watershed

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Introduction

Public concerns over environmental quality have been focused on agricultural production, one of the major contributors to NPS (nonpoint source) pollution. The crop-livestock system can pose threats to ground and surface water. Inappropriate nutrient management can cause nutrient leaching or runoff from livestock confinement areas even prior to collection. Nutrients in manure may be lost to the environment either through improper storage and handling or inappropriate application rates and/or methods. Weather variations, particularly heavy rainfall events, may result in greatly increased runoff and leaching of manure pathogens and nutrients from livestock housing areas, manure storage structures, and land-applied manure. The resulting runoff and leaching contributes to the deterioration of the quality of surface or ground water.

Although some progress has been made in farmers' awareness and adoption of suitable practices to protect water quality, NPS pollution losses from crop-livestock systems in many areas still exceed water quality goals. Traditionally farms have had few obligations to control nutrient losses from manure storage and cropland. The major exception was the regulation of large confined animal operations with over 1,000 animal units through the National Pollutant Discharge Elimination System (NPDES) established under the Federal Water Pollution Control Act of 1972 (Ribaudo, Horan, and Smith). Recently there has been more movement by the federal government and many states to regulate farms to achieve water quality protection. The Coastal Zone Management Act Reauthorization Amendments require states with approved coastal zone management programs to develop NPS pollution control plans for coastal zone areas including agriculture. States must be prepared to enforce these plans if voluntary compliance programs fail to achieve water quality objectives (Ribaudo, Horan, and Smith).

Many states also have regulations affecting livestock operations. Recently Maryland passed the Maryland Water Quality Improvement Act of 1998, possibly the most comprehensive nutrient management law in the nation (Maryland Cooperative Extension Service, 1999). By the year 2005 all farmers in the state will be required to have implemented nutrient management plans which result in application of nitrogen (N) and phosphorus (P) at rates at or below agronomic recommendations. In 1999, Virginia passed HB 1207 Poultry Waste Management Bill, which will require poultry growers to have P-based nutrient management plans (Virginia Department of Planning and Budget). Such regulations could greatly reduce manure applications particularly on farms with high ratios of confined animals and/or poultry to land. Farmers' compliance with these regulations may alter their crop and livestock management practices. There may be strong trade-offs between farmers' economic gains and environmental risks.

Farm-level economic and environmental effects of nutrient management plans depend on how the plan is specified as well as the farm's resource situation. N-based nutrient management plans require that N applications not exceed agronomic recommendations while P-based plans require that neither N nor P applications exceed agronomic recommendations. Studies by Pease, Parsons, and Kenyon; and VanDyke et al. have found that N-based plans actually increased farm net income modestly while reducing potential N and P losses to the environment. Farm income increased because of savings from reducing unnecessary N applications. P-based plans reduced potential P losses to the environment by a larger amount than N-based plans but resulted in a reduction in farm net income (Pease, Parsons, and Kenyon) because of reduced manure application rates to crops and the need to dispose of excess manure off the farm. Net income losses were higher on farms with dairy and poultry compared to farms with only dairy.

The objective of this study was to evaluate the effects of P-based nutrient management plans on economic and environmental risks on intensive livestock/poultry farms. Integrated stochastic procedures were developed to quantify environmental and economic risk trade-offs for crop-livestock/poultry systems. The procedures were applied to two representative farms in Virginia, one with dairy only and one with dairy and poultry (broilers). Two farmer objectives regarding manure management were analyzed: 1) maximize net returns from manure produced on the farm, and 2) maximize manure utilization on farm. A farmer following objective 2 would sell manure only after all needs for applied nutrients on his/her own farm were met. A farmer following objective 1 would sell manure and buy commercial fertilizer if the manure was worth more when sold off farm than when used on farm to replace commercial nutrients. The two farms were evaluated under a baseline in which there were no restrictions on manure applications and under a P-standard, in which P applications from manure and/or commercial fertilizer do not exceed crop agronomic recommendations or crop P removal, whichever is greater.

Empirical Framework

Study Area

The study area is the Muddy Creek Watershed located in Rockingham County, Virginia, the state’s leading livestock-producing county. This watershed contains 100-110 farms of which 60-70 percent are dairy or dairy-poultry. Table 1 shows the resource situations of the two farms. The number of livestock and the cow-land ratio are typical of the watershed where cow-land ratios range from 1 to 1.25 acres per cow. Levels of animal manure production and P content in animal manures were based on the Virginia Nutrient Management Handbook. The initial soil test P levels shown in table 1 were set at ‘medium’ for the dairy only farm and ‘very high’ for the dairy-poultry farm to reflect its much higher level of manure P production per acre, which is likely to lead to higher levels of manure application and P accumulation in soils. Analysis of over 3,700 soil test samples in Rockingham County for 1993 and 1994 revealed that over 89 percent were high or very high in P (Parsons).

A Geographic Information System database containing digital layers of soil types, field boundaries, and elevations was used to further specify the land resource. Six contiguous fields with a total land area of 122 acres were selected from the watershed. Productivity ratings of the soils for corn and potential P removal by the harvested portion of the corn crop are shown in Table 2. Productivity ratings are based on the Virginia Agricultural Land Use Evaluation System (VALUES, Simpson et al.).

Farm Economic Model

The farm economic model, ECONPLAN, is a linear programming model written in GAMS (General Algebraic Modeling System) (Brooke, et al.). The model maximizes total gross margins which equal total gross returns minus variable costs of crop and livestock production. Gross returns were obtained from livestock product sales (milk, calves, and cull cows), crop sales, manure sales, and broiler contract fees. Variable costs include machinery variable expenses (fuel, oil, repairs), crop seed, lime, nutrient, and chemical purchases, purchased feed, veterinary-medical supplies, marketing expenses, operating interest, and part-time hired labor. Fixed costs such as facility and machinery depreciation and interest, insurance, full-time hired labor costs, family living expenses, rent, and taxes were not included.

Crops considered were corn silage, corn grain, rye cover, ryelage, alfalfa, fescue hay, fescue hay and pasture, and permanent pasture. Crops were grown in rotations, including corn-rye cover, corn-ryelage, corn-alfalfa, continuous grass (fescue) hay, continuous pasture, and continuous hay-pasture. Corn and alfalfa and hay establishment could be done with conventional-till or no-till. The model contained upper bounds on dairy, poultry, and crop production as shown in tables 1 and 2. Full-time labor was limited by season and its cost was assumed fixed, but additional part-time labor could be hired at $6 per hour.

Crop yields and recommended nutrient applications of N, P, and K (potassium) by soil type were based on VALUES (Simpson et al.). Assumed manure nutrient contents shown in Table 3 were taken from the Nutrient Management Handbook (Department of Conservation and Recreation). Recommended nutrient applications were used as the minimum required nutrient applications to crops. In the baseline there was no maximum limit on crop nutrient applications. Under the P standard, the maximum limit on N application was set at the VALUES recommendation while the maximum limit on P application was the greater of the VALUES recommendation or estimated crop P removal. For example, field 1 on the dairy with poultry farm had a ‘very high’ P soil test and under VALUES no P application would be recommended. However, if corn were grown, the estimated crop P removal of 48.9 pounds/acre would be the upper limit on P applications.

Nutrient prices

Under the baseline, the dairy farm could sell dairy manure for a negative price (-$5) reflecting its low dry matter and nutrient content relative to weight which results in a high hauling cost (Table 4). Purchase and sale prices for broiler litter and purchase prices for turkey litter varied by season with higher prices in spring and fall when there is more demand for litter to be applied to cropland. Purchase prices were set at $6 above sale prices, where the difference represents the cost of hauling litter to the purchasing farm. Under the P standard, manure prices were assumed to fall reflecting the fact that livestock farms would have to sell more manure in order to comply with the limitation on manure applications to crops based on P content. Dairy manure prices were set at -$10 while litter sale prices were $0 and purchase prices were $6 which is the assumed hauling cost. Commercial nutrient prices were held constant under the baseline and P-standard.

Economic risk

The effects of crop yield uncertainty on farm net returns above variable costs were incorporated. The VALUES yield used in ECONPLAN for each crop was the median yield. A yield distribution was generated for each crop-soil combination adopted by each farm under the baseline and P-standard. Corn silage, alfalfa, and ryelage yield distributions elicited from 12 farmers in Rockingham County (Johnson) were used to simulate yield risk. Johnson's elicited distributions were whole-farm distributions. These distributions were adapted to the specific crop-soil combinations in this study based on differences between the median values of the elicited distributions and the VALUES yield rating. Each percentile yield in this study was constrained to lie the same percentage distance from the median as those in the elicited distributions. For example, the maximum, median, and minimum elicited corn silage yields were 36, 17, and 4 tons, respectively. The maximum value was 112 percent above the median and the minimum was 76 percent below the median. The VALUES rated corn silage yield capacity for Sequioa-Berks silt loam, one of the soils in the study, is 16 tons/acre. Its distribution was generated based on a median yield of 16 tons, a maximum of 33.9 tons, and a minimum of 3.8 tons/acre. Yields corresponding to other percentiles of the distribution were generated in the same way. The empirical distributions were then fitted to statistical distributions using BestFit (Palisade Corporation).

One hundred yield vectors were randomly generated using @RISK (Palisade Corporation) where each yield vector contained a crop yield for each crop-soil combination. The same yield distribution was used for each farm type and under the baseline and P-standard. Correlations between crops were used to generate yield vectors. Correlations between crop yields were 0.62 (Bosch and Johnson) and correlations of yields of the same crop across soil groups were set to 0.9.

Yield variations were used to estimate variations in total gross margins by adding revenues from crop sales when yields were above the VALUES yield and subtracting expenses of crop purchases when yields were below the VALUES yield. The underlying assumption was that the farmer would keep the ration fed to animals constant regardless of crop yield. Crop purchase and sale prices used were, alfalfa, $147 and $117/ton, corn silage, $32 and $29/ton, and grass hay, $80 and $110/ton.

P runoff risk

Phosphorus runoff was simulated using an expanded version of the event-based ANSWERS (Beasley et al., 1980) model. The expanded version, sometimes called ANSWERS-2000 (Bouraoui and Dillaha, 1996), is a watershed-scale, distributed parameter, continuous NPS model that simulates transport and fate of sediment, N, and P. The model divides a watershed into a uniform grid of cells. Parameters representing soil type, crop characteristics, and management practices are defined for each cell. Within each cell, the model estimates processes of interception, infiltration, surface storage, surface flow, soil water movement, sediment detachment, transport and deposition, and nutrient movement and transformations. The continuity equation is used to integrate the individual elemental responses into a system response that describes the watershed as a whole. The distributed parameters in the ANSWERS-2000 model allow the spatial variability of watershed and farm characteristics to be included in the analysis.

The continuous version of ANSWERS has been tested and validated using data from several watersheds (Bouraoui, 1994). The model performed well in predicting runoff, sediment, NO_3, dissolved ammonium, sediment-bound total Kjeldahl N (TKN), and dissolved and sediment-bound P for two watersheds in Georgia. The model did not perform as well in predicting sediment-bound ammonium losses from either watershed. In a test on a Virginia watershed, the model performed well for the largest storms, which produced the majority of the sediment and nutrient losses. Testing of the model has indicated that the predictions are adequate for simulating the effects of different management scenarios as done in this study.

In this study, ANSWERS was applied to individual fields. Input parameters were determined for each field to describe soil characteristics, cropping practices, fertilizer practices, and topography. Weather data were generated using the CLIGEN weather generator. P runoff from each field was simulated for a sequence of 50 years. Annual P runoff from the farm was represented by the sum of the annual values from the six fields. The 50 annual values for each of the two scenarios, baseline and P standard, were analyzed to determine the distribution of annual P runoff.

Results

Under the baseline, total gross margins varied from $104,146 for the dairy farm to $145,440 for the dairy-poultry farm which maximized returns from manure (Table 5). Only one column is displayed for the dairy farm without poultry, because maximizing manure use on the farm gives the same results as maximizing net returns from manure due to the negative sale price of dairy manure. On the dairy-poultry farm, total gross margins from maximizing returns from manure exceeded the total gross margin for maximizing manure use. Farmers could increase returns slightly by selling poultry litter and buying ammonium nitrate to meet crop nitrogen needs. However, the increase was only about $300 indicating that maximizing manure use on the farm was a near optimal strategy.

Many farmers might prefer this strategy due to the convenience of not having to find buyers for poultry litter.

Table 6 shows how the distribution of total gross margins varied across the farms in the baseline. The variation in total gross margins from the maximum to the minimum was $43,939 for both the dairy and dairy-poultry farms because each farm grew the same combination of crops. Crop yield was the only source of risk considered.

All farms produced livestock at maximum capacity (100 cows, 320,000 broilers) as shown in Table 5. Both the dairy and dairy-poultry farms produced corn silage, rye cover, alfalfa hay, grass hay, and pasture in the same amounts probably because the same soil resource distribution was assumed for each. Nutrient applications differed between farms. The dairy only farm applied its own manure plus purchased turkey litter, ammonium nitrate, and muriate of potash. The minimum recommended P_2O_5 application for the farm, 6,800 lbs., was met from the dairy manure and turkey litter. The dairy-poultry farm which maximized returns from manure sold its broiler litter and bought ammonium nitrate. No outside sources of potash or phosphate were needed because of the very high soil levels of both nutrients. The farm which maximized manure use on the farm applied all of its dairy manure and 103 tons of its poultry litter and sold the remainder. No commercial fertilizer was required.

The minimum P_2O_5 requirement was 6,800 lbs. on the dairy farm, but zero on the dairy-poultry farm, which had high initial soil P levels. Crop P_2O_5 removal was the same across farms, because the same crops were grown and the same yields were obtained. All farms applied more than the minimum recommended P_2O_5 as a result of using manure in quantities sufficient to meet nitrogen and potash needs. The dairy-poultry farm which maximized manure use on farm had the largest excess of P_2O_5 application over the minimum recommendation, 14,422 lbs. This application also exceeded crop P_2O_5 removal by over 4,000 lbs.

Table 7 shows variations in estimated P_2O_5 runoff from the dairy-poultry farm which maximized manure use in the baseline. Runoff was highly variable with a coefficient of variation of 0.92 reflecting variations in weather conditions. Average P_2O_5 runoff, 1,904 lbs, was about half of the estimated excess of P_2O_5 applications over crop removal for the farm. Much of the excess P_2O_5 applications remained attached to sediment in the field.

Imposing nutrient management based on the P standard caused total gross margins to decline by about $400 on the dairy only farm, by almost $3,000 on the dairy-poultry farm which maximized manure returns, and by $2,600 on the dairy-poultry farm which maximized manure use (table 8). Although this reduction is a small percentage of total gross margins, it would be a much larger percentage of net revenues after deducting fixed costs. Greater reductions in gross margins occur on the dairy-poultry farm because of the decline in litter sale prices to zero. Maximizing manure use and maximizing manure returns on the dairy-poultry farm result in the same gross margins, crop and livestock production pattern, and nutrient applications because of the P limit on manure applications to crops.

As shown in Table 6, the P standard resulted in a parallel leftward shift of the cumulative distribution of total gross margins. One measure of economic risk, the variability of returns, was not affected because the P standard did not result in any change in crops grown. The constant reduction in profitabiliy resulting from lower poultry litter sale prices and somewhat higher nutrient application costs did lower the probability that total gross margins would exceed a fixed level. A farm which is concerned with meeting a given income target in order to cover fixed expenses would see its risks increase as a result of the leftward shift of the total gross margins distribution.

The P standard did not affect the mix of crops, livestock, or poultry produced on either farm. Nutrient applications did change. The dairy only farm reduced its applications of ammonium nitrate but increased use of commercial phosphate and potash. This shift is partly explained because dairy manure was no longer spread on alfalfa and was reallocated to other crops. As a result, commercial fertilizer was needed to meet phosphate and potash requirements on alfalfa while the need for ammonium nitrate on other crops declined. The dairy-poultry farm, which maximized manure returns, reduced its ammonium nitrate applications and increased applications of its broiler litter in response to the lower sale price of broiler litter. The farm which maximized manure use reduced its application of broiler litter relative to the baseline (from 103 to 23 tons) and increased ammonium nitrate use (from 0 to 80 cwt.). Litter use was reduced because of the P limit on manure applications.

All farms spread P_2O_5 at or below the maximum of estimated crop P_2O_5 removal, 10,298 lbs. However, total P_2O_5 applications actually increased by about 500 lbs. on the dairy only farm because of the reallocation of dairy manure from alfalfa to other crops and use of commercial superphosphate on alfalfa. On the dairy-poultry farm which maximized manure returns, total P_2O_5 applications increased by about 1,800 lbs. largely because 23 tons of poultry litter were spread on the farm rather than being sold because of the lower litter sale price. The dairy-poultry farm which maximized manure use reduced its P_2O_5 applications by over 4,000 lbs., a decline of almost 30 percent.

The effects of reduced P_2O_5 applications on P_2O_5 runoff are shown in table 7 for the dairy-poultry farm which maximized manure use. Average P_2O_5 runoff declined by about 545 lbs. (30 percent) and maximum runoff declined by about 1,771 lbs. (20 percent). The coefficient of variability of 0.96 was about the same as in the baseline. However, the reduction in average runoff was less than the reduction in excess P_2O_5 applications, 4,124 lbs. Much of the reduction in excess P_2O_5 applications results in slower P_2O_5 accumulations in sediment.

Conclusions and Implications

Nutrient pollution from animal manure on intensive livestock operations is viewed with increasing public concern. Many states now require nutrient management plans on some or all farms, which could greatly reduce allowable manure applications and farm net returns as well as nutrient runoff. In this study of representative dairy and dairy-poultry farms in Virginia, we evaluated the effects of a P standard on economic returns and P runoff. The P standard resulted in a small reduction in total gross margins on the dairy-only farm but larger reductions on the dairy-poultry farm. The mix of crops and livestock grown on the farm was not affected by the P standard. The P standard had mixed effects on manure applications on the farm. The dairy-poultry farm which maximized manure returns increased its litter applications by 23 tons as a result of the decline in litter sale prices. Total phosphate applications increased as well. The dairy-poultry farm which maximized litter use on farm reduced its litter application from 103 to 23 tons. Total phosphate applications declined by almost 30 percent and estimated P runoff from cropland declined also.

The effects of the P standard on phosphate applications and P runoff differ greatly between the farm maximizing manure use and the farm maximizing returns from manure. Which objective more accurately describes the way most farmers manage manure and the likely results of nutrient management planning based on a P standard? Several studies suggest that the objective of maximizing manure use is more accurate. VanDyke et al. found that farmers apply more nutrients from manure and/or commercial fertilizer than agronomic recommendations prior to adopting nutrient management plans. Bosch et al.

found that cropland sites in Rockingham County where manure was applied received on average more than 100 lbs of phosphate above soil recommendations. The prevalence in many livestock-intensive areas of soil samples testing high or very high in soil P (Parsons) also suggests a history of very high rates of manure application. Thus, it is likely that nutrient management planning with a P standard will significantly reduce P runoff risk on dairy-poultry farms.

Most of the reductions in total gross margins under the P standard resulted from reduced prices of surplus poultry litter. State and federal programs to subsidize manure transport either with financial incentives or by providing services to facilitate litter trading can reduce these losses. Policymakers can also develop programs to encourage manure use on crop farms. For example, subsidized insurance schemes could be developed to insure farmers who use manure in place of commercial fertilizer against crop yield losses resulting from manure use. Policymakers can also subsidize the development of new technologies such as adding microbial phytase to feeds in order to reduce manure P content and manure surpluses.

Further research is needed to better specify the costs of P-based nutrient management planning and to identify other ways of reducing nutrient losses from intensive livestock areas. Many farmers prefer to avoid multiple trips over the field to apply nutrients because of the potential for increased soil compaction (Pelletier, Pease, and Kenyon). However, P-based plans may result in more trips to apply nutrients because supplemental commercial fertilizer is applied when manure applications are reduced. The costs of further compaction could be estimated with further research. Some critical areas of the farm near sinkholes, where animals enter streams, and near feedlots and manure storage may be particularly vulnerable to nutrient losses from animal manure. Further research could investigate the potential for low-cost nutrient pollution control in such critical areas.

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Table 1. Resource characteristics of representative dairy and dairy-poultry farms.

	Dairy only	Dairy-poultry
Dairy cow capacity	100	100
Broiler capacity	0	2 houses (320,000 birds/year)
Dairy manure production	664,000 gallons/year	664,000 gallons/year
Broiler litter production	0	400 tons/year
Crop and pasture land	122 acres	122 acres
Animal manure P produced	66 lbs./acre/year	269 lbs./acre/year
Initial soil test P level	medium	very high
Full-time operator, family, and hired labor (hours)	6,600	7,900

Table 2. Productivity ratings of fields for representative dairy and dairy-poultry farms.

Field number (Map unit)	Size (acres)	Soil description	Potential corn yield (bu/acre)	P removal by corn harvest (lbs. P_2O_5 /acre)
1 (33C2)	27.4	Frederick and Lodi silt loam rocky	122.2	48.9
2 (24C2)	28.6	Endcav silt loam	94	37.6
3 (59B2)	10.4	Sequoia-Berks silt loam	110	44.0
4 (39B)	26.6	Laidig gravelly fine sandy loam	100	40.0
5 (21B)	13.3	Craigsville cobb	85	34.0
6 (5D2)	15.9	Berks-Weikert Shaly silt loam	52	20.8

Table 3. Manure nutrient content

	Dairy manure (1000 gal.)	Broiler litter (ton)
% dry matter	5.70	71.60
Potash (K_2O) (lbs.)	18.92	28.57
Phosphate (P_2O_5)(lbs.)	12.07	62.12
Nitrogen (lbs.)	22.61	62.58
Inorganic nitrogen (lbs.)	9.57	11.75
Inorganic nitrogen volatilization loss (%)	75.00	50.00
Plant available inorganic nitrogen (lbs.)	2.39	5.88
Organic nitrogen (lbs.)	13.04	50.83
Mineralized organic nitrogen (lbs.)	7.04	27.44
Plant available nitrogen (lbs.)	9.43	33.32

Table 4. Nutrient prices used in the study

	Baseline	P-standard
Sell dairy manure ($/1000 gal.)	-5	-10
Sell broiler litter		
Spring ($/ton)	8	0
Summer ($/ton)	4	0
Fall ($/ton)	6	0
Winter ($/ton)	4	0
Buy broiler litter		
Spring ($/ton)	14	6
Summer ($/ton)	10	6
Fall ($/ton)	12	6
Winter ($/ton)	10	6
Buy turkey litter		
Spring ($/ton)	12.50	6
Summer ($/ton)	9	6
Fall ($/ton)	10.50	6
Winter ($/ton)	9	6
Buy ammonium nitrate (33% N) ($/cwt)	8	8
Buy superphosphate (46% P2O%) ($/cwt)	11	11
Buy muriate of potash (60% K_2O) ($/cwt)	9	9

Table 5. Baseline farm production and returns with no restrictions on manure applications

		Dairy-poultry	
	Dairy only[a]	Max. manure returns	Max. farm manure use
Total gross margins ($)	104,146	145,440	145,108
Number of cows milked	100	100	100
Number of broilers produced	0	320,000	320,000
Corn silage (acres)	63	63	63
Rye cover (acres)	58	58	58
Alfalfa hay (acres)	14	14	14
Grass hay (acres)	29	29	29
Pasture (acres)	16	16	16
Litter sales (tons)	0	400	297
Dairy manure (1,000 gal.)	664	664	664
Broiler litter (tons)	0	0	103
Turkey litter (tons)	7	0	0
Ammonium nitrate (33% N) (cwt)	155	103	0
Superphosphate (46% P_2O_5) (cwt)	0	0	0
Muriate of potash (60% K_2O) (cwt)	9	0	0
Min. recommended P_2O_5 applic. (lbs.)	6,800	0	0
Crop P_2O_5 removal (lbs.)	10,298	10,298	10,298
P_2O_5 application (lbs.)	8,925	8,495	14,422

[a] On the dairy farm without poultry, only one column is displayed because maximizing manure use on the farm gives the same results as maximizing net returns.

Table 6. Distribution of farm total gross margins under baseline and P standard

	Baseline			P standard		
Total gross margins	Dairy, maximize manure revenue	Dairy-poultry, maximize manure revenue	Dairy-poultry, maximize manure use	Dairy, maximize manure revenue	Dairy-poultry, maximize manure revenue	Dairy-poultry, maximize manure use
Maximum	123,990	165,284	164,952	123,552	162,349	162,349
75th percentile	114,115	155,409	155,077	113,677	152,474	152,474
Median	109,649	150,943	150,611	109,211	148,008	148,008
25th percentile	101,844	143,138	142,806	101,406	140,203	140,203
Minimum	80,051	121,345	121,013	79,613	118,410	118,410
Mean	107,387	148,681	148,349	106,949	145,746	145,746
Std.Dev.	10,037	10,037	10,037	10,037	10,037	10,037

Table 7. Distribution of P_2O_5 runoff under baseline and P standard

	Baseline, dairy-poultry, maximize manure use	P standard, dairy-poultry, maximize manure use
	total pounds P_2O_5 runoff	
Maximum	8,612	6,841
75th percentile	2,299	1,578
Median	1,409	1,051
25th percentile	634	417
Minimum	57	57
Mean	1,904	1,359
Std.Dev.	1,747	1,318

Table 8. Farm production and returns under a P nutrient management standard			
		Dairy-poultry	
	Dairy only	Max. manure returns	Max. farm manure use
Total gross margins ($)	103,708	142,505	142,505
Number of cows milked	100	100	100
Number of broilers produced	0	320,000	320,000
Corn silage (acres)	63	63	63
Rye cover (acres)	58	58	58
Alfalfa hay (acres)	14	14	14
Grass hay (acres)	29	29	29
Pasture (acres)	16	16	16
Litter sales (tons)	0	377	377
Dairy manure (1,000 gal.)	664	664	664
Broiler litter (tons)	0	23	23
Ammonium nitrate (33% N) (cwt)	103	80	80
Superphosphate (46% P_2O_5) (cwt)	34	0	0
Muriate of potash (60% K_2O) (cwt)	69	0	0
Min. recommended P_2O_5 applic. (lbs.)	6,800	0	0
Crop P_2O_5 removal (lbs.)	9,789	10,298	10,298
P_2O_5 application (lbs.)	9,500	10,298	10,298